Festschrift in honour of Ramon López de Màntaras

Carles Sierra (Ed.)

Artificial Intelligence Research Institute, IIIA
Consejo Superior de Investigaciones Científicas, CSIC
Barcelona, Spain

Edited by: Carles Sierra

Institut d'Investigació en Intel·ligència Artificial, IIIA-CSIC
Campus de la UAB, 08193 Bellaterra, Catalonia, Spain
sierra@iiia.csic.es

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Preface

Ramon is becoming 60 on May 8, 2012. It is quite a number. Several of his friends and colleagues including myself thought that it was timely to celebrate Ramon's achievements, in science and in life. I volunteered immediately to lead the gathering of the works included in this volume. After contacting a large number of friends and colleagues many accepted with enthusiasm this initiative and some considered that we, the scientific community, should do these reflections and commemorations more often, as what scientists want after all is the recognition of the work done. There were many colleagues that although not contributing directly expressed their best wishes for Ramon's future achievements, that will be many. Everybody was very helpful and most contributions were prepared in Latex so, actually, I didn't have much work to do. Some papers were written in word and they required a bit more time to be integrated into the book, but altogether it was a pleasant job. The usual suspects requested some extension of the deadline but everything happened within reasonable limits to be able to print the book on time.

I organised this book in two parts. The first one contains scientific papers inspired by Ramon's contributions to Artificial Intelligence. The second one unveils some of Ramon's hidden secrets and provides a glimpse to Ramon's multi-faceted character. I gave freedom to every contributor to choose the language they wanted to write the contribution as one of Ramon's assets is that he commands four languages: English, French, Catalan and Spanish, and is capable of understanding italians when they are not too drunk.

I thank every contributor and those that knew about the book for participating in the plot and keeping the secret of its preparation. If everything has gone well, Ramon will receive this book on May 5 as a surprise. We will celebrate his birthday that day during one of the classical 'costellades' at Mas Puig. Hopefully, a perfect cover to hide the real meaning of the meeting!

Anna Enciso has made the beautiful design of the cover, some translations from word to Latex, and the corrections of the Spanish and Catalan texts in the book. Nuria Castellote has managed the bureaucracy of getting the ISBN and dealing with the printer so that the book could be finished on time. Finally, Tito Cruz gave his support on IT matters. I want to thank them all for the work done, they made my life much easier.

I hope the readers of this book will learn many aspects about Ramon's broad contributions to Artificial Intelligence and his pioneering of the field in Spain. I'm sure that the anecdotes explained in the second part of the book will help to understand his commitment and passion for science.

Bellaterra, May 2012 *Carles Sierra*

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Capítol 1
La distància de Mantaras en privadesa de dades

Vicenç Torra

Resum En aquest treball descrivim l'ús que hem fet de la distància de Mantaras en el camp de la privadesa de dades. La privadesa de dades estudia els mètodes que permeten publicar dades o transmetre-les a tercers evitant problemes de confidencialitat. Els mètodes d'emmascarament introdueixen alguna mena de soroll a les dades per aconseguir aquest objectiu. El soroll ha d'evitar que terceres persones accedeixin a dades confidencials i a la vegada que les anàlisis que es fan amb aquestes dades donin els mateixos resultats que els que s'obtindrien amb les dades originals. Per avaluar els mètodes d'emmascarament s'han desenvolupat diferents tipus de mesures, les mesures de pèrdua d'informació i les mesures de risc de revelació. La distància de màntaras ens permet definir mesures de pèrdua d'informació.

1.1 Introducció

La gran quantitat d'informació emmagatzemada existent en l'actualitat permet als seus posseidors construir perfils molt acurats dels usuaris. Quan aquesta informació cal transferir-la a tercers per a una anàlisi més detallada, o per a poder-la relacionar amb altres dades, hi ha un perill important de que informació confidencial dels usuaris quedi al descobert.

Vicenç Torra
IIIA-CSIC, e-mail: vtorra@iiia.csic.es

La privadesa de dades [8] estudia com podem transferir dades a tercers per al seu anàlisi de manera que el risc quedi minimitzat. Hi ha diferents aspectes que entren en joc segons el tipus d'escenari que es plantegi.

Un dels escenaris, l'esmentat breument més amunt, correspon al cas en que una empresa vol transferir les seves dades a un tercer per tal de que aquest tercer en faci una anàlisi més profunda. Seria el cas d'un hospital que vol transferir la seva base de dades de pacients a un investigador per descobrir patrons entre les medicines preses i l'evolució en un diagnòstic, o establir relacions entre origen i malalties. En aquest cas, s'espera que l'investigador no pugui descobrir entre la informació subministrada les malalties o el tractament dels seus coneguts.

Un altre escenari és quan una empresa vol fer un càlcul de forma conjunta amb altres empreses, però sense compartir les dades. L'objectiu és fer el càlcul de manera que al final tothom en conegui el resultat final però sense que cap empresa conegui cap dada particular addicional que no sigui el resultat final.

En el primer escenari s'apliquen sovint els mètodes de protecció basats en les dades, habitualment mètodes d'emmascarament. En el segon cas s'apliquen mètodes basats en la computació, habitualment mètodes criptogràfics.

Els mètodes pertorbatius esmentats en el primer dels dos escenaris introdueixen algun tipus de soroll a les dades, modificant-ne la seva utilitat amb l'objectiu de reduir el risc de revelació quan les transmetem a tercers. En aquest capítol descriurem breument alguns mètodes de protecció, i les mesures de risc de revelació i de pèrdua d'informació.

Cal dir que hi ha altres escenaris possibles. Un d'ell, per exemple, és el cas de la recuperació d'informació privada. En aquest escenari tenim un usuari que vol fer una consulta a una base de dades i no volem que la base de dades sigui capaç de saber quina és la consulta que l'usuari vol realitzar. La solució trivial és que l'usuari modifiqui la seva consulta per tal que se li retorni tota la base de dades de manera que després en pugui fer el filtratge localment. Naturalment això té un cos computacional massa elevat, només cal pensar en aplicar aquesta aproximació al nostre cercador preferit!

L'estructura del capítol és com segueix. En la secció 1.2 es descriuen breument els mètodes de protecció, en la secció 1.3 es descriuen breument les mesures de pèrdua d'informació i de risc de revelació. El capítol acaba amb unes breus conclusions.

1.2 Mètodes de protecció

Els mètodes de protecció orientats a les dades introdueixen algun tipus de soroll a les dades originals amb l'objectiu de reduir-ne la qualitat. L'objectiu és que sigui més difícil per a un intrús poder trobar informació confidencial.

La dificultat del problema de la privadesa rau en el fet que no n'hi ha prou en protegir les dades que són clarament identificatives d'un usuari. En una base de dades els atributs es poden dividir entre els que son identificadors i quasi-identificadors. Els primers són els que de forma unívoca ens determinen un registre. Seria el cas del número del document d'identitat, o el de la seguretat social. Un quasi-identificador és un registre que en combinació amb d'altres permet determinar de forma unívoca un registre. En una base de dades, la majoria d'atributs són quasi-identificadors. Un exemple és el codi postal i l'any de naixement, perquè és possible que en una població hi hagi una única persona que ha nascut en un determinat any. Encara més quan en lloc d'any de naixement hi ha la data exacte.

La forma habitual de procedir és suprimir o encriptar els identificadors, i aplicar un mètode d'emmascarament dels quasi-identificadors. Els mètodes d'emmascarament són un d'aquests mètodes que s'apliquen als quasi-identificadors. L'objectiu és impedir que l'intrús trobi un registre concret a partir de la seva informació. En el cas anterior, que l'intrús no sigui capaç de trobar un cert individu a partir del seu codi postal i el seu any de naixement.

Els mètodes d'emmascarament introdueixen soroll a la base de dades. Així, en general, tenim mètodes ρ que construeixen una base de dades Y a partir de l'original X fent

$$Y := \rho(X) = X + \varepsilon.$$

Existeixen diverses families de mètodes d'emmascarament. En general, els podem agrupar en dos grans grups: els pertorbatius i els no-pertorbatius.

Els mètodes d'emmascarament no pertorbatius introdueixen el soroll sense provocar que a la base de dades hi hagi dades erronees. El soroll s'afegeix reduïnt la qualitat de les dades, la seva granularitat. Són exemples la generalització i la supressió. En el primer cas es pot canviar, per exemple, una població (Matadepera) per la seva comarca (Vallès Occi-

dental), o un districte (Gràcia) per la població (Sabadell). En el segon cas, simplement s'elimina la dada corresponent. Això es pot veure com una generalització extrema. Naturalment, cap d'aquestes dades és errònea. Tanmateix, evidentment, les anàlisis que es poden realitzar seran de menys qualitat en no poder distingir, per exemple, entre districtes o poblacions.

Els mètodes d'emmascarament pertorbatius modifiquen les dades introduïnt errors. Un dels mètodes és introduir un soroll seguint una distribució normal amb mitjana zero i una certa desviació. Hi ha també la possibilitat d'introduir soroll d'acord amb la correlació entre els atributs. D'aquesta manera els coeficients de correlació entre les variables no es veu modificat. Existeixen molts altres mètodes de protecció. Els més efectius són la microagregació [3] i l'intercanvi de posicions (*rank swapping*).

1.3 Mesures de pèrdua d'informació i de risc de revelació

Quan apliquem un mecanisme d'emmascarament ρ a una base de dades X per obtenir una base de dades Y ens trobem que algunes de les propietats que satisfeia X no són satisfetes per Y. Per altra banda, construir Y a partir d'una certa modificació de X no implica que Y no tingui problemes de confidencialitat. Per avaluar aquests dos aspectes s'han desenvolupat les anomenades mesures de pèrdua d'informació i de risc de revelació.

- Les mesures de pèrdua d'informació s'han definit per avaluar fins a quin punt el soroll introduït ens modifica els resultats de les anàlisis en introduir soroll a les dades.
- Les mesures de risc de revelació s'han definit per avaluar fins a quin punnt el soroll introduït ens assegura la confidencialitat.

A continuació presentem amb una mica més de detall aquests dos tipus de mesures, començant per les mesures de risc de revelació.

1.3.1 Mesures de risc de revelació

Existeixen en l'actualitat diverses families de mesures de risc de revelació. Unes estan basades en les inferències que l'intrús pot fer sobre individus concrets, i en com aquestes inferències es veuen afectades (són més precises) quan s'utilitzen les dades publicades. Aquestes mesures estan orientades al que es coneix com revelació d'atribut (*attribute disclosure*). La mesura de risc d'interval correspon a una anàlisi d'aquest tipus. Unes altres mesures estan centrades en si l'intrús és capaç d'enllaçar o no els seus coneixements amb registres concrets de la base de dades publicada. Això és, s'analitza si les dades de que disposa l'intrús li permeten trobar un registre concret de la base de dades. Aquest cas s'anomena revelació d'individu (*individual disclosure*). Els mètodes d'enllaç de registre permeten avaluar aquest tipus de risc. Donades X i Y, el nombre d'enllaços correctes entre X i Y, sota diversos escenaris sobre els atributs que l'intrús coneix, dona una estimació del risc.

1.3.2 Mesures de pèrdua d'informació

Una mesura de pèrdua d'informació és la que permet avaluar la divergència entre els resultats que obtenim amb les dades originals i aquells que obtenim amb les dades protegides. Un bon mètode de protecció és aquell que pot assegurar confidencialitat minimitzant aquesta divergència.

Una mesura de pèrdua d'informació donarà zero quan $X = Y$ o quan els resultats que s'aconsegueixen amb Y siguin els mateixos que els que s'aconsegueixen amb X. Altrament, la mesura serà màxima, quan inferim resultats completament diferents amb X i Y. Per tant, podem definir la mesura en termes d'una distància d entre els resultats de les anàlisis.

D'acord amb tot això, tenim que una mesura de pèrdua d'informació es pot definir com:

$$IL(X,Y) = d(analisi(X), analisi(Y)),$$

o quan $Y = \rho_p(X)$ on p és el paràmetre de ρ:

$$IL_{\rho,p,analisi}(X) = d(analisi(X), analisi(\rho_p(X))),$$

Naturalment, anàlisis diferents defineixen mesures diferents. Això és, les mesures depenen de l'ús que es vulgui fer de les dades (*data use*). La literatura presenta mesures genèriques per quan no es pot saber quin tipus d'anàlisi vol fer aquella persona que rebrà les dades, i mesures específiques per quan se sap el tipus d'anàlisi a aplicar a les dades. En el cas de dades numèriques, les mesures genèriques es basen en alguns estadístics com ara la mitjana dels atributs, les seves desviacions, o les correlacions entre parells d'atributs. La diferència entre aquests estadístics sobre X i sobre Y defineix les mesures.

Entre les mesures específiques que hem considerat en els nostres treballs, podem destacar les orientades a categorització (*clustering*). Això és, l'avaluació de la pèrdua d'informació quan sabem que les dades s'utilitzaran per clustering. En aquest cas, el resultat de l'anàlisi acostuma a ser una partició, sigui nítida (*crisp partition*) o difusa (*fuzzy partition*). Aleshores, la distància d ha de ser una distància entre particions.

En els nostres treballs hem utilitzat, entre d'altres índexs i distàncies, la distància de Màntaras [6]. L'hem aplicada a l'estudi de mètodes de protecció, per comparar la seva eficiència quan l'usuari vol utilitzar les dades per fer categorització.

Per exemple, suposem primer que volem avaluar el mètode de protecció *microagregació* amb paràmetre p. Denotem això per $\rho = \mu.ag_p$. Suposem ara que volem avaluar aquest mètode en termes d'un mètode de categorització concret: el k-means (km) amb paràmetre concret k. Aleshores, pel conjunt de dades X tenim la mesura de pèrdua d'informació següent:

$$IL_{\mu.ag,p,km,k}(X) = d(km_k(X), km_k(\mu.ag_p(X)))$$

D'acord amb aquesta definició, la distància s'aplicarà a dues particions d'objectes de X, les dues amb k elements.

La distància de Màntaras ens permet calcular la divergència entre les dues particions.

Per a dues particions Π i Π' on $\Pi = \{\pi_1, \ldots, \pi_n\}$ i $\Pi' = \{\pi'_1, \ldots, \pi'_n\}$ (això és, les dues tenen el mateix nombre de parts), la distància de Màntaras [6] es defineix com segueix:

$$MD(\Pi, \Pi') = \frac{I(\Pi/\Pi') + I(\Pi'/\Pi)}{I(\Pi' \cap \Pi)}$$

on

$$I(\Pi/\Pi') = -\sum_{i=1}^{n} P(\pi_i') \sum_{j=1}^{n} P(\pi_j/\pi_i') \log P(\pi_j/\pi_i')$$

$$I(\Pi' \cap \Pi) = -\sum_{i=1}^{n} \sum_{j=1}^{n} P(\pi_i' \cap \pi_j) \log P(\pi_i' \cap \pi_j)$$

A banda de la distància de Màntaras, hem fet servir també els índexs de Jaccard, Rand, Rand ajustat i Wallace. Tots aquests índexs són vàlids per comparar particions, tot i que calculen semblances entre particions i no distàncies.

La utilització d'aquestes funcions de semblança i distància ens han permés, per una banda, l'anàlisi dels mètodes de protecció i veure quins d'ells tenen un millor comportament en relació a la pèrdua d'informació quan l'usuari vol fer categorització de les dades. A més a més, ens han permés [4] també comparar fins a quin punt les mesures de pèrdua d'informació genèriques i les específiques per categorització tenen un comportament similar.

En relació a la comparació de mesures, els resultats aconseguits ens mostren que les mesures genèriques tenen un comportament similar a les específiques. Per exemple, en la taula 1.1 (vegeu [4]) es mostra que la distància de Màntaras té una correlació de 0.91 en relació a la mesura de pèrdua d'informació genèrica. La taula inclou dues columnes, una en la qual la correlació es calcula a partir dels resultats de tots els mètodes i un altre en la qual la correlació es calcula a partir dels resultats restringits a la microagregació. En aquest segon cas, la correlació entre les mesures genèriques i les específiques és encara més gran.

Els generadors de dades sintètiques s'utilitzen també com a métodes per protegir dades. Així doncs, són també un mètode d'emmascarament. L'aproximació consisteix en construir un model de les dades que tenim a X i utilitzar aquest model per construir després la matriu Y. Es diu que un dels inconvenients d'aquesta aproximació és que Y només manté aquelles propietats que s'han inclòs de forma explícita en el model. A [5] vam estudiar si la generació de dades sintètiques mitjançant el mètode IPSO [2] era apropiat quan l'usuari volia fer categorització de les dades. L'avaluació dels resultats de la categorització, utilitzant entre d'altres la distància de Màntaras, mostrava que els generadors de dades sintètiques tenen un comportament similar a la microagregació.

Índex / Distància	Correlació (a) tots els mètodes	Correlació (b) Microagregació
Índex Rand	-0.79281	-0.86099
Índex Jaccard	-0.89094	-0.94859
Índex Adjusted Rand	-0.91609	-0.96114
Índex Wallace	-0.92559	-0.97593
Distància Màntaras	0.91617	0.97216

Taula 1.1: Correlació entre la mesura de pèrdua d'informació genèrica i les mesures de pèrdua d'informació específica per categorització. (a) Cas en que es consideren els resultats de tots els mètodes de protecció. (b) Cas en que només es consideren els resultats dels mètodes de microagregació.

1.4 Conclusions

En aquest treball hem repassat l'aplicació de la distància de Màntaras a la privadesa de dades. Hem vist que aquesta distància s'ha utilitzat en mesures de pèrdua d'informació quan es preveu que les dades siguin utilitzades en categorització. Els resultats esmentats aquí s'han aconseguit per a bases de dades numèriques, tanmateix la mateixa aproximació es pot utilitzar per altres tipus de dades com dades categòriques o les dades provinents dels cercadors. Actualment estem treballant amb dades categòriques en una línia de treball similar.

Agraïments

La recerca esmentada aquí per dades numèriques s'ha fet en col·laboració amb la Susana Ladra (U. A Coruña) (vegeu [4, 5]). En Jordi Marés treballa actualment amb dades categòriques per a problemes de categorització (vegeu [7]).

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Chapter 2
Localization and Object Recognition for Robots

Arnau Ramisa

2.1 Introduction

If some day robots are to get closer to what science fiction depicts, they will definitely require a rich perception and representation of the environment. Since the early days of robotics research, how to create such representations and how to use them, have been central topics of work and, although significant progress has been already made, there is still much to be done if we are to fulfill this vision.

During past decades, emphasis was put in approaches focused on building representations of spatial layout for mobile robots with a focus on localization, such as the ones described in the survey made by Filliat et al. [1]. Recently, more ambitious approaches in the cognitive sense have been undertaken, as the one proposed by Vasudevan et al. [2], that proposed a hierarchical probabilistic concept-oriented representation of space, constructed from objects detected in the environment and their spatial relationships. Such representation allows to endow the robot with a reasoning capacity that transcends the question "*where am I?*", typically pursued by previous localization systems, by giving it the ability to infer the purpose or category of the room through the semantically meaningful elements or objects that can be detected. However, if this type of approaches are to succeed, they will undoubtedly require much

Arnau Ramisa
IIIA-CSIC, e-mail: aramisa@iiia.csic.es

more advanced perception capacities than the ones typically found in a robot nowadays.

During my PhD I've enjoyed working in these exciting research challenges. The problems I encountered were daunting, but also the reward was exceptional: witnessing and understanding the cutting-edge advances made by the whole scientific community, and feeling part of them in this endeavor to push the boundaries of knowledge. However, what truly helped me endure this research baptism called PhD, was the support of the IIIA community and, most remarkably, of my advisor, Ramon Lopez de Mantaras. He helped me go through the doubts and dilemmas of research, and to him I owe the result of this work. Furthermore, even after the end of my PhD, he kindly helped me with all the difficult career decisions I had to make. This document is an abbreviated version of some of the most relevant experiments conducted during my PhD. The rest of the article is organized as follows: in Section 2.2 a global localization method based in panoramas is presented, in Section 2.3 we propose a homing method to navigate between panorama nodes. In Section 2.4, two computer vision object recognition methods are evaluated in a mobile robot setting, and in Section 2.5 one is used in an object-based robot localization experiment. Finally, in Section 2.6 the main conclusions of this work are presented.

2.2 Global Localization

We propose a topological vision-based localization approach of a mobile robot evolving in dynamic indoor environments. Robot visual localization and place recognition are not easy tasks, and this is mainly due to the perceptive ambiguity of acquired data and the sensibility to noise and illumination variations of real world environments. We propose to approach this problem by using a combination of affine covariant detectors so as to extract a robust spatial signature of the environment.

The proposed representation to characterize a place is a *constellation* of feature regions extracted from a panoramic image of the room. The local nature of this representation makes it robust against partial changes in the image due to occlusions, change in point of view or dynamic changes in the environment. Nevertheless, combining different region detectors increases the computational time and memory require-

ments. For this reason we show that a re-ranking mechanism based on a global appearance-based similarity measure can be used to prioritize the most similar map nodes.

To compare two panoramas, matches are first established as nearest neighbors between the SIFT [3] feature descriptors of the local regions found in both panoramas. Then, potentially false matches are rejected if the first and the second nearest neighbor are not separated enough. Additionally, reciprocal matching is used to filter even more false matches.Next, the epipolar constraint between the panoramas is enforced by computing the essential matrix. The most straightforward way to automatically compute the essential matrix is using the normalized 8-point algorithm [4]. However, assuming that the robot will only move through flat surfaces, it is possible to use a simplified version where only 4 correspondences are necessary.

$$E = \begin{bmatrix} 0 & e_{12} & 0 \\ e_{21} & 0 & e_{23} \\ 0 & e_{32} & 0 \end{bmatrix} \tag{2.1}$$

Therefore, with a set of at least four correspondences of points of the form

$$p = [x, y, z] = [sin(2\pi\tilde{x}), \tilde{y}, cos(2\pi\tilde{x})] \tag{2.2}$$

where $\tilde{x}$ and $\tilde{y}$ are the normalized point coordinates in the planar panorama image, the following equations can be written:

$$\begin{bmatrix} y'_1 x_1 & x'_1 y_1 & z'_1 y_1 & y'_1 z_1 \\ \vdots & \vdots & \vdots & \vdots \\ y'_n x_n & x'_n y_n & z'_n y_n & y'_n z_n \end{bmatrix} \begin{bmatrix} e_{12} \\ e_{21} \\ e_{23} \\ e_{32} \end{bmatrix} = 0 \tag{2.3}$$

where (x_i, y_i, z_i) and (x'_i, y'_i, z'_i) is the i^{th} pair of corresponding points. As outliers may still be present among the matches, RANSAC is used to automatically compute the essential matrix with most support. Finally, the set of inlier feature matches that agree with the epipolar constraint is used as the evidence of the relation between the two panoramas.

We validated our approach using a dataset of sequences of panoramas from rooms of varied shape and appearance in several buildings[1]. Each

[1] The dataset, as well as more experimental results, can be found in `http://www.iiia.csic.es/~aramisa`

sequence consists of several panoramas acquired every 20 cm following a straight line predefined path. In order to test the proposed method, we evaluated all possible combinations of the three selected region detectors.

Table 2.1, shows the average percentage of correctly classified test panoramas for each combination of the three considered region detectors: Harris Affine, Hessian Affine and MSER [5]. Results are provided using the 8-point algorithm, the 4-point algorithm and also the later with reciprocal matches. From the results illustrated in the table, it can be seen that by reducing the number of false matches with the reciprocal matches technique, improves substantially the performance. Looking at the feature detectors individually, the best results have been obtained by Harris Affine, while Hessian Affine and MSER had a similar performance. Overall, the combinations of detectors outperformed the indi-

Combination	8 points algorithm		4 points algorithm		4 points and recipr. match	
	acl	std	acl	std	acl	std
HA	74%	23%	69%	23%	82%	22%
HE	58%	24%	73%	26%	75%	25%
M	62%	28%	78%	18%	76%	23%
HA+HE	64%	15%	78%	19%	86%	14%
M+HE	56%	23%	75%	23%	87%	15%
M+HA	65%	21%	79%	19%	86%	14%
M+HA+HE	62%	16%	82%	19%	89%	11%

Table 2.1: Average percentage of correctly localized panoramas (acl) across all sequences and standard deviation (std). For convenience we have labeled M: MSER, HA: Harris-Affine, HE: Hessian-Affine.

vidual detectors. The best performance in the localization test has been achieved by the combination of the three detectors, which classified correctly 90% of the panoramas. This performance is mainly due to their good complementarity.

Sequences acquired in large rooms typically achieved a good performance no matter the combination used. However, small rooms and specially long and narrow corridors seem to be more difficult environments, even if they are well textured. This can be explained because the distance between the robot and the perceived objects is short and, therefore, the

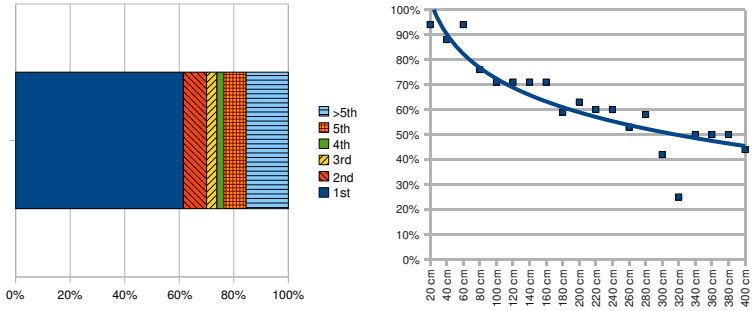
objects' appearance changes rapidly resulting in an unreliable matching in the lateral regions of the panorama.

Most of the similar approaches to global localization, like [6], use feature detectors only invariant to scale but not affine covariant, mainly because of its more expensive computational cost. For comparability, we have evaluated the performance of the Difference of Gaussians detector with the SIFT descriptor [3]. For our tests we used the implementation provided by Lowe[2]. On average, using points detected with the DoG and SIFT, the correct location was selected in 72% of the cases. However, it had an irregular performance depending on the environment type (27% standard deviation), with perfect results in large rooms, but very poor results in narrow corridors and small rooms. This was an expected outcome as this detector is less resistant to viewpoint changes.

2.2.1 Re-Ranking of Map Nodes

Given the high dimensionality of the feature descriptors, matching is several orders of magnitude more expensive than the other stages of the method in terms of computational cost, even for a small set of nodes. An alternative to exhaustive matching is to use a global similarity measure to re-rank the map nodes and estimate the essential matrix only for the k top map nodes or, applying an *any-time* algorithm approach, until a node with a certain ratio of inliers is met. The global similarity measure should be fast to compute and exploit the differences between the map nodes to improve the re-ranking. We have applied the Vocabulary Tree proposed in [7] for object categorization to re-rank the map nodes for a new query image as it fulfilled both requirements. In short, this method constructs a *visual vocabulary tree* of feature descriptors applying hierarchical k-means on a training dataset. Next, images are described as a normalized histogram of *visual word* counts. To give more emphasis to discriminative *visual words*, they are weighted using a Term Frequency-Inverse Document Frequency (TF-IDF) approach. Finally, the images in the training set can be re-ranked according to its Euclidean distance to the new image visual word histogram. To evaluate the proposed ap-

[2] `http://www.cs.ubc.ca/~lowe/keypoints/`



(a) (b)

Fig. 2.1: (a) Position of the correct map node after re-ranking using the vocabulary tree. (b) Ratio of query images with the correct node re-ranked at the top position against distance to first panorama of the sequence. The logarithmic regression curve is also shown.

proach, we have build the vocabulary tree with Harris Affine features.

We used only the map nodes to train both the vocabulary tree and the classifier. This gives only one training instance for each "class". Despite so limited training data, the approach achieved the notable overall result of re-ranking the correct node in the first position for 62% of the query panoramas, and among the top five nodes 85% of times as can be seen in Figure 2.1.a. As expected, the percentage of times the correct map node is re-ranked at the top position decreases as distance to the query panorama increases (see Figure 2.1.b).

2.2.2 Localization with 45° *FOV images*

Constructing a panoramic image with a rotating camera on a pan-tilt unit is a time-consuming step that requires the robot to stay in a fixed position during the acquisition. In order to assess the decrease in performance that would cause using just a single conventional image to localize the robot we have done the following experiment: For every test panorama,

a random area that spans 45° and has at least 100 features is extracted and matched to the map nodes. This procedure is repeated for every test panorama. After a 10 repetitions experiment with all test panoramas, the average number of correct localizations was above 70% using Harris Affine combined with MSER. This result is good considering how limited the field of view is. In addition to the time saved in image acquisition, the matching time is reduced almost one order of magnitude on average.

2.3 Robot Homing with the Average Landmark Vector

To complement the proposed global localization method, we have investigated a biologically inspired homing method, the *Average Landmark Vector* (ALV), that can be used to travel between the nodes of the map graph. The advantages of this model are its simplicity, that only the orientation and the ALV at the home location have to be stored instead of a whole image and, as a third advantage, that no matching of the landmarks is needed.The ALV is defined as the average of the landmark (or feature) position vectors:

$$ALV(F, \overrightarrow{x}) = \frac{1}{n} \sum_{i=0}^{n} \overrightarrow{f_i} \tag{2.4}$$

Where $F = \{\overrightarrow{f_1}, \overrightarrow{f_2}, \ldots, \overrightarrow{f_n}\}$ is the collection of features that define the signature taken at the current position $\overrightarrow{x}$ and f_i are the coordinates of the i^{th} landmark position vector. The home vector is defined as follows:

$$homing(F, \overrightarrow{x}, \overrightarrow{d}) = ALV(F, \overrightarrow{x}) - ALV(F, \overrightarrow{d}) \tag{2.5}$$

Where $\overrightarrow{x}$ is the current location of the robot and $\overrightarrow{d}$ the destination. One important prerequisite of the ALV is that it is necessary to have the panoramic images aligned to an external compass reference before computing the homing direction.

Since we would like the method to work also in unprepared environments, we propose to use the ALV with feature points detected in the images. Here we evaluate the Differences of Gaussians from [3] and the Maximally Stable Extremal Regions from [8]. Only the x and z coordi-

nates of the feature points are used to compute the ALV because of the flat world assumption. As a way to solve the constant orientation prerequisite, all test panoramic images have been acquired with the robot facing a constant direction as is common practice in similar works [9, 10]. In order to apply the ALV method in a navigation experiment a magnetic compass, or another system to acquire the global orientation, is required to align the panoramas.

After successfully evaluating the proposed method in a simulated setting, we tested this method in a real robot. Several panorama were acquired at a grid of known points in three rooms of different sizes. The orientation of the robot was kept constant for each panorama so no alignment step is necessary between the panoramas. Three types of landmarks/feature points were used: 1) DoG feature points; 2) MSER feature points; and, only in the robot laboratory, 3) artificial landmarks. A scaled map of the rooms can be seen in Figure 2.2.

The home angle calculated by the homing method is compared to the ground truth home angle (All angles are in degrees and counter-clockwise). To find out how well the method works for each room and each type of feature, all the panorama positions per data set are used. For each data set (the *square room*, the *robot laboratory* and the *corridor*) all the locations where a panorama was created are used to calculate the home vector to each of the other locations.

From the error between the estimated and ground truth angles, for each possible panorama pairings in one room, the mean, median, standard deviation and a score are calculated. The score is calculated by using the proportion of the maximum error and ranges between 0 and 1 being 1 best. Namely:

$$s = 1 - \frac{\sum_{i=1}^{n} \sum_{j=1;i\neq j}^{n} \theta_{\text{diff}}(h_{\text{h}}(P_i,P_j), h_{\text{c}}(P_i,P_j))}{180n(n-1)} \tag{2.6}$$

where P is the set of panoramas and n its cardinality. The ground truth angle is represented as h_{c} and the estimated homing angle is h_{h}. Next we discuss the results obtained for the three different areas.

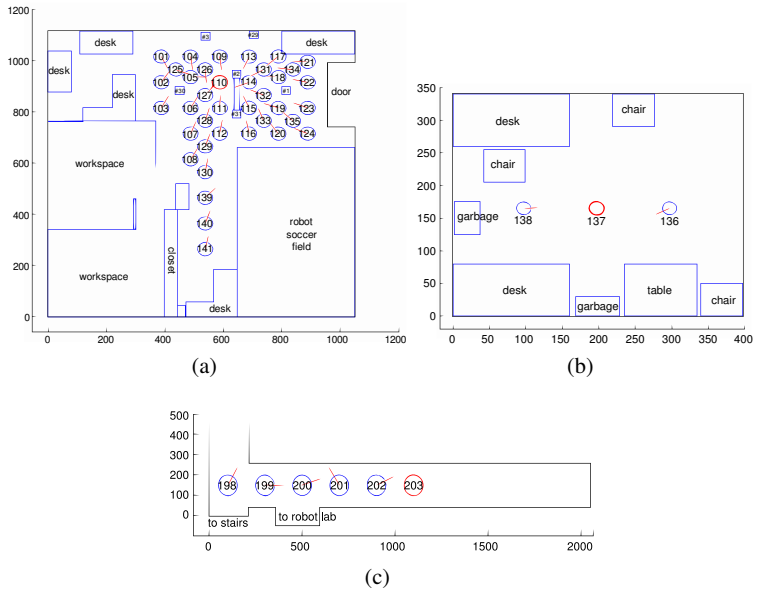


Fig. 2.2: (a) Homing to panorama 110 in the *robotics laboratory*, (b) the *square room*, and (c) the *corridor*, using MSER feature points. All measures are in cm. The panorama locations are marked as circles with its identifying number and a line pointing to the direction of the estimated home vector. The home location is shown as a red circle without line. The small squares in (a) show the artificial landmark positions and its ID number.

Robotics laboratory:

Most panoramas, 38 in total, were acquired in the *robotics laboratory*, a room of 10.5 m $\times$ 11.2 m. Only the half of the room is really used for this experiment because the other part is filled with working places and the robot soccer field as can be seen in Figure 2.2.a. The home vectors have an error equal to or lower than 90° in 89.3% of the cases when the DoG detector was used, 92.6% for the MSER detector and 99.6% when the landmarks were used. An error of 10° or less was obtained in 22.6%

of the cases for the DoG detector, 32.7% for the MSER detector and 64.3% for landmarks.

Table 2.2 shows the results for each type of detector used. The homing errors for the three methods are all significantly different ($p < 0.001$) according to the rank sum test, and the t-test after bootstrapping ($n = 1000$). From this can be concluded that the homing method worked best with the artificial landmarks, as expected, and worst with the DoG detector.

Square room:

The square room is 4.0 m $\times$ 3.4 m big. Figure 2.2.b shows the map of the room and the home vectors to panorama 137 using MSER features. Table 2.2 shows the statistics of the homing method using both feature types. MSER feature points achieved lower error rates than DoG feature points, but this is not significant (confirmed by the rank sum test and the t-test) and it must be noted that only three panoramas were created in this room.

Corridor:

Although the simulation showed that the ALV homing method works better in square rooms, we wanted to find out what the impact of a very long and very narrow room in a real environment would have on the method. A corridor was chosen for that reason as last experiment room. The part of the corridor in which the robot moved is 2.2 m wide and about 22.5 m long.

In Figure 2.2.c the home vectors to panorama 203 are shown using MSER features. An error of 90° or less was obtained in 73.3% of the cases for both feature types, an error of 10° or less was only obtained in one case (6.7%). Table 2.2 shows the average error of this data set; the differences between the results with DoG and MSER are not statistically significant.

	Robotics Laboratory			Square Room		Corridor	
	DoG	MSER	AL	DoG	MSER	DoG	MSER
Mean err.	35.6°	27.8°	14.9°	13.8°	9.7°	56.3°	52.7°
Median err.	22.9°	16.0°	10.2°	12.0°	12.0°	44.6°	35.7°
Std err.	36.7°	35.5°	14.9°	11.3°	7.8°	43.6°	44.9°
Score	0.80	0.85	0.92	0.92	0.95	0.69	0.71
Best home	117	117	110	138	138	203	200

Table 2.2: The homing error using the panoramas from the different rooms. The *best home* field shows the number of the panorama which attained lowest average error when chosen as home (see Figure 2.2). AL stands for Artificial Landmarks.

Upper and lower part:

In an attempt to improve the results, the view of the image was limited to only the lower half of the panorama. This part contains objects which are closer to the robot and therefore decrease the size of the visible world, for this reason a room may look more square. In the *robotics laboratory* using only the lower half of the panorama resulted in a lower error than using all feature points of the panorama ($p < 0.001$ with the t-test and the rank sum test for both DoG and MSER). For the other rooms there was no significant difference in performance.

2.3.1 Discussion

As has been seen, with the real robot experiments the ALV homing method using local features as natural landmarks gave very positive results, specially in rooms were width and length are similar like the *square room*. This has been explained by the way the feature points are projected on the panorama and by the *equal distance assumption* [11].

Looking at the difference in performance using DoG and MSER feature points it can be concluded that the use of MSER significantly outperforms the use of DoG. As expected, the results with the artificial landmarks were significantly better than using invariant feature points, the error was about 7° less than using MSER (with only the lower half of the panorama). However this difference seems low enough to justify the

applicability of the presented homing method, because does not require setting up the environment by placing artificial landmarks.

This method is suitable, for example, for directing the robot from one of the nodes of a topological map to the next with the minimal cost (i.e. no matches have to be established between visual feature points of the images).

2.4 Object Recognition for Mobile Robots

Even though the localization method proposed in section 2.2 is able to reliably model and recognize places, still few semantic knowledge about the world is available to the robot to reason with. As mentioned earlier, [2] proposed a powerful space representation constructed from semantically rich elements of the environment. However, in order for this model to be applicable, a fast and robust object recognition or classification method is indispensable.

Indeed, not only localization would benefit from having a robust, generalistic and easily trainable object recognition system. Also other fields such as robot manipulation, human robot interaction and, in general, any discipline that addresses a practical use of robotics in a not highly structured environment would benefit from such a method. On the other side, computer vision is obtaining impressive results with recent object recognition and classification methods, but we are aware of little effort on porting it to the robotics domain. Therefore, a lightweight object perception method which allows robots to interact with the environment in a human cognitive level is still lacking.

In order to help reduce a bit this gap, we evaluate two successful state of the art object recognition methods – the SIFT object recognition method from [3], and the [7] Vocabulary Tree – on a realistic mobile robotics scenario, that includes many of the typical problems that will be encountered when roboticists try to use these methods on practical matters. Both methods have several properties that make them attractive for the problem of mobile robotics: the SIFT object recognition method detects object hypothesis location up to an affine transformation and has a low ratio of false positives; the Vocabulary Tree is a *bag of features* type method that was designed with the objective of being fast and scal-

able. Furthermore, it is suitable for types of objects that may confuse the SIFT method because of few texture or repetitive patterns.

In order to evaluate the methods in a realistic mobile robots setting, we have created the IIIA30 and the ASL databases[3]. The IIIA30 that consists of three sequences of different length acquired by our mobile robot while navigating in a laboratory type environment. Image size is 640x480 pixels. The environment has not been modified in any way and the object instances in the test images are affected by lightning changes, blur caused by the motion of the robot, occlusion and large scale and viewpoint changes. We have considered a total of 30 categories (29 objects and background) that appear in the sequences. The objects have been selected to cover a wide range of characteristics: some are textured and flat, like the posters, while others are textureless and only defined by its shape. The ASL dataset consists of nine household objects with varying levels of texture, with 20 training images and 36 test images with several of the objects at the same time in an office environment.

2.4.1 Scale Invariant Feature Transform

We extensively cross-validated the multiple parameters of the Scale Invariant Feature Transform (SIFT) method to find those configurations that attained a good level of precision and recall, while maintaining a run-time of around one second.

In general all possible combinations of parameters performed better in well textured and flat objects, like the books or posters. For example the *Hartley book* or the *calendar* had an average recall of 0.78 and 0.54 respectively. This is not surprising as the SIFT descriptor assumes local planarity, and depth discontinuities can severely degrade descriptor similarity. On average, textured objects achieved a recall of 0.53 and a precision 0.79 across all sequences. Objects only defined by shape and color were in general harder or even impossible to detect. Recall for this type of objects was only 0.05 on average. Finally, and somewhat surprisingly, objects with a repetitive texture such as the *landmark cubes* had a quite good recall of 0.46 on average. Furthermore, the result becomes

[3] `http://www.iiia.csic.es/~aramisa`

even better if we take into consideration that besides the self-similarity, all three *landmark cubes* were also similar to one another.

Regarding the image quality considerations, all combinations behaved in a similar manner: the best recall, as expected, was obtained by images not affected by blur, occlusions or strong illumination changes. From the different disturbances, what was tolerated best was occlusion, followed by blur and then by illumination. Combinations of problems also had a demolishing effect in the method performance, being the worst case the combination of *blur* and *illumination* that had 0 recall. Object instance size (for objects with a bounding box defining an area bigger than 5000 pixels) did not seem to have such an impact in performance as image quality has.

2.4.2 Vocabulary Tree

The main drawback of the Vocabulary Tree method is that it needs at least a rough segmentation of the object to be recognized. To overcome this limitation two alternatives may be used: divide the input image using a grid of fixed overlapping regions and process each region independently, or use a segmentation algorithm to yield meaningful regions to be recognized.

Sliding windows:

This option has the advantage of simplicity and universality: Results do not depend on a particular method or set of segmentation parameters, but just on the positions and shapes of the windows evaluated. However a square or rectangular window usually does not fit correctly the shape of the object we want to detect and, in consequence, background information is introduced.

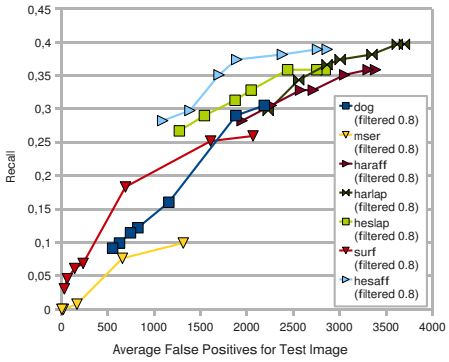
The main drawback of the sliding windows approach is the amount of false positives it introduces; to filter out as many as possible, in addition to rejecting windows with less than a determined minimum number of features, we have evaluated the effect of requiring a ratio between the first and the second classes in the k-NN voting. Namely, the restriction $V_2 < \delta \cdot V_1 \mid \delta \in [0,1]$ had to be satisfied, where V_1 is the score of the

most voted class, V_2 that of the second, and δ is the threshold we want to impose. In Figure 2.3.a results of this filtering schema with $\delta = 0.8$ are shown using the different feature detectors. It practice, this approach reduced the number of false positives in around 500 per image on average at the price of reducing also the recall by 5%. In spite of this improvement, the number of false positives is still too high for the method to be usable.

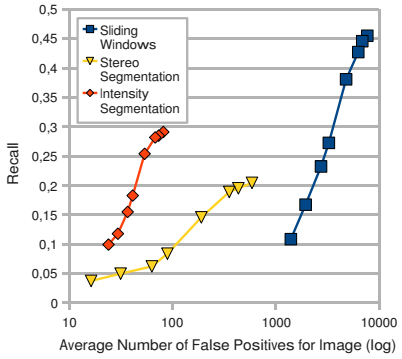
Segmentation methods:

The second alternative is using a segmentation method to divide the image into a set of regions that must be recognized. Various options exist for this task which can be broadly classified as intensity based and, if stereo pairs of images are available, depth based. We have evaluated an intensity based method and a depth based one. The intensity based method we propose, that we called *floodcanny*, consists on first applying the Canny edge detector to the image, and use the resulting edges as hard boundaries in a *flood filling* segmentation process. For each region of sufficient size, a set of five windows of different sizes centered at the detected region are defined. As can be seen in Figure 2.3.b, the number of false positives has decreased from thousands to only tens. Despite this results, the segmentation scheme we have applied is not optimum, as it usually works well for large and textureless objects, that can be segmented as a big single region, but misses small and textured objects, as no single large enough region can be found.

The second segmentation alternative proposed consists of directly matching features between the left and right image to detect areas of constant depth. Epipolar geometry constraints can be used together with the scale and orientation of a given feature to reduce the set of possible matches. To determine the location of candidate windows, a grid of 3D cells of different sizes is used. Reprojected features cast a vote for a cell of a grid if it lies within the 3D cell coordinates. Cells that have a minimum number of votes are reprojected to the image and added as a candidate window. Figure 2.3.b shows the results for this experiment. Although the maximum attained recall is slightly lower than that of sliding windows it must be noted that, at a similar level of recall, false positives are much lower.



(a)



(b)

Fig. 2.3: (a) Recall against average number of false positives per image for the VT in the ASL dataset with different feature detectors, filtering windows as described in the text with $\delta = 0.8$. (b) Results of the proposed sub-window generation methods for the first sequence of the IIIA30 dataset. For the three experiments the DoG detector and a tree with branch factor 10 and depth 4 have been used.

2.5 Object-Based Localization

To illustrate the interest for object recognition methods for topological localization, we perform a preliminary object-based localization experiment using a dataset of stitched panoramic images acquired with a mobile robot.

The method used for object recognition is the one proposed by Lowe [3], as it was found to have the most acceptable false positive rate and run-time. We use one training image (frontal view) per object in the library except in some cases, where the object can be found in two different views (e.g. fire extinguisher). For this objects we collected a second training image and treated it as a separate object in the library. All training images are taken from a 1Mpx digital camera. The testing dataset consists of five sequences of 11-22 panoramas taken with our mobile robot in our facilities. Panoramic images have a size about 6000x500 pixels.

The processing time for each panorama, ignoring panorama acquisition time and feature extraction, is about 1 second for descriptor matching using the FLANN library set at 90% of retrieval precision, 5 ms for Hough Transform and 1-2 ms for the affine stage (RANSAC+IRLS or IRLS alone), so the processing can go near real-time. Tests have been done in a 3 Ghz Pentium IV with 1 Gb of RAM. In order to test the applicability of object recognition in a place classification task we set up the following test. Object presence mean vectors are computed for each panorama sequence, except in the sequence we are testing, where one panorama is used to test and the rest are used to compute the mean vector, resulting in a leave-on-out evaluation strategy and a minimum distance classifier. The results of this test are shown in Table 2.3. As can be seen, localization rate is good despite that object recognition only recalls 50% of objects and there is a significant amount of false positives.

Furthermore, object recognition as a middle stage between image data and place recognition helps reduce the complexity of the place descriptor while increasing its robustness. It can also help reduce irrelevant information and noise from the background that could confuse approaches that rely on low-level information. In this approach we only take into account *natural landmarks* formed with groups of locally coherent features, filtering potential false matches arising from spurious features. A

Sequence	**Hit**	**Miss**	**Rate (%)**
lab02	10	1	91
actes03	13	1	93
actes04	11	3	79
lab08	18	1	95
passadis04	19	3	86

Table 2.3: Place recognition results.

possible extension to our approach would be incorporating position information to the detected objects along with a degree of mobility (for example a window would have mobility zero, while a chair would have a higher value).

2.6 Conclusions

During my time at the IIIA, I've worked with Ramon Lopez de Mantaras in many problems aimed at enabling high-level vision-based robot perception. We have proposed and evaluated a signature to characterize places that can be used for global localization, consisting of a constellation of local feature descriptors, extracted from a panorama, that can be used to localize the robot by matching the local features of a new panorama to the ones of those stored in the map. False matches are rejected by imposing geometric constrains. We also proposed some improvements, such as combining different feature detectors and a method to speed-up the localization.

To complement the proposed global localization system, we investigated the applicability of the ALV, a homing method with very low computational complexity, to travel from one map node to another using local features instead of artificial landmarks. Two local feature detectors were tested: The Differences of Gaussians (DoG) [3] and the Maximally Stable Extremal Regions (MSER) [8]. The ALV homing was found to be a good working method; however, in accordance with previous findings, it performed worse in rooms where the width and length differ greatly.

Although equipping a robot with robust methods to extract semantic information from perceptual data is of utmost importance in order to have truly cognitive robots capable of realizing complex tasks in complex environments, we are aware of only a few works devoted to this

problem. Consequently, we address this gap by comparing and improving two state of the art object recognition methods with a focus on making them useful for mobile robotics, and we demonstrate their applicability in an object-based localization task.

Acknowledgments

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Chapter 3
What's CRI, Logically Speaking?*

Enric Trillas+

3.1 Introduction

One of the theoretically most relevant goals of fuzzy logic is the representation of larger parts of Natural Language than those classical logic is able to represent. At this respect, for Fuzzy Logic all that concerns Commonsense Reasoning if of an upmost importance, since it is permeated by linguistic imprecise terms that, to be represented, do be specified by means of fuzzy sets, fuzzy connectives, modifiers, quantifiers, fuzzy relations, and so on.

Central to the topic of Approximate Reasoning, is the well known Compositional Rule of Fuzzy Inference (CRI) introduced by Lotfi A. Zadeh, and that basically allows Fuzzy Control through, for instance, the methods of Mamdani-Larsen, and Takagi-Sugeno. At this respect, it seems dubious the (non incorrect) way in which most textbooks introduce CRI (see [2, 4]). It is also the case, for instance, of the nice booklet [3] that does that by linking CRI with a particular interpretation of fuzzy sets, namely the possibilistic one, and that hiddens the logical character

Enric Trillas
European Centre for Soft Computing, e-mail: enric.trillas@softcomputing.es

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+**To Ramon, old student, colleague, excellent researcher, and, over all, friend.**

of the Rule. In particular, it is hidden what represents the output for both, someone who knows the input and the rules, and someone (an external observer) for whom the system is a black box and only knows the input. Something that, notwithstanding, can be easily done by looking at CRI from an interpretation of 'reasoning', and considering the values of the membership functions instead of them.

A good part of reasoning consists in deducing logical consequences, abducing hypotheses, inducing speculations, and refuting, or deducing refutations, with the three first concepts giving rise to the idea of conjecturing [7]. To learn on the subject of the formalization of conjectures, see [8, 1, 5, 6], in which framework what follows is inscribed.

If instead of the partially ordered set of all fuzzy sets is taken the totally ordered unit interval, is is obtained a simpler way to work than with membership functions, even producing some small shortcomings, only appreciated by the dissaparition of inductive speculations. Anyway, such setting is good enough for posing CRI after a correct design of the involved linguistic terms by fuzzy items is done [9].

3.2 Conjectures in the unit interval

3.2.1

Almost all in [5] holds in any De Morgan algebra, but in what follows the universe of discourse will be the set [0,1] endowed with the restriction of the total order of the real line. Hence its elements are the numbers $a \in \mathbb{R}$ such that $0 \leq a \leq 1$, and the algebraic structure ([0,1] , min, max, N_φ), is a De Morgan algebra if $N_\varphi = \varphi^{-1} \circ N_\varphi = (1-\varphi)$ is a strong negation, with $\varphi : [0,1] \to [0,1]$ an order auto-morphism of the ordered unit interval [2].

Let F be the familly of subsets P of [0,1], such that $\inf\{P\} = p \not\leq N_\varphi \circ p$,equivalent to $p > N_\varphi \circ p$,that is, such that p is not self-contradictory. If $P = \{p_1, p_2, ..., p_n\}$ is finite, it is $p = \min(p_1, p_2, ..., p_n)$. From $N_\varphi \circ p = \varphi^{-1}(1-\varphi(p))$, follows that p is not self-contradictory if and only it is $p > \varphi(\frac{1}{2})$. If $\varphi = id$, it is $N_{id} = 1 - id$, and $\varphi^{-1}(\frac{1}{2}) = \frac{1}{2}$.

Of course, $\varphi^{-1}(\frac{1}{2}) \in [0,1]$ is the only fixed point of N_φ , and for any $r \in [0,1]$ there are many many strong negations such that $\varphi^{-1}(\frac{1}{2}) = r$, for instance the linear piecewise strong negation,

$$N_\varphi(x) = \begin{cases} 1-(\frac{1-r}{r})x, & \text{if } 0 \le x \le r \\ (1-x)(\frac{r}{1-r}), & \text{if } r \le x \le 1 \end{cases} \tag{3.1}$$

Given $P \in F$, the set $C(P) = \{q \in [0,1]; p \le q\} = [p,1]$,verifies:

a. $\inf\{C(P)\} = p$. Hence, $C(P) \in F$, and $C : F \to F$. In addition, $C(P) = C(\{p\})$, since $\{p\} \in F$.
b. If $q \in C(P)$, then $N_\varphi \ o \ q \notin C(P)$, since $p \le N_\varphi \circ q$ is equivalent to $q \le N_\varphi \circ p$, from what follows the absurd $p \le N_\varphi \ o \ p$. Thus, C is consistent.
c. Obviously, $P \subset C(P)$, and C is extensive.
d. $P \subset Q \Rightarrow q \le p$. Hence $p \le q^* \Rightarrow q \le q^*$, and $C(P) \subset C(Q)$. Thus, C is monotonic.
e. It is $q^* \in C(C(P))$ if and only if $p \le q^*$, or $q^* \in C(P)$. That is, $C(C(P)) = C(P)$, and C is a clausure.

In conclusion, C is a consistent consequence operator in F , and $([0,1], F, C)$ is a logic.

3.2.2

The operator, $Conj(P) = \{q \in [0,1]; N_\varphi \circ q \notin C(P)\} = \{q \in [0,1]; p > N_\varphi \circ q\} = (N_\varphi \circ p, 1]$, verifies:

i. $Conj(P) = Conj(\{p\})$, since $p \in F$.
ii. Obviously, $P \subset C(P) \in Conj(P)$, and in particular, $Conj$ is extensive.
iii. If $P \subset Q$, from (d) follows immediatelly $Conj(Q) \subset Conj(P)$, and $Conj$ is anti-monotonic.
iv. Although $P \in F$, it is not always $Conj(P) \in F$. For instance, with the strong negation $1 - id$, and $P = \{0.6, 0.8\}$ it is $p = 0.6$, and $C(P) = \{0.6, 1\}$, and $Conj(P) = (0.4, 1]$. Hence, $\inf\{Conj(P)\} = 0.4 < 0.6 = 1 - 0.4$, and $Conj(P) \notin F$. Notice that $Conj(P)$ is not consistent, since $0.5 = 1 - 0.5$ is in it.
v. $1 \in C(P)$, and $1 \in Conj(P)$, but since $0 \notin Conj(P)$, it is $0 \notin C(P)$, $\forall P \in F$. Thus, $Conj$ is a conjecture operator [1].

Remark

Provided some empirical reason indicates that there is a threshold of self-contradiction $r \in (0,1)$, it suffices to take a strong negation N_φ with r as its fix point, like it is the case of (3.1).

3.2.3

Obviously, $Conj(P) - C(P) = (N_\varphi \circ \ p, 1] - [p, 1] = (N_\varphi \circ p, p)$, since $p > N_\varphi \circ p$. That is ([5]), the set $Hyp(P) = \{q \in [0,1]; N_\varphi \circ p < q < p\} = (N_\varphi \circ p, p)$, can be called that of the hypotheses of P, and it is smaller than the interval $(0, p)$ defined in the general case of De Morgan algebras [5], except if $N_\varphi \circ p = 0$, or $p = 1$, in which case it is $p = p_1 = ... = p_n = 1$.

In this current particular case, it is $(Conj(P) - C(P)) - Hyp(P) = Sp(P) = \emptyset$, that is, there is no room to inductively speculate on P, something that in the universe $[0,1]^X$ of all fuzzy sets, and due to its partial pointwise ordering, only sometimes is the case. Out of a totally ordered universe, the operator Sp is neither monotonic, nor anti-monotonic, that is, in general it is properly non-monotonic ([1]).

For instance, in the example iv of 3.2.2, is $Hyp(P) = (0.4, 0.6)$, and $Conj(P) = [0.6, 1] \bigcup (0.4, 0.6) = (0.4, 1]$. Since $\inf\{P\} = 0.4$, it is not $Hyp(P) \in F$, and thus the operator is a mapping $Hyp : F \to [0,1]$. In addition, since $0.5 = 1 - 0.5$ is in $Hyp(P)$, these sets are not always consistent. Contrarily to $C(P)$, neither $Conj(P)$, nor $Hyp(P)$, can be taken as sets of premises, they are not liable as 'good' information.

3.3 The Compositional Rule of Fuzzy Inference

3.3.1

Once the scheme of the Generalized Modus Ponens (GMP),

$$\begin{array}{l} \text{If } x \text{ is } P \Rightarrow y \text{ is } Q \\ \underline{x \text{ is } P^*} \\ y \text{ is } Q^*, \end{array}$$

for $x \in X$ and $y \in Y$, is translated into fuzzy terms by

$$J(\mu_P(x), \mu_Q(y)), \mu_{P^*}(x) : \mu_{Q^*}(y)$$

with $J : [0,1] \times [0,1] \to [0,1]$ representing the rule, the problem of finding $\mu_{Q^*}(y)$ as a logical consequence of $P = \{J(\mu_P(x), \mu_Q(y)), \mu_{P^*}(x)\}$, is posed in the unit interval once x and y are fixed, and provided $m(x,y) = min(J(\mu_P(x), \mu_Q(y)), \mu_{P^*}(x))$ is not self-contradictory with respect to some strong negation N_φ. That is, if $m(x,y) > N_\varphi(m(x,y))$. Then $\mu_{Q^*}(y)$ does verify $m(x,y) < \mu_{Q^*}(y)$.

Since the last inequality implies $K(y) := Sup\{m(x,y)\} \leq \mu_{Q^*}(y)$, and from this follows $m(x,y) \leq \mu_{Q^*}(y)$, it is clear that $\mu_{Q^*}(y) \in C(P)$ if and only if $K(y) \leq \mu_{Q^*}(y)$. Hence, from

$$C(P) = \{r \in [0,1] \,;\, \sup_{x \in X}\{\, min(J(\mu_P(x), \mu_Q(y)), \mu_{P^*}(x)) \leq r\}$$

it follows that $K(y)$ is the smallest consequence of P, and it can be taken

$$\mu_{Q^*}(y) := \sup_{x \in X}\{\, min(J(\mu_P(x), \mu_Q(y)), \mu_{P^*}(x)),\ \forall\, y \in Y,$$

a definition known as the Compositional Rule of Fuzzy Inference.

3.3.2

In the typical scheme of Fuzzy Control

$$\text{Input } \mu_{P^*}(x) \longrightarrow \boxed{\text{rule}} \longrightarrow \text{Output } \mu_{Q^*}(y) \tag{3.2}$$

where both the input and the rule are known, the output is a logical consequence of both. Nevertheless, for an external observer for whom this scheme is a 'black box' and the rule is unknown, depending on the strong negation N_φ she/he could choose, the output will seems to be,

- A conjecture of the input if: $\mu_{Q^*}(y) > N_\varphi(\mu_{P^*}(x))$

- A refutation of the input if : $\mu_{Q^*}(y) \leq N_\varphi(\mu_{P^*}(x))$
- A consequence of the input if: $\mu_{Q^*}(x) \leq \mu_{Q^*}(y)$
- A hypothesis of the input if: $\mu_{P^*}(x) > \mu_{Q^*}(y) > N_\varphi(\mu_{P^*}(x))$.

This shows how a partial information on a system could make to vary the logical character played by the output.

Example

Suppose that the scheme,

$$\frac{\begin{array}{l}\text{If } x \text{ is } \textit{small}, \text{ then } y \text{ is } \textit{big}\\ x \text{ is } \textit{very small}\end{array}}{y \text{ is } Q^*}$$

with $x \in [0,1]$, and $y \in [0,10]$, is translated into fuzzy terms by $J(\mu_S(x), \mu_B(y)) = J(1-x, \frac{y}{10}) = (1-x).y/10$ (Larsen's conditional), and $\mu_{VS}(x) = (1-x)^2$. Thus,

$$\mu_{Q^*}(y) := \sup_{x\in[0,1]} \min((1-x)^2, (1-x).y/10) = \frac{y}{10} = \mu_Q(y)$$

is always a logical consequence of the input and the rule.

For an external observer who considers $x = 0.2$,the negation $N(x) = \frac{1-x}{1+x}$, and only knows the input '*0.2 is very small*' (she/he represents by $N(0.2)^2 = 0.44$), and the output represented by y/10, it could seem the following:

- From $0.44 > N(\frac{y}{10}) = \frac{10-y}{10+y}$, equivalent to $y > 3.9$, follows that for all $y \in (3.9, 10]$ the conclusion is a conjecture of the input. Hence, all $y \in [0, 3.9]$ give a refutation of the input.
- The $y \in (3.9, 10]$ giving hypotheses, are those for which $\frac{y}{10} < 0.44$, or $y < 4,4$. Hence, the hypotheses are the numbers $y \in (3.9, 4.4)$.
- Finally, the logical consequences come from the inequality $0.44 \leq \frac{y}{10}$, or $4.4 \leq y$, and the consequences are given by the numbers $y \in [4.4, 10]$.

Remarks

Although in the totally ordered universe $[0,1]$ there are not speculative conjectures once they are defined from the consequence operator C, in the partially ordered universe $[0,1]^X$ it is not always $Sp(P) = \emptyset$ (see [5]). Thus, if instead of taking the numbers $\mu_{P^*}(x)$, $m(x,y)$, and $\mu_{Q^*}(y)$, what are considered are the membership functions

$$\mu_{P^*} \in [0,1]^X,\ J \circ (\mu_P \times \mu_Q) \in [0,1]^{X \times Y},\ \text{and}\ \mu_{Q^*} \in [0,1]^Y,$$

it is possible for the 'observer' to also consider $\mu_{Q^*} \in Sp(P)$ when $\mu_{P^*} \not\leq N_\varphi \circ \mu_{Q^*}$, and $\mu_{P^*}\ NC\ \mu_{Q^*}$, with NC shortening 'not comparable under the partial pointwise order of fuzzy sets'.

3.4 To conclude

As it is well known, to preserve the typical Modus Ponens (If $P = P^*$, then $Q^* = Q$), it is necessary that in the CRI, and instead of doing it with min, it should be done with a continuous t-norm T for which $T(\mu_P(x), J(\mu_P(x), \mu_Q(y))\ ) \leq \mu_Q(y),$ for all $x \in X,$ and $y \in Y$. For instance, $J(a,b) = \max(1-a,b)$ -*Kleene-Dienes* conditional- does not preserve Modus Ponens with $T = \min$ and it should be used $T = W$.

This remark reduces the importance of what has been said to those few conditionals J for which it is $\min(a, J(a,b)) \leq b,$ *or* $J(a,b) \leq J_{\min}(a,b),\ \forall a,b \in [0,1]$, as it is the case of the *Mamdani-Larsen* type $J(a,b) = T(\varphi(a),b)$, and the min-residuated implication $J_{\min}$ - Gödel -, since S,Q, and D conditionals verify Modus Ponens with a T in the familly of Lukasiewicz. The residuated implications J_T verify that inequality with T; for instance, J_{prod} verifies it with $T = prod$. Thus, what can be said for the case of $T \neq \min$?

Given a continuous t-norm T, let F^* be the family of finite subsets of [0,1] such that $T(p_1,...,p_n) > N_\varphi(T(p_1,...p_n))$. It is $F^* = F$, if $T = \min$. If $P \in F^*$, define

$$C_T(P) = \{q \in [0,1]; T(p_1,...,p_n) \leq q\} = [T(p_1,...,p_n), 1]$$

that is not in F^*, and hence is a mapping from F^* into [0,1] . This set verifies the following properties:

a. $C_T(P)$ is consistent for any strong negation N_φ, since q and $N_\varphi \circ q \in C_T(P)$ produce the absurd $T(p_1,...,p_n) < N_\varphi(T(p_1,...,p_n))$.
b. From $T(p_1,...,p_n) \leq p_i (1 \leq i \leq n)$, follows that C_T is extensive, $P \subset C_T(P)$.
c. C_T is monotonic, since $P \subset Q$ implies $T(q_1,...,q_m) \leq T(p_1,...,p_n)$, and $C_T(P) \subset C_T(Q)$.
d. Since C_T cannot be applied to $C_T(P)$, C_T is not a clausure, and hence it is not a consequence operator.

Nevertheless, properties a, b, and c, allow [1], to define

$$\mathrm{Conj}_T(P) = \{q \in [0,1]; N_\varphi(q) \notin C_T(P)\}$$

that verifies $P \subset C(P) \subset C_T(P) \subset \mathrm{Conj}_T(P)$, and thus is extensive and contains the logical consequences in $C(P)$. It is also anti-monotonic since if $P \subset Q$, from $N_\varphi(q) \notin C_T(Q)$ it follows $N_\varphi(q) \notin C_T(P)$. Obviously, it is $\mathrm{Conj}_T : F^* \to [0,1]$. All that allows to consider $\mathrm{Conj}_T(P)$ as a conjecture operator for all T. Of course, these operators open the door to look at the Generalized Modus Ponens, posed with a continuous t-norm T, as a deductive scheme of Approximate Reasoning [6].

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Chapter 4
Case Based Reasoning, Reinforcement Learning and Heuristics: a Successful Combination

Reinaldo A. C. Bianchi

Abstract This paper presents some results of the collaboration between me and Professor Lopez de Mantaras, who received me as a visiting researcher at the IIIA from 2007 to 2009. The aim of the collaboration was to investigate a new approach that allows the use of cases in a case base as heuristics to speed up Single and Multiagent Reinforcement Learning algorithms, combining Case-Based Reasoning and Reinforcement Learning techniques. This approach, called Case-Based Heuristically Accelerated Reinforcement Learning, builds upon an emerging technique, Heuristic Accelerated Reinforcement Learning, in which RL methods are accelerated by making use of heuristic information. Algorithms that incorporates CBR techniques into the Heuristically Accelerated Q-Learning and Minimax–Q were proposed and a set of empirical evaluations were conducted in a simulator for the robot soccer domain. Experimental results showed that the algorithms proposed learn faster than methods using RL, CBR or Heuristics alone.

Reinaldo A. C. Bianchi
Centro Universitário da FEI São Bernardo do Campo, São Paulo, Brazil. e-mail: rbianchi@fei.edu.br

4.1 Introduction

Heuristic Accelerated Reinforcement Learning (HARL) [5] is an emerging technique in which Reinforcement Learning (RL) methods are sped up by making use of a conveniently chosen heuristic function, which is used for selecting appropriate actions to perform in order to guide exploration during the learning process.

HARL techniques are very attractive: as RL, they are based on firm theoretical foundations. As the heuristic function is used only in the choice of the action to be taken, many of the conclusions obtained for RL remain valid for HARL algorithms, such as the guarantee of convergence to equilibrium in the limit – given that some predefined conditions are satisfied – and the definition of an upper bound for the error [5]. Although several methods have been successfully applied for defining the heuristic function, a very interesting option has only recently been explored: the reuse of previously learned policies, using a Case-Based Reasoning approach.

This paper is the result of a collaboration that started in 2007, when Professor Lopez de Mantaras received the author as a visiting researcher at the IIIA. The goal of the collaboration was to investigate possible combinations of Case-Based Reasoning (CBR) and Single and Multiagent Heuristically Accelerated Reinforcement Learning (HARL and HAMRL) [5, 4] techniques, aiming the speeding up of algorithms by using previous domain knowledge, stored as a case base. We also proposed two new algorithms, the Case-Based Heuristically Accelerated Q–Learning (CB-HAQL), which incorporates CBR techniques into an existing HARL algorithm, the Heuristically Accelerated Q–Learning, (HAQL), and the Case-Based Heuristically Accelerated Minimax–Q (CB-HAMMQ), which incorporates CBR into the Heuristically Accelerated Minimax–Q (HAMMQ).

The paper is organized as follows: section 4.2 briefly reviews the Single and Multiagent Heuristically Accelerated Reinforcement Learning problem, while section 4.3 describes Case-Based Reasoning. Section 4.4 shows how to incorporate CBR techniques into RL algorithms, in a modified formulation of the HAQL and HAMMQ algorithms. Section 4.5 describes the domain used in the experiments, presents the experiments performed, and shows the results obtained. Finally, Section 4.6 provides our conclusions.

4.2 Single and Multiagent Heuristically Accelerated Reinforcement Learning

The single agent RL problem can be formulated as a discrete time, finite state, finite action Markov Decision Process (MDP), while systems where multiple agents compete among themselves to accomplish their tasks can be modeled as a discrete time, finite state, finite action Markov Game (MG) – also known as Stochastic Game (SG). MDPs and MGs are well described in several good surveys, such as [11, 13].

Formally, a Heuristically Accelerated Reinforcement Learning (HARL) algorithm [5] is a way to solve a MDP problem with explicit use of a heuristic function $\mathscr{H} : \mathscr{S} \times \mathscr{A} \rightarrow \Re$ for influencing the choice of actions by the learning agent. In the multiagent case (HAMRL), a heuristic function $\mathscr{H} : \mathscr{S} \times \mathscr{A} \times \mathscr{O} \rightarrow \Re$ is used. $H(s,a)$ or $H(s,a,o)$ define a heuristic that indicates the importance of performing the action a when visiting state s. The heuristic function is strongly associated with the policy: every heuristic indicates that an action must be taken regardless of others.

The first HARL algorithm proposed was the Heuristically Accelerated Q–Learning (HAQL) [5], as an extension of the Q–Learning algorithm. The only difference between them is that in the HAQL makes use of an heuristic function in the action choice rule, a modified $\varepsilon - greedy$ mechanism where a heuristic formalized as a function $H(s,a)$ is considered:

$$\pi(s) = \begin{cases} \arg\max_a \left[\hat{Q}(s,a) + \xi H(s,a)^\beta\right] & \text{if } q \leq p, \\ a_{random} & \text{otherwise,} \end{cases} \tag{4.1}$$

where ξ and β are design parameters that control the influence of the heuristic function, q is a random value uniformly distributed over $[0,1]$ and p ($0 \leq p \leq 1$) is a parameter that defines the exploration/exploitation tradeoff, and a_{random} is an action randomly chosen among those available in state s.

In a similar way, the first HAMRL algorithm proposed was the Heuristically Accelerated Minimax Q (HAMMQ) [4], as an extension of the Minimax–Q algorithm. Again, the only difference between them is that in the HAMMQ the heuristic function is used in the action choice rule:

$$\pi(s) = \begin{cases} \arg\max_a \min_o \left[\hat{Q}(s,a,o) + \xi H_t(s,a,o)\right] \text{ if } q \leq p, \\ a_{random} \text{ otherwise,} \end{cases} \tag{4.2}$$

.

As a general rule, the value of $H(s,a)$ or $H_t(s,a,o)$ used in HAQL should be higher than the variation among the $\hat{Q}(s,a)$ values for the same $s \in \mathscr{S}$, in such a way that it can influence the choice of actions, and it should be as low as possible in order to minimize the error. For example, it can be defined for the single agent case as:

$$H(s,a) = \begin{cases} \max_i \hat{Q}(s,i) - \hat{Q}(s,a) + \eta \text{ if } a = \pi^H(s), \\ 0 \text{ otherwise.} \end{cases} \tag{4.3}$$

where η is a small real value (usually 1) and $\pi^H(s)$ is the action suggested by the heuristic policy. Convergence of this algorithm was presented by Bianchi, Ribeiro and Costa [4], together with the definition of an upper bound for the error.

Despite the fact that RL is a method that has been traditionally applied in the Robotic Soccer domain, only recently have HARL methods been used in this domain. Bianchi, Ribeiro and Costa [4] investigated the use of a HAMRL algorithm in a simplified simulator for the robot soccer domain and Celiberto *et al.* [7] studied the use of the HARL algorithms to speed up learning in the RoboCup 2D Simulation domain. The heuristic used in both of these papers were very simple ones: in the first paper the heuristic was 'if the agent is with the ball, go to the opponent's goal', and in the second paper it was simply 'go to the ball'.

4.3 Case-Based Reasoning

Case-based reasoning (CBR) [8] uses knowledge of previous situations (cases) to solve new problems, by finding a similar past case and reusing it in the new problem situation. According to López de Màntaras *et al.* [8], solving a problem by CBR involves "obtaining a problem description, measuring the similarity of the current problem to previous problems stored in a case base with their known solutions, retrieving one or more similar cases, and attempting to reuse the solution of the retrieved case(s), possibly after adapting it to account for differences in

problem descriptions". In the CBR approach, a case usually describes a problem and its solution, i.e., the state of the world in a given instant and the sequence of actions to perform to solve that problem.

In this work, a case is composed of three parts [14]: the problem description (P), the solution description (A) and the case scope (K), and it is formally described as a 3-tuple:

$$case = (P, A, K). \tag{4.4}$$

The problem description P corresponds to the situation in which the case can be used. For example, for a Robotic Soccer problem, the description of a case can include the robot position, the ball's position and the positions of the other robots in the game. For a game with n robots (teammates and opponents), P can be:

$$P = \{x_B, y_B, x_{R_1}, y_{R_1}, \ldots, x_{R_n}, y_{R_n}\}. \tag{4.5}$$

The solution description is composed by the sequence of actions that each robot must perform to solve the problem, and can be defined as:

$$A = \{R_1 : [a_{1_1}, a_{1_2}, ..., a_{1_{p_1}}], \ldots, R_m : [a_{m_1}, a_{m_2}, ..., a_{m_{p_m}}]\},$$

where m is the number of robots in the team, a_{i_j} is an individual or joint action that robot R_i must perform and p_i corresponds the number of actions the robot R_i performs.

The case scope defines the applicability boundaries of the cases, to be used in the retrieval step. In the case of a robot soccer problem, K can be represented as circles or ellipsoids centered on the ball's and opponents' positions indicated in the problem description. It can be defined as:

$$K = \{\tau_B, \tau_{R_1}, \ldots, \tau_{R_n}\}, \tag{4.6}$$

where τ_B is the radius of the region around the ball and $\tau_{R_1} \ldots \tau_{R_n}$ the radius of the regions around the n robots in the game (teammates and opponents). The case retrieval process consists in obtaining from the base the most similar case, the retrieved case. Therefore, it is necessary to compute the similarity between the current problem and the cases in the base. The similarity function indicates how similar a problem and a case are. In most cases, the function is defined by the distance between the ball and the robots in the problem and in the case.

$$Sim(p,c) = dist(B^c, B^p) + \sum_{i=1}^{n} dist({R_i}^c, {R_i}^p), \tag{4.7}$$

where B^c is the position of the ball in the case and B^p its position in the problem, ${R_i}^c$ the position of the Robot i in the case and ${R_i}^p$ its position in the problem, and $dist(a,b)$ is the gaussian distance between object a and b. This distance is computed as follows:

$$dist(a,b) = e^{-\left((a_x-b_x)^2+(a_y-b_y)^2\right)/2\tau^2}, \tag{4.8}$$

where τ is the radius of the scope around the object. In this work, τ is the same for the ball and robots positions. The Gaussian distance is used because the larger the distance between two points, the lower the similarity between them. Finally, τ is used as a threshold that defines a maximum distance allowed for two points to have some degree of similarity: if $dist(a,b) > \tau$, $Sim(a,b) = 0$.

Before a case can be reused, it might be necessary to adapt it to the present situation. Adaptation of a case means that the retrieved solution is modified, by translation, rotation or the addition of steps to the sequence of actions in the solution before it can be used. In this work, we assume that rotation and translation costs are small when compared to the cost of the additional steps, because the first two are trivial computations, while the performance of additional steps by the robots are actions that must be executed (in the simulator or in the real world), taking more time. Therefore, we define the cost as the number of steps added to the adapted solution. In this work, the case that will be reused is the one that maximizes the similarity while minimizing the adaptation cost.

In recent years, CBR has been used by several researchers in the Robotic Soccer domain. By far, the Robocup 2D Simulation League is the domain where most work has been done. To mention a few, Lin, Liu and Chen [12] presented a hybrid architecture for soccer players where the deliberative layer corresponds to a CBR system, Ahmadi *et al.* [1] presented a two-layered CBR system for prediction for the coach and Berger and Lämmel [3] proposed the use of a CBR system to decide whether a pass should be performed. A more extensive review of the use of CBR in Robotic Soccer can be found in the work by Ros *et al.* [14].

Table 4.1: The CB-HAQL algorithm.

Initialize $\hat{Q}_t(s,a)$ and $H_t(s,a)$ arbitrarily.
Repeat (for each episode):
  Initialize s.
  Repeat (for each step):
    Compute similarity and cost.
    If there is a case that can be reused:
      Retrieve and Adapt if necessary.
      Compute $H_t(s,a)$ using Equation 4.3 with the
        actions suggested by the case selected.
    Select an action a using Equation 4.1.
    Execute the action a, observe $r(s,a)$, s'.
    Update the values of $Q(s,a)$ in the traditional way.
    $s \leftarrow s'$.
  Until s is terminal.
Until some stopping criterion is reached.

4.4 Combining Case-Based Reasoning and Multiagent Reinforcement Learning

In order to provide HARL algorithms with the capability of reusing previous knowledge from a domain, we propose two new algorithms, the Case-Based HAQL, that extends the HAQL algorithm, being capable of retrieving a case stored in a base, adapting it to the current situation, and building a heuristic function that corresponds to the case, and the Case-Based HAMMQ, that extends the HAMMQ in the same way.

As the problem description P corresponds to one defined state of the set of states $\mathscr{S}$ in an MDP, an algorithm that uses the RL loop can be implemented. Inside this loop, before action selection, we added steps to compute the similarity of the cases in the base with the current state and the cost of adaptation of these cases. A case is retrieved if the similarity is above a certain threshold, and the adaptation cost is low. After a case is retrieved, a heuristic is computed using Equation 4.3 and the actions suggested by the case selected. The complete CB-HAQL algorithm is presented in Table 4.1. The CB-HAMMQ algorithm is essentially the same one, using $\hat{Q}_t(s,a,o)$ and $H_t(s,a,o)$ instead.

Although this is the first work that combines CBR with RL using an explicit heuristic function, this is not the first work on combining the both fields. Drummond [9] was probably the first to use CBR to speed

up RL, proposing to accelerate RL by transferring parts of previously learned solutions to a new problem. Sharma *et al.* [15] made use of CBR as a function approximator for RL, and RL as a revision algorithm for CBR in a hybrid architecture system; Juell and Paulson [10] exploited the use of RL to learn similarity metrics in response to feedback from the environment and Auslander *et al.* [2] used CBR to adapt quickly an RL agent to changing conditions of the environment by the use of previously stored policies.

Our approach differs from all previous works combining CBR and MRL because of the heuristic use of the retrieved case. Bianchi, Ribeiro and Costa [4] proved that if the heuristic used is an admissible one, there will be a speed up in convergence time, if not, the use of the heuristic will not impede the RL method to converge to the optimal policy. As we use the case base as a heuristic, if the case base corresponds to an admissible heuristic there will be a speed up in the convergence time. But if the case base does not contain any useful case – or even if it contains cases that implement wrong solutions to the problem, the agent will learn the optimal solution anyway, by using the RL component of the algorithm [4].

4.5 Experiments in the Robotic Soccer Domain

Soccer competitions, such as RoboCup, have been proven to be an important challenge domain for research, and one where RL techniques have been widely used. The application domain of this paper is a simulator for the robot soccer domain that extends the one proposed by Littman [13], called "Expanded Littman's Soccer". Nevertheless, the technique proposed in this work is domain independent.

In this domain two teams, A and B, of three players each compete in a 10 by 15 grid presented in figure 4.1. Each team is composed by the goalie (g), the defender (d) and the attacker (a). Each cell can be occupied by only one player. The actions that are allowed are: keep the agent still, move – north, south, east and west – or pass the ball to another agent. The action "pass the ball" from agent a_i to a_j is successful if there is no opponent in between them. If there is an opponent, it will catch the ball and the action will fail. Actions are taken in turns: all actions from one team's agents are executed at the same instant, and

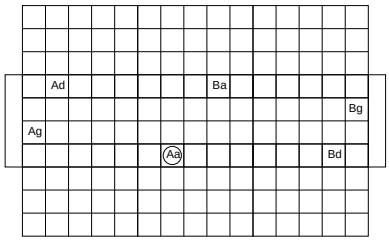

Fig. 4.1: The “Expanded Littman’s Soccer” environment.

then the opponents’ actions are executed. The ball is always with one of the players. When a player executes an action that would finish in a cell occupied by the opponent, it loses the ball and stays in the same cell. If an action taken by one agent leads it out the board, the agent stands still. When a player with the ball gets into the opponent’s goal, the trial ends and its team scores one point. The starting positions of all players are random, and the ball is given to one of the agents in a random fashion at the beginning of a trial.

To solve this problem, six algorithms were used: two traditional RL algorithms, Q–Learning and Minimax–Q; two Heuristically Accelerated algorithms, HAQL and HAMMQ; and the CB-HAQL and CB-HAMMQ algorithms, proposed in section 4.4.

The heuristic used in the HAQL and the HAMMQ algorithms was defined using a simple rule: if holding the ball, go to the opponents’ goal, not taking into account the teammates’ and opponents’ positions, leaving tasks such as learning to pass the ball or to divert the opponent to the learning process.

The heuristic value used in the CB-HA algorithms is computed during the games, as described in section 4.4. The case base used contains a set of basic cases that can be used without adaptation costs. The case base used in this experiment is composed of 5 basic cases, which cover the most significant situations that are observed during a game in the expanded Littman’s Soccer environment. These cases can be described as:

- If the agent is with the ball and there is no opponent blocking it, then move to the goal.
- If the agent is with the ball and there is an opponent blocking it, then move up.

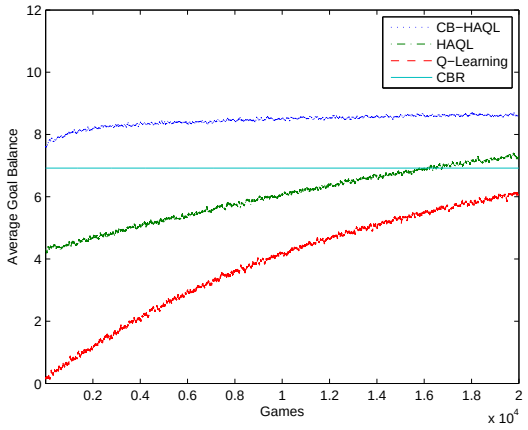

Fig. 4.2: Goals balance for the CBR, Q–learning, the HAQL and the CB-HAQL algorithms against a random opponent for the Expanded Littman's Robotic Soccer.

- If the agent is with the ball and there is an opponent blocking it, then move down.
- If the agent is with the ball and a teammate is closer to the goal, then pass the ball to the other agent.
- If the ball is with an opponent and the agent is close to the opponent, then stay in front of the opponent.

Is important to notice that this case base does not correspond to the optimal solution of the problem.

The reward the agents receive are the same for all algorithms: the agent that is holding the ball receives $+100$ every time it reaches the goal.

Thirty training sessions were run for the six algorithms, with each session consisting of 20,000 games of 10 trials.

Figure 4.2 shows the learning curves for the Single agent (Q-Learning, HAQL and CB-HAQL) algorithms when the learning team plays against an opponent moving randomly, and presents the average goal balance, which is the difference between goals scored and goals received by the learning team in each match. It is possible to verify that at the beginning of the learning phase Q-Learning has worse performance than HAQL,

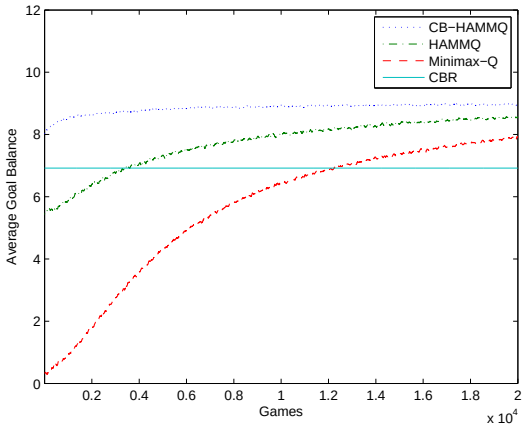

Fig. 4.3: Goals balance for the CBR, Minimax–Q, the HAMMQ and the CB-HAMMQ algorithms against a random opponent for the Expanded Littman's Robotic Soccer.

and that this has a worse performance than CB-HAQL. As the matches proceed, the performance of the three algorithms become similar, as expected.

Figure 4.3 shows the learning curves for the Multiagent (Minimax-Q, HAMMQ and CB-HAMMQ) algorithms when the learning team plays against an opponent moving randomly. It is possible to verify that, similarly to the single agent case, HAMMQ performs better than Minimax–Q, and that CB-HAMMQ is the best one. As it can be seen in this figure, the Minimax–Q is still learning after 20,000 games: as it is slower than the other two algorithms, it will only reach the optimal solution after 100,000 games.

In both figures the performance of a team of agents using only the case base (CBR) can also be observed: a line with values close to 7. As the case base does not contain the optimal solution to the problem, the agents have a performance that is worse than the one presented by the other teams at the end of the learning process. It is also worth noticing that for similar algorithms, the multiagent implementation have better results than the single agent one (Minimax–Q is better than Q–Learning, HAMMQ is better than HAQL and CB-HAMMQ is better than CB-HAQL). Finally, Table 4.2 shows the average number of goals scored at

the end of 20,000 games while playing against a random opponent, for all algorithms, and Table 4.3 shows and the average number of games won. It can be seen that the agents that are using CBR did not lose a single game.

Table 4.2: Goals made against Random opponent.

Algorithm	Goals made × Goals conceded
Q–Learning	$(133768 \pm 306) \times (57473 \pm 276)$
HAQL	$(158469 \pm 265) \times (38971 \pm 257)$
CB-HAQL	$(184279 \pm 448) \times (15417 \pm 436)$
Minimax–Q	$(140207 \pm 174) \times (38498 \pm 164)$
HAMMQ	$(166208 \pm 150) \times (22065 \pm 153)$
CB-HAMMQ	$(188168 \pm 155) \times (11292 \pm 140)$

Table 4.3: Game results against Random opponent.

Algorithm	Games won × Games lost
Q–Learning	$(16550 \pm 60) \times (1955 \pm 47)$
HAQL	$(19254 \pm 29) \times (227 \pm 15)$
CB-HAQL	$(19987 \pm 3) \times (0 \pm 0)$
Minimax–Q	$(18297 \pm 33) \times (1037 \pm 28)$
HAMMQ	$(19469 \pm 9) \times (27 \pm 4)$
CB-HAMMQ	$(19997 \pm 1) \times (0 \pm 0)$

The parameters used in the experiments were the same for all the algorithms. The learning rate is $\alpha = 0,9$, the exploration/ exploitation rate was defined as being equal to 0.2 and the discount factor $\gamma = 0.9$ (these parameters are similar to those used by Littman [13]). The value of η was set to 1. Values in the Q table were randomly initialized, with $0 \leq Q(s_t, a_t, o_t) \leq 1$.

4.6 Conclusion

This work presented a new approach to combine Case Based Reasoning, Reinforcement Learning and the use of Heuristics in Reinforcement Learning, which was the result of the work with Professor Lopez de Mantaras that started in 2007. We have proposed and evaluated two new algorithms, called Case-Based Heuristically Accelerated Q–Learning and Minimax–Q (CB-HAQL and CB-HAMMQ), which allow the use of a case base to define heuristics to speed up Single and Multiagent Reinforcement Learning algorithms.

The experimental results obtained using a new domain proposed for the Robotic Soccer games showed that CB-HAMMQ attained better results than HAMMQ and Minimax–Q alone. For example, after playing 1000 learning trials against a random opponent (Figure 4.3), the Minimax-Q, still could not produce policies that scored many goals on the opponent, while the HAMMQ was able to score some goals but less than the CBR alone and the CB-HAMMQ. Another interesting finding is that the number of goals scored by the CB-HAMMQ after 1000 trials was even higher than the number of goals scored by the CBR approach alone, indicating that the combination of the Reinforcement Learning and the case base out-performs the use of the case base on its own.

The algorithms presented here are only the initial results of the collaboration and friendship between me and Professor Lopez de Mantaras. As our work together continued, some articles about using CB-HARL in Transfer Learning problems, a natural extension of this work, have already been published [6].

Finally, we are convinced that heuristic functions will allow RL algorithms to solve problems where the convergence time is critical, as in many real time applications. Future works includes incorporating CBR in other well known RL algorithms, like SARSA, Minimax-SARSA, Minimax–Q(λ) and expanding this framework to deal with General Sum Markov Games [13] using algorithms such as Nash-Q and Friend-or-Foe Q-Learning.

Acknowledgments

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Chapter 5
Case-based and analogical reasoning

Didier Dubois, Henri Prade, Gilles Richard

Abstract This discussion paper proposes a parallel between two forms of reasoning that aim at exploiting reported cases for drawing plausible conclusions about a new case at hand, namely case-based reasoning and analogical reasoning (based on analogical proportions). Moreover, in both cases, the use of fuzzy set tools in relation with the idea of graded similarity makes sense. The paper contrasts the two forms of reasoning, and points out some possible mutual enrichments.

5.1 Introduction

A large part of the research work of Ramon López de Mántaras over the last three decades can be associated with the following key words: 'fuzzy clustering' [31], 'classification' [36], 'approximate reasoning' [28], and still more importantly 'case-based reasoning' (CBR) [27, 29, 30, 46] with applications ranging from musics to robotics. The two first authors have themselves worked on a fuzzy set-based approach to CBR and decision, and had the pleasure to work on some papers in collaboration with him and other members of his laboratory.

Didier Dubois, Henri Prade, Gilles Richard
IRIT, CNRS and Toulouse University, France.
e-mail: dubois@irit.fr, prade@irit.fr, richard@irit.fr

CBR [1] is a very important form of reasoning often used in order to draw conclusions or judgments in daylife, but also in creative thinking. As indicated in its name, it relies on repertories of particular cases, rather than on generic rules as in deductive reasoning. CBR is a special form of analogical reasoning, and is based on the idea that similar problems may have similar solutions. In that respect, the notion of similarity may be modeled by means of a fuzzy relation, and CBR then amounts to exploit the meta rule 'the more similar two problems, the more possible they have similar solutions', or 'the more similar two situations in various respects, the more possible they are similar in other respects', or still 'the more similar two situations, the more similar the appropriate decisions'.

This approach, jointly developed with Ramon López de Mántaras and then further investigated, is recalled in the next section. Then, an approach to analogical reasoning, based on the logical modeling of analogical proportions, recently developed by the last two authors, is presented. As CBR, analogical reasoning exploits known cases for predicting plausible conclusions about new cases. However, analogical reasoning departs from CBR by its ability to jointly take advantage of *several* cases for proposing conclusions about the new case. It then appears fruitful to make a parallel between CBR and analogical reasoning for a better understanding of their underlying assumptions, and for their mutual enrichment. This is the topic of the last section of this discussion paper, which we are glad to offer and dedicate to Ramon at the occasion of his 60 years birthday.

5.2 Fuzzy case-based reasoning

The idea underlying the fuzzy logic approach to CBR is to relate the similarity of situations or problems to the similarity of classes, outcomes, results or solutions by means of fuzzy "if ... then" rules. It may be viewed as an extension of functional dependency in a relational table, which has also motivated an attempt at formalizing analogical reasoning in a logical manner [7]. Here, the relational table is incomplete, and one tries to extrapolate the unknown feature value of an item on the basis of its similarity with other items for which the corresponding feature value is known. This idea was first discussed in a fuzzy setting in [2, 3]; see also chapter XII in [25]. This approach has been further explored in [9, 10, 11];

see also [22]. A basic issue is then the type of fuzzy rules [16] that is used, in the setting of Zadeh's approach to approximate reasoning [51]. There are several potential candidates. In particular, one may insist that the similarity of situations should entail the similarity of the associated results, or one may only admit that the similarity of the results is a serious option, but which does not necessarily follow from the similarity of the situations.

Let us examine the question more formally. Let $\mathscr{C}$ be a repertory of n cases $c_i = (s_i, r_i)$ with $i = 1, ..., n$, where $s_i \in \mathscr{S}$ (resp. $r_i \in \mathscr{R}$) denotes a situation (resp. a result). Let S and R be two graded similarity relations (assumed to be reflexive and symmetrical) defined on $\mathscr{S} \times \mathscr{S}$ and $\mathscr{R} \times \mathscr{R}$ respectively, where $S(s, s') \in [0, 1]$ and $R(r, r') \in [0, 1]$. Let us assume that we use a CBR principle based on the gradual rule "the more similar s_0 to s_i, the more similar r_0 to r_i", where s_0 denotes the situation under consideration, and r_0 the unknown associated result. Then, it leads to the following expression for the fuzzy set $\widetilde{r_0}$ of possible values for the unknown value y of r_0:

$$\widetilde{r_0}(y) = \min_{(s_i, r_i) \in \mathscr{C}} S(s_0, s_i) \to R(y, r_i) \tag{5.1}$$

where $\to$ denotes Gödel implication $a \to b = 1$ if $a \leq b$ and $a \to b = b$ if $a > b$. It is worth noticing that the above expression underlies an *interpolation* mechanism. For instance, if a second hand car s_0 is identical to two other cars s and s', except that its mileage is between the ones of s and s', then the estimated price r_0 will be between r and r', and may be quite precise due to the min-based combination in (1). Thus, the estimation of r_0 is not just based on the closest similar case, but takes advantage of the "position" of s_0 among the s_i's such as $(s_i, r_i) \in \mathscr{C}$. In order to insure the normalization of the fuzzy set $\widetilde{r_0}$ in (1), it is necessary for the repertory of cases to be consistent (see [10] for details), which means, informally speaking, that the cases in the repertory should themselves obey to the principle "the more similar two case situations, the more similar the case results". In particular, if we want to insure $\widetilde{r_i}(r_i) = 1$ for any i, we should have $\forall i \, \forall j \; S(s_i, s_j) \leq R(r_i, r_j)$.

If, on the contrary, there exist i and j such that $S(s_i, s_j) > R(r_i, r_j)$, i.e., the situations are more similar than the results, then another weaker principle should be used. Namely, the fuzzy CBR principle reads "the more similar s_0 to s_i, the more *possible* the similarity r_0 and r_i", and then we obtain [16]

$$\widetilde{r_0}(y) = \max_{(s_i,r_i)\in\mathscr{C}} \min(S(s_0,s_i),R(y,r_i)) \tag{5.2}$$

As can be seen, we now take the *union* (rather than the intersection) of the fuzzy sets of values close to the r_i's weighted by the similarity of s_0 with s_i, for all $(s_i,r_i) \in \mathscr{C}$. For instance, if a second hand car s_0 is quite similar to two other cars s and s', thus themselves quite similar, but having quite different prices r and r', then the estimated price r_0 will be the union of the fuzzy sets of values that are close to r or close to r'. Generally speaking, the result may be quite imprecise due to the max-based combination in (2). Still, it is a weighted union of all the possibilities that are supported by known cases. One might also think of using a fuzzy rule of the form "the more similar s_0 to s_i, the more *certain* the similarity r_0 and r_i", leading to an expression similar to (1) where Gödel implication is replaced by Dienes implication ($a \to b = \max(1-a,b)$). However, such a rule seems less appropriate here, even if it leaves room for exceptions, since we observe that $\widetilde{r_i}(r_i) = 1$ holds for any i, only if $\forall i\, \forall j\, S(s_i,s_j) > 0 \Rightarrow R(r_i,r_j) = 1$, which is a condition stronger than the one for (1) with Gödel implication.

This approach can be readily extended to case-based decision [20], where we have a repertory $\mathscr{D}$ of experienced decisions under the form of cases $c_i = (s_i,d,r_i)$, which means that decision d in situation s_i has led to result r_i (it is assumed that r_i is uniquely determined by s_i and d). Classical expected utility is then changed into $U(d) = \frac{\Sigma_{(s_i,d,r_i)\in\mathscr{D}} S(s_0,s_i)\cdot u(r_i)}{\Sigma_{(s_i,d,r_i)\in\mathscr{D}} S(s_0,s_i)}$, where u is a utility function, here supposed to be valued in $[0,1]$. Then, counterparts to (1) and (2) are

$$U_*(d) = \min_{(s_i,d,r_i)\in\mathscr{D}} S(s_0,s_i) \to u(r_i)$$

and

$$U^*(d) = \max_{(s_i,d,r_i)\in\mathscr{D}} min(S(s_0,s_i),u(r_i)).$$

$U_*(d)$ is a pessimistic-like qualitative utility that expresses that a decision d is all the better as the fuzzy set of results associated with situations similar to s_0 where d was experienced is included in the fuzzy set of good results. When $\to$ is Dienes implication, $U_*(d) = 1$ only if the result obtained with d in any known situation somewhat similar to s_0 was fully satisfactory. $U^*(d)$ is an optimistic-like qualitative utility since it expresses that a decision d is all the better as it was already success-

fully experienced in a situation similar to s_0. See [12] for postulate-based justifications.

A situation s is usually described by means of several features, i.e., $s = (s^1, ..., s^m)$. Then the evaluation of the similarity between two situations s and $s' = (s'^1, ..., s'^m)$ amounts to estimating the similarity according to each feature k according to a similarity relation S^k, and to combine these partial similarities using some aggregation operator agg, namely

$$S(s, s') = agg_{k=1,m} S^k(s^k, s'^k).$$

A classical choice for agg is the conjunction operator min, which retains the smallest similarity value as the global evaluation. But one may also think, for instance, of using some weighted aggregation if all the features have not the same importance. See [11] for a detailed example (with min).

Besides, the approach can be extended to prediction about some imprecisely or fuzzily specified cases (e.g., one has to estimate the price of a car with precisely specified features except that the horse power is between 90 and 110). A further generalization is necessary in order to accommodate incompletely specified cases in the repertory. See [13] for these extensions in the case of possibility rules (thus corresponding to (2)), and [23] for the discussion of several other generalizations (including the discounting of untypical cases and the flexible handling and adequate adaptation of different similarity relations, which provides a way of incorporating domain-specific (expert) knowledge). A comparative discussion with instance-based learning algorithms can be found in [24]. Applications to flexible querying [8] and to recommendation systems [14] have been also proposed. A thorough study of the formalization of CBR principles linking the similarity of solutions to the similarity of problems is presented in the research monograph [21].

5.3 Analogical proportion-based reasoning

The notion of similarity is as essential to CBR as it is to the idea of analogy, or more precisely, to analogical proportions. The core idea underlying analogical proportions comes from the numerical field where proportions express an equality of ratios, e.g. $\frac{1}{2} = \frac{5}{10}$, which could be

read "1 is to 2 as 5 is to 10". It is also agreed that "read is to reader as lecture is to lecturer" is a natural language analogical proportion, and the notation *read* : *reader* :: *lecture* : *lecturer* is then preferred. More generally, an analogical proportion is an expression usually denoted $a : b :: c : d$ involving 4 terms a, b, c, d, which reads "a is to b as c is to d". It clearly involves comparisons between the pairs (a, b) and (c, d). Recent works to which the last two authors of this paper have largely contributed, have led to a logical formalization of analogical proportions, where similarities / dissimilarities existing between a and b are equated to similarities / dissimilarities existing between c and d. Let us restate it formally in the following subsection. This view may also lead to the introduction of other proportions [38, 39, 41], an issue that will not be developed here.

5.3.1 Analogical proportion as a logical formula

Let us assume that the items a, b, c, d represent sets of binary features belonging to a universe U (i.e. an item is then viewed as the set of binary features in U that it satisfies). Then, the dissimilarity between a and b can be appreciated in terms of $a \cap \overline{b}$ and / or $\overline{a} \cap b$, where $\overline{a}$ denotes the complement of a in U, while the similarity is estimated by means of $a \cap b$ and / or of $\overline{a} \cap \overline{b}$. Then, an analogical proportion between subsets is formally defined as [33, 34]:

$$a \cap \overline{b} = c \cap \overline{d} \text{ and } \overline{a} \cap b = \overline{c} \cap d \tag{5.3}$$

This expresses that "a differs from b as c differs from d" and that "b differs from a as d differs from c". It has an easy counterpart in Boolean logic, where a, b, c, d now denote simple Boolean variables. In this logical setting, "are equated to" translates into "are equivalent to" ($\equiv$), $\overline{a}$ is now the negation of a, and $\cap$ is changed into a conjunction ($\wedge$), and we get the logical condition expressing that 4 Boolean variables make an analogical proportion:

$$(a \wedge \overline{b} \equiv c \wedge \overline{d}) \wedge (\overline{a} \wedge b \equiv \overline{c} \wedge d) \tag{5.4}$$

It is logically equivalent to the following condition that expresses that the pairs made by the extremes and the means, namely (a,d) and (b,c), are (positively and negatively) similar [34]:

$$(a \wedge d \equiv b \wedge c) \wedge (\overline{a} \wedge \overline{d} \equiv \overline{b} \wedge \overline{c}).$$

An analogical proportion is then a Boolean formula. It takes the truth value "1" only for any of the 6 following patterns for $abcd$: $1111, 0000, 1100, 0011, 1010,$
0101. For the 10 other lines of its truth table, it is false (i.e., equal to 0). As expected, it satisfies the following remarkable properties:

$a : b :: a : b$ (reflexivity) (and thus $a : a :: a : a$ (identity));
$a : b :: c : d \implies c : d :: a : b$ (symmetry);
$a : b :: c : d \implies a : c :: b : d$ (central permutation).

Another worth noticing property [39, 41] is the fact that the analogical proportion remains true for the negation of the Boolean variables. It expresses that the result does not depend on a positive or a negative encoding of the features:

$a : b :: c : d \implies \overline{a} : \overline{b} :: \overline{c} : \overline{d}$ (code independency).

Finally, analogical proportions satisfy a unique solution property, which means that, 3 Boolean values a, b, c being given, when we have to find a fourth one x such that $a : b :: c : x$ holds, we have either no solution (as in the cases of $011x$ or $100x$), or a unique one (as, e.g., in the case of $110x$). More formally, the analogical equation $a : b :: c : x$ is solvable iff

$$((a \equiv b) \vee (a \equiv c)) = 1$$

In that case, the unique solution x is $a \equiv (b \equiv c)$ [34]. This allows us to deal with Boolean analogical proportions in a simple way.

More generally, one may try to make sense of non Boolean proportions such as, e.g., $0 : 1 :: 0 : 0.9$. Intuitively, this proportion should be "more true" than $0 : 1 :: 0 : 0.5$ for instance, which is farther from $0 : 1 :: 0 : 1$. We have to turn to multiple-valued logic (see [33, 40]) to give a precise meaning (i.e., a truth value) to such proportions. If we consider the Boolean expression of the analogical proportion, one may think of many possible multiple-valued extensions, depending on the operations chosen for modeling $\wedge, \equiv$ (which in turns rely on $\rightarrow$). Moreover, a formula such as (4) can be written in many equivalent forms in Boolean logic. These forms are no longer necessarily equivalent in a non-Boolean setting where $[0,1]$ is the truth space. So it is important to make proper

choices that are in agreement with the intended meaning of the considered proportion. Some properties seem very natural to preserve, such as

i) the independence with respect to the positive or negative encoding of properties (one may describe a price as the extent to which it is cheap, as well as it is not cheap), which leads to require that $\neg a : \neg b :: \neg c : \neg d$ holds if $a : b :: c : d$ holds (this is the code independency property)

ii) the knowledge of a and of the differences between a and b and between b and a, should enable us to recover b. A careful analysis (see [40] for details) of these 2 requirements leads to choose

- $1-a$ for $\neg a$;
- the minimum operator for $\wedge$;
- the Lukasiewicz implication $\min(1,1-s+t)$ for $s \to t$;
- which leads to $1-|s-t|$ for the equivalence $s \equiv t = (s \to t) \wedge (t \to s)$.

Applying these connectives to definition (4) leads to the following expression giving the gradual truth value $v(a : b :: c : d)$ of $a : b :: c : d$, which both generalizes the Boolean case to multiple-valued entries and introduces a graded view of the analogical proportion:

$$v(a:b::c:d) = \min(1-|\min(a,1-b)-\min(c,1-d)|, \\ 1-|\min(1-a,b)-\min(1-c,d)|)$$

which can be equivalently rewritten

$$v(a:b::c:d) = 1-|\,(a-b)-(c-d)\,| \text{ if } (a \geq b \text{ and } c \geq d) \text{ or } (a \leq b \text{ and } c \leq d)$$

$$\text{and } v(a:b::c:d) = 1-\max(|\,a-b\,|,|\,c-d\,|) \text{ otherwise} \qquad (5.5)$$

As can be seen, $a : b :: c : d$ is all the closer to 1 as the differences $(a-b)$ and $(c-d)$ have the same sign and have similar absolute values. Note that $v(1:0::c:d) = 0$ as soon as $c \leq d$. It then makes sense, having a, b, c only to look for a value d such that $v(a : b :: c : d) = 1$. We are simply faced to an equation solving problem (as in the Boolean case). When the solution exists, the previous formula (5) enables us to compute the solution. For instance, there is no solution to $v(0.2 : 0.5 :: 0.9 : x) = 1$, but the unique solution of $v(0.2 : 0.5 :: 0.6 : x) = 1$ is just $x = 0.9$. In the Boolean case as well as in the graded case, these proportions can be used for inference purpose, as we are going to see.

5.3.2 Inference with analogical proportions

Let us start with the Boolean viewpoint where instead of dealing with atomic Boolean values, we consider 4-tuple of Boolean vectors (a,b,c,d). The basic idea is as follows: *if there is a proportion that holds between the first p components of these vectors, then this proportion should hold for the last remaining components as well*. This inference principle [39, 41] can be formally stated as below:

$$\frac{\forall i \in [1,p],\ \ a_i : b_i :: c_i : d_i \text{ holds}}{\forall j \in [p+1,n],\ \ a_j : b_j :: c_j : d_j \text{ holds}}$$

This is a generalized form of analogical reasoning, where we transfer knowledge from some components of our vectors to their remaining components.
It is worth pointing out that properties such as *full identity* or *code independency* are especially relevant in that perspective. Indeed, it is expected that in the case where d is such that it exists a case a in the repertory with $\forall i \in [1,p], d_i = a_i$, then $a_i : a_i :: a_i : d_i$ holds. Thus, the approach includes the extreme particular case where we have to classify (or to predict components of) an item whose representation (in the input space) is completely similar to the one of a completely known item. The code independency property, which expresses independence with respect to the encoding, seems also very desirable since it ensures that whatever the convention used for the positive or the negative encodings of the value of each feature and of the class, one shall obtain the same result for features in $[p+1,n]$.

Let us consider for instance a database of homes to let, containing houses (1) and flats (0), which are well equipped or not (1/0), which are cheap or expensive (1/0), where you have to pay a tax or not (1/0). Then a house, well equipped, expensive and taxable is represented by the vector $a = (1,1,0,1)$. Having 2 other cases $b = (1,0,1,1)$, $c = (0,1,0,1)$, we can predict the price and taxation status of a new case d which is a flat not well equipped, i.e. $d = (0,0,x,y)$ where 2 values are unknown. Applying the above approach, and noticing that an analogical proportion $a : b :: c : d$ holds for the 2 first components of each vector, we "infer" that such a proportion should hold for the 2 last components as well, yielding $x = 1$ and $y = 1$ (i.e. cheap and taxable). This approach, using Boolean analogical proportions, has been successfully applied to classification

problems [4, 32], where the attribute to be predicted is the class of the new item.

Let us now move to the *graded* case with, for instance
$a = (1, 1, .2, .9)$,
$b = (1, 0, .8, .8)$,
$c = (1, 1, .3, .6)$.
where the degrees estimate the extent to which the price is cheap and the level of the tax. Applying a difference-based approach (formula (5)), we get $d = (1, 0, .9, .5)$, i.e. the price is relatively cheap (.9) and the tax is relatively low (.5). This kind of analogical reasoning allows us to take into account both the similarities and dissimilarities. Its relative difficulty lies in the fact that we have to find ordered triples of cases which form an analogical proportion with the new case: the time complexity of this approach is $|\mathscr{C}|^3$ where $|\mathscr{C}|$ denotes the size of the set $\mathscr{C}$ of available examples.

In practice, the graded view can be applied in the following way [44] for classification purpose, where the features may be real valued (and normalized between 0 and 1). Starting from a new real valued vector d to be classified, we first look for for 3-tuples $(a,b,c) \in \mathscr{C}^3$ such that the Boolean class equation $cl(a) : cl(b) :: cl(c) : x$ has a solution ($cl(a)$ denotes the class of a). Obviously, the other triples (a,b,c) are useless for our objective because, whatever the coming d, they cannot suggest a class for d. This processing of the suitable set of triples can be done offline.

When an item d has to be classified, we have to look among the set of suitable triples for the one(s) that seem(s) the most appropriate for predicting the class $cl(d)$. For doing this, each suitable triple we have is evaluated by means of the following vector $(a_1 : b_1 :: c_1 : d_1, \ldots, a_i : b_i :: c_i : d_i, \ldots, a_p : b_p :: c_p : d_p)$. Then the vectors (and thus the triples) are ordered in a lexicographic decreasing order.[1] Then we may choose for $cl(d)$ the class associated to the triple having the best evaluation, or the most frequent class among the k best triples. In this latter case, one might also consider the different classes as possible solutions, between which we have not enough information for making a proper choice. Note that it should not be considered as a problem if some $a_i : b_i :: c_i : d_i$ are close to 0, i.e., almost false: indeed it should not be required that an

[1] $(u_1, \ldots, u_i, \ldots, u_p) >_{lexicographic} (v_1, \ldots, v_i, \ldots, v_p)$, *once the components of each vector have been decreasingly ordered*, iff $\exists j < p \; \forall i = 1, j \; u_i = v_i$ and $u_{j+1} > v_{j+1}$.

analogical proportion holds for all features (even approximately), since some features may turn to be irrelevant for the classification and have then no reason to exhibit any regularity with respect to it.

5.4 Case-based reasoning vs. analogical proportion-based reasoning

The parallel made in the two previous sections between fuzzy CBR and analogical proportion-based reasoning raises many interesting issues that we are going to review and further discuss in this section.

We first observe that (fuzzy) CBR relies on the idea of (graded) similarity, while the analogical proportion refers to dissimilarity as much as similarity. Then, as can be seen in the above examples, a form of *adaptation* is at work through the simultaneous comparison of the considered case d with 3 other cases a, b, c, while classical CBR would compare d with each case in the repertory, separately. Note also that in the above example a, b, c and d correspond to the descriptions of 4 *different* houses. Analogical proportions can also account for patterns involving functions or predicates, such as $x : f(x) :: y : f(y)$, or $P(x) : Q(x) :: P(y) : Q(y)$ [42]. The latter proportion involves two situations / cases, x and y, and corresponds to a basic pattern of analogical reasoning, which amounts to conclude, if x and y share a property P, i.e. $P(x)$ and $P(y)$ hold, and if moreover x satisfies another property Q ($Q(x)$ holds), that $Q(y)$ also holds, by an "analogical jump". This can be viewed as another simple form of adaptation.

As illustrated by the following (creative) cooking example (where the meaning of the features may be easily guessed)

a= apple: (fruit, no stone, not very juicy, cut in pieces, tart)
b= lemon: (fruit, no stone, juicy, juice & yolks & sugar, tart)
c= apricot: (fruit, stone, not very juicy, cut in pieces, tart)
d= cherry: (fruit, stone, juicy, ?, ?)

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juice & yolks & sugar, tart

analogical proportion-based reasoning is not always a matter of predicting the most plausible class, or the most plausible value(s), it may be just a way of finding a solution among many possible ones, as in the

above example, where there are many possible cakes with cherries, but one may for instance try to adapt a recipe for lemon tart to cherries.

A crucial issue (already underlying the proposal made in [7]) in this kind of reasoning is to make, or not, the hypothesis that the examples that are in the repertory of cases follow some deterministic law. This means that the features describing the examples can be partitioned into two subsets corresponding to $\mathscr{S}$ and $\mathscr{R}$ respectively, and that the value of any feature involved in $\mathscr{R}$ is possibly determined by the values of a subset of features involved in $\mathscr{S}$. For example, in a classification task, the n binary features describing any item as vectors in $\mathscr{S}$ may be enough, or not, to completely predict the class of an item. Then the repertory $\mathscr{C}$ is a set of labeled examples $(s, cl(s))$, i.e, the class cl is the unique feature in $\mathscr{R}$. When $\nexists (s,r)$ and $(s,r') \in \mathscr{C}$, with $r \neq r'$, one may assume that the class of an item is uniquely determined by the features at hand. In other words, this agrees with the view of cl as an underlying classifying function, this function being only known for the elements in $\mathscr{C}$. Then, the idea of transduction [19] refers to the process of predicting the class of a new piece of data on the basis of the previously observed data in $\mathscr{C}$, without any attempt to guess a generic model for the observed data (which would be induction). The approach recalled in the previous section for the Boolean case can be split in two steps:

step 1: One first looks for triples (a,b,c) of available examples in $\mathscr{C}$ whose classes $cl(a), cl(b), cl(c)$ are known, such that the Boolean class equation $cl(a) : cl(b) :: cl(c) : x$ is solvable (an analogical proportion that holds involves one or two distinct classes).

step 2: When a new data $d = (d_1, \ldots, d_p)$ is available, one looks for candidate triples $a = (a_1, \ldots, a_p), b = (b_1, \ldots, b_p)$ and $c = (c_1, \ldots, c_p)$) such that analogical proportions hold componentwise for the feature values involved in $\mathscr{S}$ (i.e. the proportion holds on the input space, or at least on a maximum number of features). Then, the solution of the class equation $cl(a) : cl(b) :: cl(c) : x$ for any such triple (a,b,c) is possibly the class of d. This is just an application of the principle described in the previous section.

In the graded case, the same idea applies, but instead of checking the proportions componentwise, we compute their truth values componentwise, getting a real-valued vector of truth values $(v_1, \ldots, v_p)$ where $v_i = v(a_i : b_i :: c_i : d_i)$. By aggregating these truth values (here, with min), we get a graded truth value $v(a : b :: c : d)$ for the corresponding proportion:

$$v(a:b::c:d) = \min_{i=1,p} v(a_i:b_i::c_i:d_i)$$

However, one might use an ordered weighted min [15] requiring only the high satisfaction of most of the proportions, or even an ordered weighted average [50]. Then a class x is all the more possible for d as it is the class solution of an analogical proportion $cl(a):cl(b)::cl(c):x$ for a triple (a,b,c) for which an analogical proportion holds to a high degree for each feature involved in $\mathscr{S}$.

In the transduction process described in the previous section, we allocate to d the class x associated to the triple (a,b,c) that maximizes the number of proportions satisfied with d to a high degree (using the lexicographic ordering of the vectors of proportion grades). One might also estimate the possibility for d to belong to the class x, using here for simplicity the above crude estimate for $v(a:b::c:d)$ that requires that *all* proportions hold at a high degree, as:

$$\widetilde{cl(d)}(x) = \max(\{v(a:b::c:d) |\ (a,b,c) \in \mathscr{S}^3 \text{ such that } cl(a):cl(b)::cl(c):x \text{ holds}\})$$

This is formally similar to (2), replacing similarity relations by analogical proportions. This idea [37] of aggregating in a disjunctive manner extrapolated values through analogical proportions between several triples of examples, and of weighting the possibility levels according to the truth degree of the analogical proportions, could be applied as well to the prediction of the value x of any feature t outside $\mathscr{S}$, including numerical ones, namely following (2),

$$\widetilde{d}_t(x) = \max_{(a,b,c)\in\mathscr{S}^3} \min(v(a:b::c:d), v(a_t:b_t::c_t:x))$$

This expresses the principle that it is all the more possible that an analogical proportion holds for the solution, as it is satisfied on the characteristic features of the problem. Again the expression here supposes that all the features are relevant.

In case of binary-valued features, whose values is pervaded with uncertainty, the principle underlying the analogical-proportion-based reasoning should accommodate this uncertainty under the form “the more certain analogical proportions hold on the descriptive features, the more guaranteed the possibility that it also holds for the predicted feature", as suggested in [43].

Besides, it has been mentioned in the previous section, that a less permissive CBR principle, namely the one encoded by (1), which implicitly presupposes the existence of a deterministic function between the descriptive features and the predicted feature, stating that "the more similar the descriptive features of two cases, the more similar the features to be predicted", leads to an interpolation mechanism as soon as several cases are considered. Then we come closer to approximate reasoning concerns, where it is tempting to write the generalized modus ponens pattern [51] from "if X is A, then Y is B" and "X is A'", infer "Y is B' ", as an analogical proportion of the form:[2]

$$A : B :: A' : B'$$

and even to write some similarity equation of the form

$$sim_1(A,A') = sim_2(B,B')$$

where sim_1 and sim_2 are two similarity relations to be defined, or some weaker constraint linking these two similarity degrees. This view has been investigated in [49, 6, 5]. However, several questions are worth raising. We have seen that an analogical proportion is as much a matter of dissimilarity as it is a matter of similarity (see (4) and its similarity counterpart), and is expressed by the conjunction of two conditions. This questions the above equation, even if the dissimilarity is just defined as the complement to 1 of the similarity. Moreover, similarity applies here to fuzzy sets, not just to Boolean, or scalar values. Then, is it a matter of similarity between fuzzy values, or of fuzzy similarity between ill-known feature values? The interpolation problem becomes still more acute in case of a collection of *scarce* rules "if X is A_i, then Y is B_i" with an imput "X is A'" is just in between some A_j and A_k without overlapping them. See [35] for an overview and a discussion of different approaches.

[2] The first mention of the parallel between analogical reasoning and approximate reasoning at least dates back to [18]. Besides, it is worth mentioning that an original approach to approximate reasoning (but not referring to analogy or similarity), the so-called "triple I method" [26], is based on the idea that $(A(x) \to B(y)) \to (A'(x) \to B'(y))$, where $\to$ is a multiple-valued implication connective, should be true to degree 1 for any value (x,y) of (X,Y). This may be paralleled with the fact that in the Boolean case, $(a \to b) \to (c \to d) = 1$ requires that $(a,b) = (1,0)$ as soon as $(c,d) = (1,0)$, where we recognize one of the characteristic patterns of the analogical proportion.

This problem may however receive a more symbolic treatment, where no membership function is needed [48], and which appears to agree with an analogical proportion view, but remains more cautious, see [45] and also [47]. For instance, considering the example "if a second hand car s_0 is identical to two other cars s_1 and s_2 except that its mileage is exactly midway between the ones of s_1 and s_2, then using (5)[3], the estimated price r_0 will be exactly midway between the prices r_1 and r_2 of these two cars, while the symbolic approach will conclude that the price r_0 is "between r_1 and r_2" without more precision.

5.5 To conclude

It is obvious and widely acknowledged that similarity plays an important role in our way of perceiving the world [52] and trying to make sense of it. Still, even if the idea of similarity plays a key role in information processing, from cluster analysis to reasoning, decision, or learning processes, there is not really any unifying view of the many approaches exploiting this notion; see [17] however for a limited attempt. Moreover, this paper has made a parallel between fuzzy CBR and (graded) analogical proportion-based reasoning. We have emphasized several points. First, in case-based reasoning we deal with pairs of cases, while analogical reasoning involves 4-tuples of cases. Second, the later type of reasoning is potentially more powerful (but also perhaps more risky) since it enables us to extrapolate on the basis of both similarities and dissimilarities, by considering triples of cases rather than cases individually, and when the triple involves identical cases, we are back to CBR. We have also pointed the formal resemblance between the principles underlying non deterministic CBR (allowing for distinct outputs associated with identical inputs) and analogical proportion-based reasoning. Lastly, we have indicated some potentials of a deterministic fuzzy CBR principle for interpolation. We are glad to offer this preliminary discussion as a small tribute to our old friend Ramon López de Mántaras on the occasion of his sixtieth birthday, since he has himself contributed a lot and in many ways to these important issues.

[3] We have then to solve a continuous analogical proportion equation, which is of the form $v(r_1 : x :: x : r_2) = 1$.

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Chapter 6
On the López de Mántaras distance

Eva Armengol, Pilar Dellunde and Àngel García-Cerdaña

Abstract In this paper we introduce FLM, a divergence measure to compare a fuzzy and a crisp partition. This measure is an extension of LM, the López de Mántaras distance, which allows to handle domain objects having attributes with continuous values. This means that for some domains the use of fuzzy sets may report better results than the discretization that is the usual way to deal with continuous values. We experimented with both FLM and LM in the context of the lazy learning method called *Lazy Induction of Descriptions* useful for classification tasks.

6.1 Introduction

Decision trees are the most popular paradigm of inductive learning methods. Based on the generalization of a set of known examples, decision trees are structures from which general domain rules can be obtained.

Eva Armengol
IIIA-CSIC e-mail: eva@iiia.csic.es
Pilar Dellunde
IIIA-CSIC and Departament de Filosofia. Universitat Autònoma de Barcelona. e-mail: pilar@iiia.csic.es
Àngel García-Cerdaña
IIIA-CSIC and Departament de Lògica, Història i Filosofia de la Ciència. Universitat de Barcelona. e-mail: angel@iiia.csic.es

The key point of the construction of a decision tree is to assess at each step the most relevant attribute. Common measures used to choose such attribute are the Quinlan's gain [19] and the Shannon's entropy [21]. It is known that these measures are biased by the number of values that an attribute can take. In his Ph.D [12], Ramón López de Mántaras proposed a distance based on entropy. The advantage of the LM distance, compared with other selection measures such as Quinlan's, is that LM does not favor attributes with large numbers of values, as shown in 1991 [13]. The LM distance is defined using the measures of information of the different partitions involved. Given two partitions $\mathscr{P}$ and $\mathscr{Q}$ of a set X, the distance between them is computed as follows:

$$LM(\mathscr{P},\mathscr{Q}) = 2 - \frac{I(\mathscr{P}) + I(\mathscr{Q})}{I(\mathscr{P} \cap \mathscr{Q})}$$

where $I(\mathscr{P})$ and $I(\mathscr{Q})$ measure the information contained in the partitions $\mathscr{P}$ and $\mathscr{Q}$ respectively and $I(\mathscr{P} \cap \mathscr{Q})$ is the mutual information of the two partitions. The LM measure is based on a distance between partitions such that the selected attribute in a node induces the partition which is closest to the correct partition of the subset of training examples corresponding to this node as shown in Fig. 6.1.

Although the original purpose of this distance was to select the relevant attribute during the construction of decision trees. LM was also used in two new learning methods: INDIE [4] and LID [5]. INDIE is an inductive learning method and LID is a lazy learning method. In particular, the LID method has been used in several real domains such as classification of marine sponges [5], assessment of the risk of complications on diabetic patients [17], predictive toxicology [1], and recently, to obtain a model useful to diagnose malignant melanoma in early stages [8]. Also, LID has been used to construct explanations justifying the result of automatic systems [7, 6].

In [18] a paradigm apparatus was introduced for the evaluation of clustering comparison techniques and distinguish between the goodness of clusterings and the similarity of clusterings by clarifying the degree to which different measures confuse the two. Using these methods, it is shown that LM is one of the measures that exhibit the desired behaviour under each of the test scenarios.

In previous works (see for instance [2, 8]) we used LM in the framework of a lazy learning method called *Lazy Induction of Descriptions*

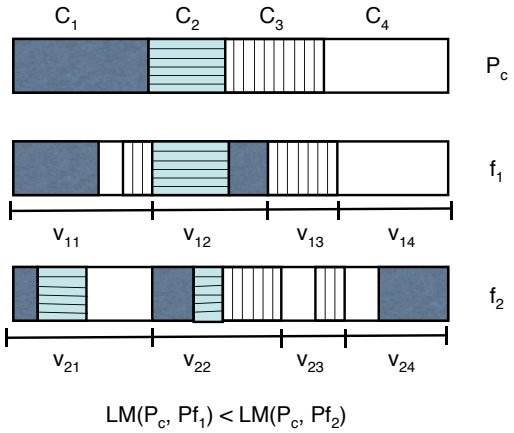

Fig. 6.1: *P_c is the correct partition, P_{f_1} and P_{f_2} are the partitions induced by the attributes f_1 and f_2 respectively. Using the LM distance the partition P_{f_1} is assessed as closer to P_c than P_{f_2}. Thus, f_1 is more relevant than f_2.*

(LID). LID [5] is a method useful for classification tasks. Due to the characteristics of LM, LID can only deal with domain objects having attributes with nominal values. However knowledge representation of domain objects often involves the use of continuous values. Techniques dealing with this kind of values usually use the discretization, consisting on building intervals of values that should be considered as equivalent. There are two kinds of discretization: crisp and fuzzy. In crisp discretization the range of the continuous values is split into several intervals. Elements of an interval are considered as equivalent and each interval is handled as a discrete value. In some domains, the crisp discretization shows some counter-intuitive behavior around the thresholds of the intervals: values around the threshold of two adjacent intervals are considered as different but may be they are not so. For this reason, sometimes is interesting to build a fuzzy discretization from a crisp one, as it is done for instance in [15]. In the context of Case-based Reasoning, the use of fuzzy sets to discretize attributes with continuous values could make the retrieval task more accurate.

The Rand index [20] is a common measure used to compare two clusterings. The Rand index, as it was originally formulated, allows uniquely the evaluation of crisp clustering partitions. In [10], Campello proposed a fuzzy extension of the Rand Index for clustering and classification assessment. This index is defined using basic concepts from fuzzy set theory. Hullermeier-Rifqi [14] introduced another extension of the Rand index suitable for comparing two fuzzy partitions. Since neither in [10] nor in [14] experimental results were conducted, in [3] we experimentally compared the two fuzzy versions of the Rand Index. From these experiments we saw that both measures had a high computational cost. In this context it seems natural to try to introduce an extension of the LM distance for dealing with fuzzy partitions.

In this paper we introduce a fuzzy extension of the LM distance and prove some basic properties of this extension. Finally we report some experimental results comparing both LM and FLM when used by the LID method as measure to compare partitions.

6.2 A fuzzy version of the López de Mántaras distance

In this section, first we define a fuzzy extension of the LM distance, that we call FLM. This measure allows to compare a fuzzy partition with respect to a crisp partition. We also prove some basic formal properties of this measure.

Definition 6.1 (Fuzzy n-partition, normal partition [23]). Given a finite data set $X = \{x_1, \ldots, x_k\}$ and a positive integer $1 < n < k$, a *fuzzy n-partition* on X is any finite collection $\mathscr{P} = \{P_1, \ldots, P_n\}$ of fuzzy subsets on X such that:

1) $\sum_{i=1}^{n} P_i(x_h) = 1, \;\; 1 \leq h \leq k$
2) $0 < \sum_{h=1}^{k} P_i(x_h) < k, \;\; 1 \leq i \leq n$

We will say that a fuzzy n-partition on a set X is *normal* if and only if for each set $P_i \in \mathscr{P}$, there exists an element $x \in X$ such that $P_i(x) = 1$. This element is called *prototypical* w.r.t. the class P_i.

The number $\sum_{h=1}^{k} P_i(x_h)$ is the *scalar cardinality* of the fuzzy set P_i and it will be denoted by $|P_i|$.

Definition 6.2 (Fuzzy LM). Let $X = \{x_1, \ldots, x_k\}$ be a given a data set, let $\mathscr{P} = \{P_1, \ldots, P_n\}$ be a fuzzy n-partition of X, and $\mathscr{Q} = \{Q_1, \ldots, Q_m\}$ a crisp partition of X. The measure $FLM(\mathscr{P}, \mathscr{Q})$ is computed as follows:

$$FLM(\mathscr{P}, \mathscr{Q}) = 2 - \frac{I(\mathscr{P}) + I(\mathscr{Q})}{I(\mathscr{P} \cap \mathscr{Q})}$$

where

$$I(\mathscr{P}) = -\sum_{i=1}^{n} p_i log_2 p_i; \quad p_i = \frac{|P_i|}{k}$$

$$I(\mathscr{Q}) = -\sum_{j=1}^{m} q_j log_2 q_j; \quad q_j = \frac{|Q_j|}{k}$$

$$I(\mathscr{P} \cap \mathscr{Q}) = -\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij} log_2 r_{ij}; \quad r_{ij} = \frac{|P_i \cap Q_j|}{k}$$

and $P_i \cap Q_j : X \to [0,1]$ is the fuzzy set defined as:

$$(P_i \cap Q_j)(x) = \begin{cases} P_i(x), \text{ when } Q_j(x) = 1 \\ 0, \quad \text{otherwise} \end{cases}$$

So defined, when $\mathscr{P}$ and $\mathscr{Q}$ are both crisp partitions, $FLM(\mathscr{P}, \mathscr{Q})$ is exactly $LM(\mathscr{P}, \mathscr{Q})$. Let us prove now some formal properties of FLM.

Proposition 6.1 (Basic facts). *Let X, $\mathscr{P}$, and $\mathscr{Q}$ be as in Definition 6.2. The following conditions hold:*

1) $p_i, q_j \in (0,1)$,
2) $r_{ij} \in [0,1)$,
3) $\sum_{j=1}^{m} r_{ij} = p_i$,
4) $\sum_{i=1}^{n} r_{ij} = q_j$,
5) $\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij} = 1$,
6) $\sum_{i=1}^{n}\sum_{j=1}^{m} p_i.q_j = 1$.

Proof: 1) and 2) are clear by Definition 6.1.

3) Let $1 \leq i \leq n$ and $1 \leq h \leq k$. Since $\mathscr{Q}$ is a crisp partition of X, $Q_l(x_h) = 1$ for some equivalence class Q_l of the partition. Then we have:

$$\sum_{j=1}^{m} (P_i \cap Q_j)(x_h) = (P_i \cap Q_l)(x_h) = P_i(x_h) \tag{6.1}$$

and therefore, by (6.1) and by definition of r_{ij},

$$\sum_{j=1}^{m} r_{ij} = \frac{1}{k}\sum_{j=1}^{m}\sum_{h=1}^{k}(P_i \cap Q_j)(x_h) =$$

$$= \frac{1}{k}\sum_{h=1}^{k}\sum_{j=1}^{m}(P_i \cap Q_j)(x_h) = \frac{1}{k}\sum_{h=1}^{k} P_i(x_h) = p_i$$

4) Let $1 \leq j \leq m$ and $1 \leq h \leq k$. Since $\mathscr{Q}$ is a crisp partition of Xwe have:

$$\sum_{i=1}^{n}(P_i \cap Q_j)(x_h) = \begin{cases} \sum_{i=1}^{n} P_i(x_h), & \text{when } Q_j(x_h) = 1 \\ 0, & \text{otherwise} \end{cases}$$

Consequently, since $\mathscr{P}$ is a fuzzy n-partition of X, $\sum_{i=1}^{n} P_i(x_h) = 1$ and thus,

$$\sum_{i=1}^{n}(P_i \cap Q_j)(x_h) = Q_j(x_h) \tag{6.2}$$

Now using (6.2) we obtain

$$\sum_{i=1}^{n} r_{ij} = \frac{1}{k}\sum_{i=1}^{n}\sum_{h=1}^{k}(P_i \cap Q_j)(x_h) =$$

$$= \frac{1}{k}\sum_{h=1}^{k}\sum_{i=1}^{n}(P_i \cap Q_j)(x_h) = \frac{1}{k}\sum_{h=1}^{k} Q_j(x_h) = q_j$$

5) $\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij} = \sum_{i=1}^{n}(\sum_{j=1}^{m} r_{ij}) = \sum_{i=1}^{n} p_i = 1$.

6) $\sum_{i=1}^{n}\sum_{j=1}^{m} p_i \cdot q_j = \sum_{i=1}^{n}(p_i \sum_{j=1}^{m} q_j) = \sum_{i=1}^{n} p_i \cdot 1 = \sum_{i=1}^{n} p_i = 1$. □

Proposition 6.2. *Given a fuzzy n-partition $\mathscr{P}$ and a crisp m-partition $\mathscr{Q}$ on a finite set $X = \{x_1, \ldots, x_k\}$, it holds that $LM(\mathscr{P}, \mathscr{Q}) \in [0,1]$.*

Proof: First, let us see that $I(\mathscr{P} \cap \mathscr{Q}) \geq I(\mathscr{P})$. By item 3) of Proposition 6.1, for every $1 \leq i \leq n$ and $1 \leq j \leq m$, $r_{ij} \leq p_i$, and since the logarithm function is increasing, we have that $\log r_{ij} \leq \log p_i$. Therefore,

$$\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij} log_2 r_{ij} \leq \sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij} log_2 p_i = \sum_{i=1}^{n}(\sum_{j=1}^{m} r_{ij}) log_2 p_i = \sum_{i=1}^{n} p_i log_2 p_i$$

Consequently,

$$I(\mathscr{P}\cap\mathscr{Q}) \geq I(\mathscr{P}) \tag{6.3}$$

Secondly, we show that $I(\mathscr{P}\cap\mathscr{Q}) \geq I(\mathscr{Q})$. By item 4) of Proposition 6.1, for every $1 \leq i \leq n$ and $1 \leq j \leq m$, $r_{ij} \leq q_j$, and thus $\log r_{ij} \leq \log q_j$. Therefore,

$$\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}log_2 r_{ij} = \sum_{j=1}^{m}\sum_{i=1}^{n} r_{ij}log_2 r_{ij} \leq \sum_{j=1}^{m}\sum_{i=1}^{n} r_{ij}log_2 q_j =$$

$$\sum_{j=1}^{m}(\sum_{i=1}^{n} r_{ij})log_2 q_j = \sum_{i=1}^{n} q_j log_2 q_j$$

Consequently,

$$I(\mathscr{P}\cap\mathscr{Q}) \geq I(\mathscr{Q}) \tag{6.4}$$

Therefore, by (6.3) and (6.4) we have

$$2\cdot I(\mathscr{P}\cap\mathscr{Q}) \geq I(\mathscr{P}) + I(\mathscr{Q})$$

and then

$$LM(\mathscr{P},\mathscr{Q}) = 2 - \frac{I(\mathscr{P})+I(\mathscr{Q})}{I(\mathscr{P}\cap\mathscr{Q})} \geq 0$$

Finally, we need to prove that

$$\frac{I(\mathscr{P})+I(\mathscr{Q})}{I(\mathscr{P}\cap\mathscr{Q})} \geq 1$$

It will be sufficient to prove that $I(\mathscr{P}\cap\mathscr{Q}) \leq I(\mathscr{P}) + I(\mathscr{Q})$. Indeed, by using the definitions, items 3) and 4) of Proposition 6.1, and some properties of the logarithm function, we have:

$$I(\mathscr{P}\cap\mathscr{Q}) - I(\mathscr{P}) - I(\mathscr{Q}) = -\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}log_2 r_{ij} + \sum_{i=1}^{n} p_i log_2 p_i + \sum_{j=1}^{m} q_j log_2 q_j =$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}log_2 \frac{1}{r_{ij}} + \sum_{i=1}^{n}(\sum_{j=1}^{m} r_{ij})log_2 p_i + \sum_{j=1}^{m}(\sum_{i=1}^{n} r_{ij})log_2 q_j = \sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}log_2 \frac{p_i q_j}{r_{ij}}$$

Now we will use the well known fact that $\ln x \leq x - 1$. For base 2 we have

$$log_2 x = \frac{\ln x}{\ln 2} \leq \frac{x-1}{\ln 2}$$

Now we have:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij} log_2 \frac{p_i \cdot q_j}{r_{ij}} \leq \frac{1}{\ln 2} \cdot \sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}(\frac{p_i \cdot q_j}{r_{ij}} - 1) = \frac{1}{\ln 2} \cdot \sum_{i=1}^{n}\sum_{j=1}^{m} (p_i \cdot q_j - r_{ij}) =$$

and by Proposition 6.1, items 5) and 6):

$$= \frac{1}{\ln 2}(\sum_{i=1}^{n}\sum_{j=1}^{m} p_i \cdot q_j - \sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}) = \frac{1}{\ln 2} \cdot (1-1) = \frac{1}{\ln 2} \cdot 0 = 0$$

□

6.3 Experiments

The experimentation with the extended version of the LM distance has been carried out by including it into LID. In this section we explain LID in some detail and then we report the experiments and results obtained with both the crisp and the fuzzy version of LM.

6.3.1 Lazy Induction of Descriptions

Lazy Induction of Descriptions (LID) is a lazy learning method for classification tasks. LID determines which are the most relevant attributes of a problem and searches in a case base for cases sharing these relevant attributes. The problem is classified when LID finds a set of relevant attributes shared by a subset of cases all of them belonging to the same class. We call *similitude term* the description formed by these relevant features and *discriminatory set* the set of cases satisfying the similitude term.

Given a problem for solving p, the LID algorithm (Fig. 6.2) initializes D_0 as a description with no attributes, the discriminatory set S_{D_0} as the set of cases satisfying D_0, i.e., all the available cases, and C as the set of solution classes into which the known cases are classified. Let D_i be the

```
Function LID (p, Di, SDi, C)
 if stopping-condition (SDi) then return class (SDi)
    else  fd := Select-attribute (p, SDi, C)
          Di+1 := Add-attribute (fd, Di)
          SDi+1 := Discriminatory-set (Di+1, SDi)
          LID (p, Di+1, SDi+1, C)
 end-if
end-function
```

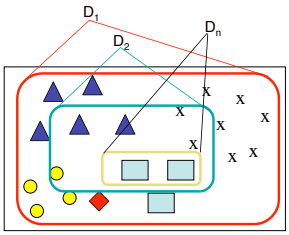

Fig. 6.2: *The LID algorithm. On the right, the intuitive idea of LID.*

current similitude term and S_{D_i} be the set of all the cases satisfying D_i. When the stopping condition of LID is not satisfied, the next step is to select an attribute for specializing D_i. The specialization of D_i is achieved by adding attributes to it. Given a set F of attributes candidate to specialize D_i, the next step of the algorithm is the selection of an attribute $f \in F$. Selecting the most discriminatory attribute in F is heuristically done using a measure Δ to compare each partition $\mathscr{P}_f$ induced by an attribute f with the correct partition $\mathscr{P}_c$. The *correct partition* is the one having as many sets as solution classes. Each attribute $f \in F$ induces in the discriminatory set a partition $\mathscr{P}_f$ with as many sets as the number of different values that f takes in the cases.

Given a measure Δ and two attributes f and g inducing respectively partitions $\mathscr{P}_f$ and $\mathscr{P}_g$, we say that f is *more discriminatory* than g iff $\Delta(\mathscr{P}_f, \mathscr{P}_c) < \Delta(\mathscr{P}_g, \mathscr{P}_c)$. This means that the partition $\mathscr{P}_f$ is closer to the correct partition than the partition $\mathscr{P}_g$. LID selects the most discriminatory attribute to specialize D_i. Let f_d be the most discriminatory attribute in F. The specialization of D_i defines a new similitude term D_{i+1} by adding to D_i the attribute f_d. The new similitude term $D_{i+1} = D_i \cup \{f_d\}$ is satisfied by a subset of cases in S_{D_i}, namely $S_{D_{i+1}}$. Next, LID is recursively called with $S_{D_{i+1}}$ and D_{i+1}. The recursive call of LID has $S_{D_{i+1}}$ instead of S_{D_i} because the cases that are not satisfied by D_{i+1} will not satisfy any further specialization. Notice that the specialization reduces the discriminatory set at each step, i.e., we get a sequence $S_{D_n} \subset S_{D_{n-1}} \subset \ldots \subset S_{D_0}$. LID has two stopping situations: 1) all the cases in the discriminatory set S_{D_j} belong to the same solution class C_i, or 2) there is no attribute allowing the specialization of the simili-

tude term. When the stopping condition 1) is satisfied, p is classified as belonging to C_i. When the stopping condition 2) is satisfied, S_{D_j} contains cases from several classes; in such situation the *majority criteria* is applied, and p is classified in the class of the majority of cases in S_{D_j}. When there is a tie between two classes, LID gives a multiple solution proposing both classes as the classification for p.

6.3.2 Conditions of the experiments

We have conducted several experiments on data sets coming from the UCI Repository [9] using LID with LM and FLM as the Δ measure. We have used the following data sets: *iris, bal, heart-statlog, glass, wdbc, glass,* and *thyroids*. For the evaluation we have taken the discretization intervals provided by Weka [22]. Thus, for instance, for the *Iris* data set, Weka gets the following intervals:

- Attribute Petalwidth: $[0.00, 0.80], (0.80, 1.75], (1.75, 2.25]$
- Attribute Petallength: $[1.00, 2.45], (2.45, 4.75], (4.75, 6.90]$
- Attribute Sepalwidth: $[2.20, 2.95], (2.95, 3.35], (3.35, 4.40]$
- Attribute Sepallength: $[4.40, 5.55], (5.55, 6.15], (6.15, 7.90]$

```
(define (object :id OBJ-50)
   (Sepallength 7.0)
   (Sepalwidth 3.2)
   (Petallength 4.7)
   (Petalwidth 1.4))
```

```
(define (object :id OBJ-50)
   (Sepallength (define (fuzzy-value)
                (Value 7.0)
                (Membership 0 0 1)))
   (Sepalwidth (define (fuzzy-value)
                (Value 3.2)
                (Membership 0 1 0)))
   (Petallength (define (fuzzy-value)
                (Value 4.7)
                (Membership 0 0.6087 0.3913)))
   (Petalwidth (define (fuzzy-value)
                (Value 1.4)
                (Membership  0 1 0))))
```

Fig. 6.3: *On the left there is a propositional representation of an object. On the right there is the representation of the same object extended with the membership vector.*

These intervals have been directly used by the LM distance. When using the FLM measure we define fuzzy sets. Firstly, we will explain how to represent the fuzzy cases handled by fuzzy LID. The left of Fig. 6.3 shows an example of an object from the *Iris* data set represented as a set of pairs attribute-value. The right of Fig. 6.3 shows the fuzzy representation of the same object. Notice that the value of each attribute is an object that has in turn two attributes: Value and Membership. The attribute Value takes the same value v that in the crisp version (for instance, 7.0 in the attribute Sepallength). The attribute Membership takes as value the *membership vector* associated to v, that is, a n-tuple μ, being n the number of fuzzy sets associated to the continuous range of an attribute. Each position i of μ represents the membership of the value v to the corresponding fuzzy set F_i. In the next we will explain how to compute the membership vector.

Given an attribute taking continuous values, let us suppose that the domain expert has given $\alpha_1,\ldots,\alpha_n$ as the thresholds determining the discretization intervals for that attribute. Let α_0 and α_{n+1} be the minimum and maximum respectively of the values that this attribute takes in its range. To each one of the $n+1$ intervals $[\alpha_0,\alpha_1],(\alpha_1,\alpha_2],\ldots,(\alpha_n,\alpha_{n+1}]$ corresponds a trapezoidal fuzzy set defined as follows, where $1 < i < n+1$:

$$F_1(x) = \begin{cases} 1 & \text{when } \alpha_0 \le x \le \alpha_1 - \delta_1 \\ \frac{\alpha_1+\delta_1-x}{2\delta_1} & \text{when } \alpha_1 - \delta_1 < x < \alpha_1 + \delta_1 \\ 0 & \text{when } \alpha_1 + \delta_1 \le x \end{cases}$$

$$F_i(x) = \begin{cases} 0 & \text{when } x \le \alpha_{i-1} - \delta_{i-1} \\ \frac{x-(\alpha_{i-1}-\delta_{i-1})}{2\delta_{i-1}} & \text{when } \alpha_{i-1} - \delta_{i-1} < x < \alpha_{i-1} + \delta_{i-1} \\ 1 & \text{when } \alpha_{i-1} + \delta_{i-1} \le x \le \alpha_i - \delta_i \\ \frac{\alpha_i+\delta_i-x}{2\delta_i} & \text{when } \alpha_i - \delta_i < x < \alpha_i + \delta_i \\ 0 & \text{when } \alpha_i + \delta_i \le x \end{cases}$$

$$F_{n+1}(x) = \begin{cases} 0 & \text{when } x \le \alpha_n - \delta_n \\ \frac{x-(\alpha_n-\delta_n)}{2\delta_n} & \text{when } \alpha_n - \delta_n < x < \alpha_n + \delta_n \\ 1 & \text{when } \alpha_n + \delta_n \le x \le \alpha_{n+1} \end{cases}$$

The parameters δ_i are computed as follows: $\delta_i = p \cdot |\alpha_i - \alpha_{i-1}|$, where the factor p corresponds to a percentage that we can adjust. Figure 6.4

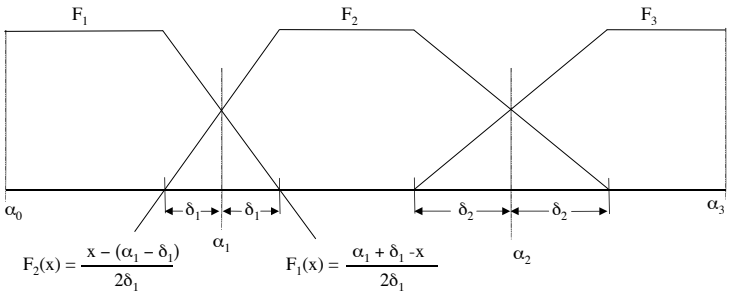

Fig. 6.4: *Trapezoidal fuzzy sets. The values α_1 and α_2 are given by the domain expert as the thresholds of the discretization intervals for a given attribute.*

shows the trapezoidal fuzzy sets defined when $n = 2$. For instance, for the *Iris* data set the values of α_i for the Petallength attribute are: $\alpha_0 = 1$, $\alpha_1 = 2.45$, $\alpha_2 = 4.75$, $\alpha_3 = 6.9$. The value 4.7 taken by the object *obj-50* in the attribute Petallength (Fig. 6.3) has associated the membership vector $(0, 0.6087, 0.3913)$, meaning that such value belongs to a degree 0 to the fuzzy set F_1 corresponding to the interval $[1, 2.45]$, to a degree 0.6087 to the fuzzy set F_2 corresponding to $(2.45, 4.75]$, and to a degree 0.3913 to the fuzzy set F_3 corresponding to $(4.75, 6.9]$.

In the fuzzy version of LID, the correct partition is the same than in the crisp case since each object belongs to a unique solution class. However, when the partitions induced by each attribute are fuzzy, an object can belong (to a certain degree) to more than one partition set. Thus the algorithm of the fuzzy LID is the same explained in Section 6.3.1 but using the particular representation for the fuzzy cases and FLM as the Δ measure.

In the fuzzy experiments, to calculate the values δ_i we have experimented with $p = 0.05$ and 0.10. Table 6.1 shows the results of LID after seven trials of 10-fold cross-validation taking $p = 0.10$. Experiments show that the fuzzy version of LID gives good predictive results and in some domains (*heart statlog* and *iris*) outperforms the crisp version. LID can produce two kinds of outputs: the classification in one (correct or incorrect) class or a multiple classification. Multiple classification means

that LID has not been capable to classify the input object in only one class. The utility of a multiple classification depends on the application domain, so it is the expert who decides what is better to force the method to give a classification (even incorrect) or to accept a "no classification". The percentage of correct classifications is similar taking both $p = 0.05$ and $p = 0.10$, but with $p = 0.10$ LID gives a lower percentage of incorrect solutions and also a higher percentage of multiple solutions than taking $p = 0.05$.

Dataset	LM	FLM	significant	LM	FLM
bal	**70.8387**	66.6465	yes	28.9769	**25.5450**
glass	**78.2703**	63.3519	yes	**21.7297**	34.5825
heart-statlog	66.5608	**76.0317**	yes	33.4381	**20.0529**
iris	93.8155	**95.7143**	yes	6.1845	**3.8095**
thyroids	95.4660	94.3692	no	**4.5340**	4.8268

Table 6.1: *The left part shows the percentage of correct classifications of LID using LM and FLM. The right part shows the percentage of incorrect classifications of LID using LM and FLM. Results are the mean of 7 trials of 10-fold cross-validation and they correspond to* $p = 0.10$.

6.4 Future Work

So far we have defined a fuzzy version of the LM distance, called FLM, in order to compare a fuzzy and a crisp partition. Further research will be devoted to explore different definitions based on different t-norms in order to extend the LM distance for comparing two fuzzy partitions. In this paper we have proved only some basic facts about the measure FLM; a systematic study of its formal properties is needed and it will be our immediate research objective.

In [11] the notion of "measure of the degree of fuzziness" or "entropy" of a fuzzy set was introduced using no probabilistic concepts. Based on this definition, some classes of divergence measures between fuzzy partitions were presented in [16]. Since the LM distance is an

information theoretic approach to the comparison of crisp partitions, it could be interesting to study the relationship of our fuzzy measure with all these divergence measures. In the future we would also like to conduct more experiments to compare the Rand index and its two fuzzy extensions introduced in [10] and [14] with the LM distance and the measure FLM.

Acknowledgments

Els autors volem agrair a en Ramon López de Mántaras l'interès que ha demostrat en aquest treball. Les discussions que hem tingut amb ell per tal d'aclarir alguns punts de la generalització de la seva distància han estat engrescadores i han provocat l'augment d'entropia de les nostres neurones (augment que, per cert, no es pot mesurar amb la distància LM...). També volem agrair els debats que hem tingut amb ell en tantes ocasions a l'hora del cafè, sobre política, ciència, cultura i d'altres temes (!?), sempre políticament incorrectes i, per tant, també interessants i divertits. Gràcies, Ramon, pel teu mestratge, la teva generositat i la teva bonhomia al llarg de tots aquests anys.

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Chapter 7
Breast cancer prognostic by fuzzy learning

Joseph Aguilar-Martin

7.1 Introduction

In his thesis work, in 1977, Ramon Lopez de Mántaras pointed out the interest of introducing the concept of membership of an element to a class to perform evolutive clustering and learning. I published, about 1972, a Bayesian learning algorithm, principal aspect of which was to be able to start without previous information. As soon as Ramon developed the possibilities of that algorithm so as to accept a wider type of data, a research stream was started, and it flows still nowadays, furnishing theoretical developments and new applications: the methodology is labeled LAMDA (Learning Algorithm for Multivariable Data Analysis).

The mentioned thesis work exhibited already a robotic use of that algorithm as well as its application to the identification of mixtures of Gaussian populations. This second application enabled the comparison of that methodology with others. Later, our simultaneous stay in professor Zadeh group in the UC Berkeley, concepts based in Fuzzy Set Theory where very helpful, as well as an exhaustive study of fuzzy Logic connectives by Núria Piera in 1990.

Joseph Aguilar-Martin
LAAS, Toulouse, e-mail: aguilar.josep@gmail.com

Many new adjustments and tunings have enabled applications as diverse as Robotics, Chemical and Biochemical processes, Steel Industry, Water treatment and distribution, analysis of Surveys and questionnaires in psychological studies, etc. Presently some members of the medical world think that LAMDA may yield a powerful tool in the field of diagnosis and prognosis.

In the issue of treatment of cancer, there are two distinct purposes: diagnosis of cancer and the prognosis for survival in the case of a previously diagnosed cancer. This work focused on developing a tool for the prognosis to better assess the potential for relapse or no relapse based on analysis of data from ana-cyto-pathological tissues.

7.2 LAMDA abductive classification method

In any method of analysis and learning classification, there are two phases: the training phase is to find the classification (all classes with their features or their attributes: number, shapes , ...) which represents at best a set of data known as training and recognition phase itself in which new cases (other than those used for learning) are examined.

This method of classification and clustering, based on fuzzy logic, determines the degree of adequacy (membership) of an element (or individual) to existing classes. This match is obtained from analysis of the contributions of each of the attributes of the individual characteristics of classes. This contribution is called degree of marginal adequacy (DAM). Once all the DAMS are calculated the global adequacy (DAG) of an individual to a given class is determined by means of aggregation operators called mixed connective with linear compensation. LAMDA simultaneously can handle data in qualitative and quantitative and interval type.

LAMDA offers the opportunity to make a supervised learning (with teacher) and / or non-supervised (self-learning). This learning is done in an incremental and sequential way, thus reducing the learning phase to one or very few iterations. The assignment of an individual to a class follows always the same procedure, the present individual initializes a class or contributes to the modification of an existing class. Figure 7.2

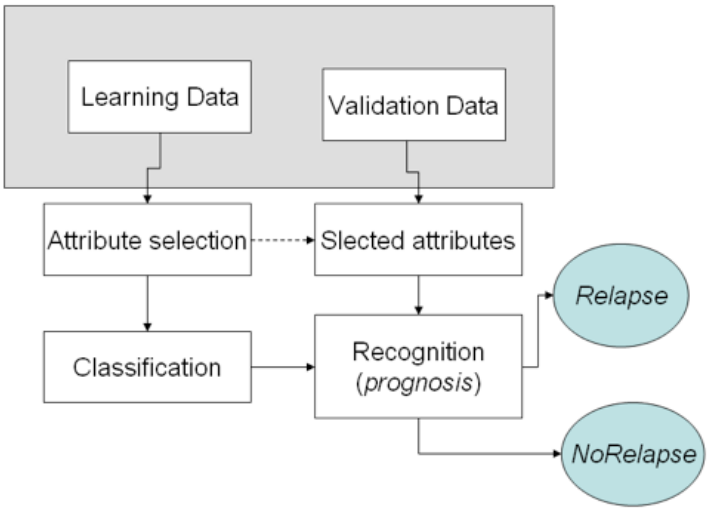

Fig. 7.1

illustrates the procedure for assigning an individual to a class

The marginal adequacy degree (MAD) is expressed as a function of marginal relevance to the Cl_k class:

$$?k_i(x_i) = MAD(x_i|ith\ descriptor\ of\ class\ Cl_k)$$

This function depends of descriptor x_i of individual X and from descriptor $?k_i$ of class Cl_k:

$$?k_i(x_i) = f(x_i, ?k_i)$$

Descriptor $?k_i$ is calculated iteratively from the i-th of all individuals belonging to the class Cl_k.
Then will be shown how is calculated the degree of marginal adequacy when the descriptor is qualitative or quantitative.

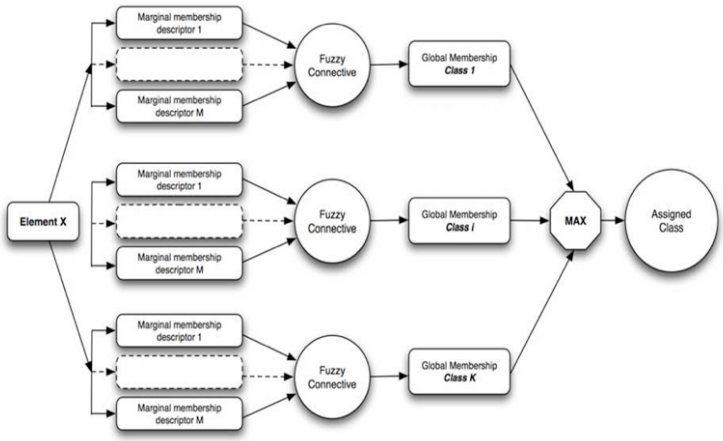

Fig. 7.2: LAMDA structure for 3 classes

Once all the DAMS are calculated, we can use the concept of mixed connective to calculate the overall membership (DAG) of the individual to the class k and this is valid even if the attributes are of different types (intervals, qualitative or quantitative).

Global level of adequacy (GAD) is expressed as the membership function to a class Cl_k, interpreted as a fuzzy set:

$$?k(X) = GAD(individual\ X|class\ Cl_k)$$

This function depends separately on each of the n descriptors of the individual, the global adjustment is the result of combining the compliance by a marginal aggregation function.
Given $X = [x_1 \dots x_i \dots x_n]'$, we have $?k(X) = F(?k_1(x_1), \dots, ?k_i(x_i), \dots, ?k_n(x_n))$ where $?k_i(x_i)$ is the degree of marginal adequacy of the i-th descriptor of the individual and the X-th descriptor of Cl_k, the descriptor may be either qualitative, quantitative or intervalar.

7.3 Application to breast cancer prognosis of possible relapse

7.3.1 Use of proteomic patterns in serum to identify ovarian cancer

In this example five spectrograms from cancer patients (red) and five from control patients (blue) are displayed. The data in this example is from the FDA-NCI Clinical Proteomics Program Databank <http://home.ccr.cancer.gov/ncifdaproteomics/ppatterns.asp >.

High resolution ovarian cancer data set was generated using the WCX2 protein array. The sample set includes 93 controls and 120 ovarian cancers. An extensive description of this data set can be found in Figure 7.3. The image shows the average profiles of the two populations.
A first application of LAMDA was done straightforward, without special tuning neither feature selection: the result was very encouraging as 75% of good prognostics were obtained, and particularly less than 11% of relapsed patients where ignored.

In a second experiment, a feature selection based uniquely in entropy concepts was performed and the improvement of the results was very meaningful, reaching 93% of good results with an entropy threshold of 0.5 . Nowadays Lyamine Hedjazi in his thesis presented in December 2011 has used the new concept of membership margin to select still more efficiently the representative variables; nevertheless the results shown here are limited to the previous selection criteria.

The next image (Figure 7.4) shows the results of the final choice made by the algorithm, the black points being the bad choices. The lower image illustrates the global memberships of each sample, a few of them are below the decision threshold, and that could be used to detect the less recognizable situations.

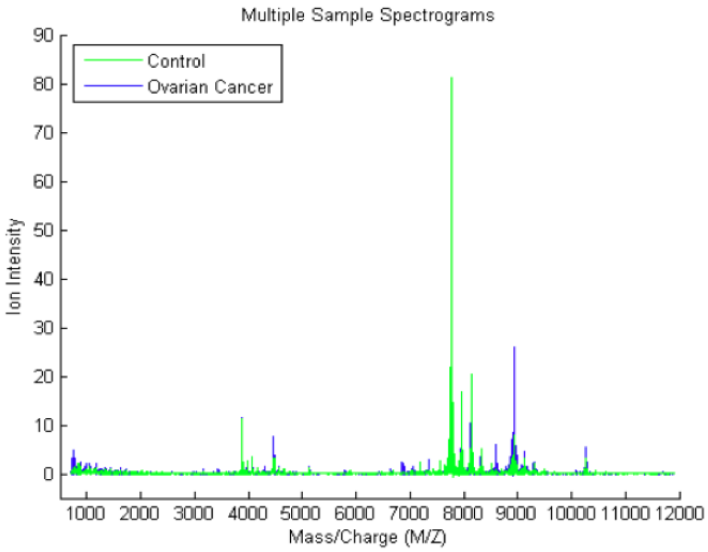

Fig. 7.3

7.3.2 Use of the characteristics of cell nuclei present in the scanned image

This second data base used is from the Center for Clinical Sciences at the University of Wisconsin (1995) on the prognosis of the possible relapse after two years. This data base has been widely used to test and compare the performance of different learning algorithms and classification. It concerns 156 patients with breast cancer, it includes only patients with invasive primary tumor, and for which no evidence of metastasis was detected at diagnosis. 118 out of 156 patients developed metastases shortly after surgery. This database contains 32 attributes for which 30 were obtained from a scanned image.
The attributes are, in this case, of several types. They describe the characteristics of cell nuclei present in the image:

The average value, the “worst” (average of three larger ones), and standard deviation of each attribute were also introduced for each im-

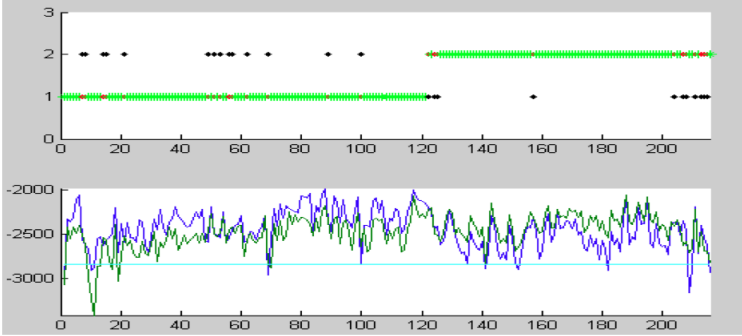

Fig. 7.4

a. radius (average distance from the center to points on the perimeter).
b. Texture (standard deviation of the values of "gray-scale").
c. perimeter
d. Area
e. smoothness (local variation in radius lengths).
f. Compactness (périmètre2 / area-1.0).
g. concavity (severity of concave parts of the contour).
h. concave points (number of concave portions of the contour).
i. Symmetry.
j. Fractal dimension (“coastline approximation” - 1).
k. And other additional, ... as the size of the tumor and the number of affected lymph nodes

Table 7.1

age, resulting in a total of 30 attributes.

In all three cases, we selected the 10 best entropy attributes or descriptors. The first list of 10 attributes is given in Table 7.1.

As regards the ACP, we used 32 attributes to identify the main components. The Figure 7.5 shows the percentage of information explained by 10 components, it reaches 93% of the total information in the database.

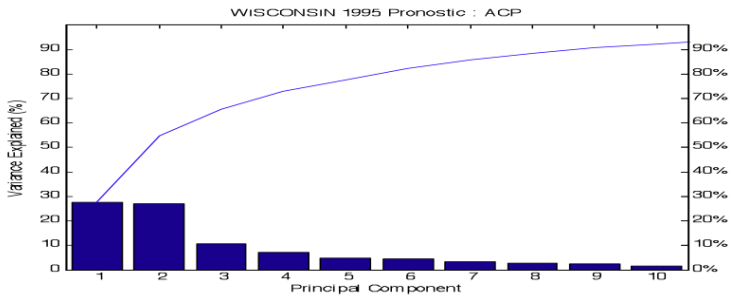

Fig. 7.5

Because the number of patients available is too small (118) the method of cross validation to estimate the rate of accuracy of this prediction could not be used. However, we applied the test "leave-one-out" which is to remove randomly given one of the learning base and used for recognition only.

In all cases, we used the classification method LAMDA, the best results, using the Gaussian function with diagonalization, are presented in Figure 7.7.
Among the 118 patients, 96 have not relapsed after 24 months and 22 relapsed. It was found that the attributes that correspond to the morphology of the tumor is directly related to the prediction of relapse. Figure **??** shows the profile of classes based showing significant attributes selected by the T-Test method.

7.4 Conclusion

It shall be enhanced here that the fuzzy approach to learning, self-learning and recognition, has been shown to be very powerful in many aspects:

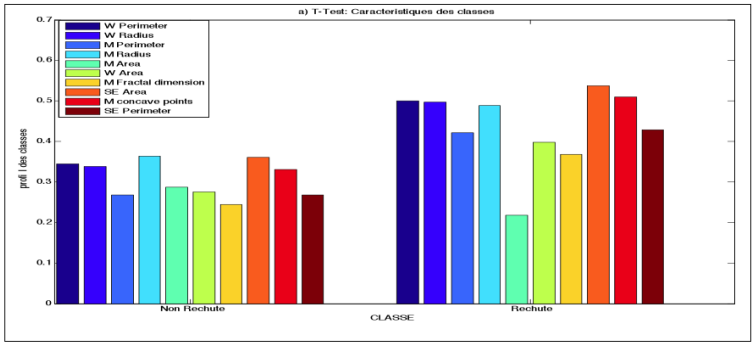

Fig. 7.6: Class characteristics with 10 attributes

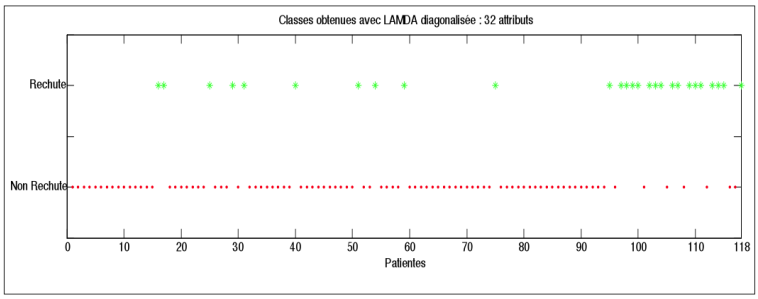

Fig. 7.7: Results of LAMDA classification

- it enables to process data of several types of representation: numerical or quantitative, by modalities or qualitative, and more recently the intervalar representation has been also introduced.
- by the use of the concept of “adequacy” to a class, otherwise membership to a fuzzy subset, transforms an heterogeneous data base into an universe that can be reprented in the form of a unitary hypercube, its dimension being the number of variables or features.
- the weight or importance of each feature that describe the individuals is easily introduced and dynamically adjusted.
- the selection of variable becomes a simple optimization problem in the space of marginal memberships.

- learning reduces almost uniquely to computation of means, and selection threshold criteria.
- The recursivity of the mean algorithms enables their use for processing flows of data, and not only static sets.

By considering those advantages, the initial research work of Ramon López de Màntaras, in the form of LAMDA algorithm, has been intensively applied mainly in the field of Supervision and Condition Monitoring, as well as in Diagnostic Engineering Management, and Maintenance Systems.

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Chapter 8
Papers, Persons and Events: an Integrated Entity-Based Platform for Knowledge Production and Dissemination*+

Fausto Giunchiglia, Ronald Chenu-Abente

Abstract Scientific papers and scientific conferences are still, despite the emergence of several new dissemination technologies, the de-facto standard in which scientific knowledge is consumed and discussed. While there is no shortage of services and platforms that aid this process (e.g. scholarly search engines, websites, blogs, conference management programs), a widely accepted platform used to capture and enrich the interactions of a research community has yet to appear. As such, we aim to explore new ways for the members and interested people (persons) that create or discuss their work (papers) in research communities to interact; before, during and after conferences (events). These papers, persons and events, represented as metadata-enriched entities, are used not only to manage a large body of new and legacy papers but also for aggregating useful information and services related to the persons and events into a new type of knowledge production and dissemination platform.

Fausto Giunchiglia, Ronald Chenu-Abente
DISI, University of Trento, Italy e-mail: faustodisi.unitn.it,chenu@disi.unitn.it

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+ The platform developed in this project has been partially funded by the LiquidPub project (Project number 213360, THEME 3: FP7-ICT-2007-C FET OPEN) http://project.liquidpub.org

8.1 Introduction

Scientific papers or Articles were introduced during the 17th century when the first academic journals appeared. Since then these papers, along with the scientific conferences or symposiums, have become the cornerstones of the scientific community and research (as described in [1] and [2]).

Currently, as detailed in [3] and not very unlike those early times, when an author wants to publish a scientific paper he has to submit a physical and or digital copy of it to an academic journal, where it goes through a process of Peer reviewing to determine if its publication is suitable (a similar process occurs in the case of submitting papers to conferences and workshops). Furthermore, the most common (and sometimes effective) way of discussing ideas with colleagues is still through the age-old tradition of organizing scientific conferences or symposiums.

This model based on papers, persons and scientific events has remained mostly undisturbed up to now. This is the case even if the Internet and the web are slowly reducing the costs related to the dissemination process and providing new ways of contact and interaction. Several studies (for example [4] and [5]) have been carried out to find the existing limitations on the creation, dissemination, evaluation and credit attribution of these scientific artefacts. Furthermore, new types of less formal artefacts like web pages, blogs, comments, bookmark sites among others have also been increasingly popular in scientific environments. While these emerging web-based new types of scientific artefacts are generally less well-regarded than the traditional ones, it is nonetheless, irrefutable that they also are increasingly being used to disseminate, discuss, structure and, ultimately, advance scientific knowledge.

Over the last years, a great variety of initiatives were developed to put these new technologies and interaction possibilities to the service of scientific discourse. Some examples include scientific-oriented social networks(e.g., ResearchGate[1], IamResearcher[2], Academia.edu[3]), digi-

[1] www.researchgate.net/

[2] www.iamresearcher.com/

[3] www.academia.edu

tal library oriented sites (e.g., DBLP[4], ACM Portal[5], Mendeley[6]) and countless custom-made software oriented to specific conference-related functionalities (e.g., registration, submission systems, agenda management, mobile device support).

To bridge the seemingly antagonistic, conventional approach and the web-enabled new technologies, we propose the creation of a community platform focused not only around the papers that contain the scientific knowledge or the persons that create it, but also around the events in which these persons meet to discuss this scientific knowledge. By using these three key elements, abstracted as metadata entities (i.e., a specific representation of objects in the real world) and enriched with semantic technology, we aim to accomplish the consistent aggregation of previously disjoint services; like providing access to conventional papers, provide information to aid and enable visiting conference events and, offer services that would enrich the interactions and contributions with other researchers.

In particular, we want to create new ways for the members and interested people working in the Artificial Intelligence (AI) research community to interact; before, during and after their conferences. To serve as a base to these interactions, we want not only to obtain, format and manage a body of legacy and new papers related to this community but also to aggregate several (previously dispersed in several sites) useful information about persons and events to the environment of a community platform. This platform, which was previewed during the International Joint Conference on Artificial Intelligence (IJCAI) 2011 and is still under development, would allow the members the community to discuss their work and to share their content (e.g. presentations, videos, notes and pictures).

The structure of this paper is as follows: first, in Section 8.2, we discuss the design and specification of the entity structures powering the platform; we then focus on the services offered by the platform in Section 8.2 and Section 8.4 to then give a quick look at it's architecture in Section 8.5. Finally, throughout the whole paper but especially in Section 8.6 and Section 8.7, we focus in the opportunities and advantages

[4] www.informatik.uni-trier.de/ ley/db/

[5] http://dl.acm.org

[6] www.mendeley.com/

of this semantic-enabled community platform and discuss related and future work.

8.2 Entities

One of the main principles behind of the proposed community platform is the use of an entity-centric abstraction to provide an uniform representation of objects, in both the real and the virtual world, that are relevant to the platform[7].

8.2.1 Entities and Entity Types

An entity En, is defined by its metadata as:

$$En =< id, type, Attr, Rel, S > \tag{8.1}$$

Where:

- *id*: is a unique identifier (e.g., an URI).
- *type*: is the type of entity, that is, the category to which it belongs to (e.g., the entity John is of type Person).
- *Attr*: is a set of attributes composed of pairs *attr* = <*attrname attrvalue*> describing the properties (e.g. Johnś date of birth is 02/01/88) of that particular entity.
- *Rel*: is a set of relational attributes composed of pairs *rel* = <*relname, relvalue*> describing the entity's relations (e.g., John is friendOf Paul) with other entities.
- *S*: is a set of services that can be leveraged on that specific entity; for example, a service "send email" can be enabled on the Person entity.

The entity types encoded on the *type* property are used to define the basic attributes and services a particular type of entity will have. For example,

[7] Discussing the subtleties of the implemented entity-based management system is beyond the scope of this paper; so topics like the concrete differences between this system and regular object-oriented inheritance systems, multiple entity type inheritance, and semantic enabled attribute names will all be left for future works more focused on this aspect.

the paper entity type defines that all instances of an entity representing a paper will have the ‘abstract’ attribute and the ’author’ relation. Furthermore, as shown in Figure 8.1, all the entity types can be arranged into an entity type lattice, which allows the inheritance and extension of the metadata and services from the parent types (at top) to the children types (at the bottom).

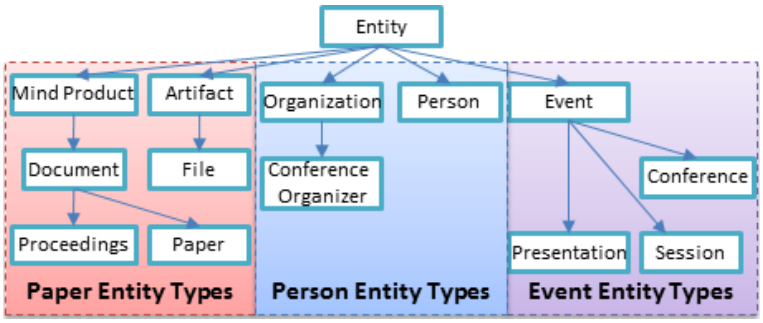

Fig. 8.1: Entity type lattice used in the platform.

As an example, consider the entity type ‘Paper’ (shown in Figure 8.1); this type would inherit metadata and services from the types Entity, Mind Product and Document.
Finally, as emphasized in Figure 8.1, there are three main groupings of entity types defined on the platform. These will be discussed in more detail in the next subsection.

8.2.2 Papers, Persons and Events

The current version of the community platform recognizes the importance of conferences as an important axis for the scientific production and discussion between peers. This focus has helped to identify three specific entity types which are key in the current approach: Persons, the main subjects who create and discuss science; Events, how persons meet to discuss; and Papers, the artefacts created by persons for the event to motivate or as a result of discussions.

Using the entity type lattice from Figure 8.1 as a guide, this section will offer a brief look at the three main groups of entity types, their structure and how they enable different features.

8.2.2.1 Papers

These entity types are used to represent the actual artefacts that emerge from the scientific production. Dublin Core[8] was used as the main inspiration for this specification.

The current data structures support three levels of specialization for these types of entities:

- *Mind product*: refers to any piece of intellectual work created by the human mind. Mind product is a fairly general entity type and as such has attributes like 'author' that apply to a wide range of artefacts.
- *Documents*: documents extends mind products to better represent artefacts created to transfer information or support claims. Examples of entities covered by this entity type include email, presentations and even videos.
- *Papers*: the paper entity type extends document to capture the information more specific to scientific papers (e.g. citations, keywords, publisher).

Table 8.1 contains some examples of attributes for the entity types related to Papers.

8.2.2.2 Persons

Persons entities represent the researchers (e.g., creators, editors, commenters, reviewers) participating in scientific activities. The inspiration of the metadata of Persons was inspired by FOAF[9], YAGO[10] and Freebase[11].

Table 8.2 contains some examples of attributes for the Person entity type.

[8] http://dublincore.org/documents/dcmi-terms/

[9] http://xmlns.com/foaf/spec/

[10] http://www.mpi-inf.mpg.de/yago-naga/yago/

[11] http://www.freebase.com/

Table 8.1: Attributes from the Mind Product, Document and Paper entity types.

Attribute	Entity	Description
Author	Mind Product	The set of entities that participated in the creation of the artefact (e.g. a person, a software company).
Representation	Mind Product	The set of entities of type File that contain the concrete representation (instance) of this mind product. e.g. A particular pdf file representing a document or a video clip for a given presentation.
Title	Document	A short text describing the document's subject. E.g. Applied Mathematics, A Midsummer Night's Dream.
Editor	Document	A set of the persons or organizations that edited (i.e. introduced changes or aggregated) this document.
Reference	Document	A related (but external to the document) resource that is referenced, cited, or otherwise pointed to by the document.
Version	Document	The set of documents that were versioned (i.e. are newer) from this document instance.
Abstract	Paper	A text that is related to the main topics/concepts of the paper.
Keywords	Paper	A text containing a set of words that are related to the main topics of the paper.
DBLP identifier	Paper	Digital Bibliography and Library Project
Citation	Paper	A set of documents that are cited on the paper.
Publisher	Paper	Person or Organization responsible for making the resource available.
Date of publication	Paper	Date of formal issuing by a publisher.

8.2.2.3 Events

Events entities are used to represent organized meetings and other activities related to the scientific production of the community.

The current data structures support four levels of specialization for these types of entities:

Table 8.2: Attributes from the Person and Organization entity types.

Attribute	Entity	Description
First Name	Person	The first name of a person(i.e., The name that precedes the surname).
Middle Name	Person	The middle name of a person (i.e., The name between the first name and the surname).
Last Name	Person	The last name of a person (i.e., The name used to identify the members of a family).
Title	Person	An identifying appellation signifying status or function (e.g., "Mr., Ms.").
Gender	Person	The sex of the person (male, female).
Nationality	Person	The nation of birth or naturalization.
Photo	Person	Link to a picture file that represents the person.
Email	Person	Email address used for contacting the person.
Webpage	Person	URL of the homepage or blog of the person.
Favorites	Person	Links to the preferred papers, people and events of the current person.
Organization	Person	Link to the current work/research related organization of the person.

- *Events*: refers to any general-purpose event. Normally special events like meetings, opening ceremonies and banquets are represented directly as event entities.
- *Conferences*: used to represent conferences and workshops that can, in turn, have sessions and presentations over one or more days.
- *Sessions*: represents groups of presentations, normally with a common topic.
- *Presentations*: represents each individual talk. Has links to both the person giving the talk and the corresponding paper.

8.3 Data-Centric Services

Using the previously defined entity-based metadata management as a base, we define the data-centric services that operate directly on the entity metadata to offer meaningful concept-enabled functionalities.

Table 8.3: Attributes from the Event, Conference, Session and Presentation entity types.

Attribute	Entity	Description
Location	Event	Specifies where the event occurs (e.g., city, city quarter, building, set of locations, etc.).
Start	Event	Start time of the event.
End	Event	End time of the event.
Organizer	Conference	Link to the person that organizes the conference
Contact	Conference	Link to the reference person for the conference.
Moderator	Session	The person moderating or regulating the session.
Track	Session	Name or number identifying this session as one of the simultaneous sessions of the conference.
Title	Presentation	A short text describing the presentation topic.
Abstract	Presentation	A short text that is related to the main topics/concepts of the paper.
Speaker	Presentation	Link to the person/s giving the presentation.
Slides	Presentation	Link to the file of the slides used during the presentation.
Video	Presentation	Link to the video of the presentation.
Paper	Presentation	Link to the corresponding paper for the current presentation.

8.3.1 Classification and Natural Language Processing

Classifications have been used for centuries to catalogue and search large sets of objects (e.g. classifying papers based on the topics they discuss). Classifications normally describe their contents by using natural language label (e.g. 'Computer Science', 'Databases').

The underlying idea of a semantic-based service is to have information encoded in a way that can be unambiguously interpreted by software agents, thus permitting them to find, share and integrate information more easily [6]. Unfortunately people normally annotate and classify documents by using ambiguous natural language, and trying to educate them to do otherwise requires them to go through a (normally considered) burdensome learning curve. A formal classification or a lightweight ontology ([7] and [7])is, on the other hand, a classification where labels are written in a propositional concept language. As

such, formal classification can be reasoned about far more easily than natural language sentences.

To obtain the best of the two worlds (i.e. the familiarity of natural language classification and the unambiguity of propositional concept language), approaches like [9] and [10] apply Natural Language Processing (NLP) to the natural language classifications to convert them into lightweight ontologies. This enables the platform to provide:

- *Document Classification*: assigning each paper to one or more categories based on their metadata. This would later be used to offer the user paper topic navigation features and also to enable better recommendation services.
- *Data Integration*: combining multiple sources of data is a non-trivial known issue [11] among large data and knowledge bases. This can be aided by the classification of each data source into a rooted tree and then the discovery of semantic relations that exist between these trees. This allows merging multiple data sources without introducing noise (in the form of duplicates or invalid data) which is a common issue for multiple-source digital libraries.
- *Semantic Search*: the system can find the semantic correspondence of an object or a set of objects that corresponds to a query entered by the user if the meaning associated with the object/s is more specific or equivalent to the meaning given to the query under a common sense interpretation. This is further elaborated and exemplified below.

8.3.2 Semantic Search

The semantic search functionality enhances the regular search text facilities, making possible to specifically search for any of the attributes belonging to an entity (e.g. search for the paper with the following keywords, author and/or references). Furthermore, thanks to the use a domain-specific the concept knowledge base, it allows the search results to contain concept-based matches besides the text-based ones.

For example, it allows the user to search for papers with the topic ‘semantic search’ and authors from ‘Italian universities’ and to find papers about the ‘concept search’ approach with authors from ‘Trento university’ (that is assuming that the underlying knowledge base contains all

of the necessary concepts and relations to allow for such inference). A semantic search approach is used to perform the matching between these individual constraints and the entity attributes, i.e., it allows us to compute that the phrase ‘concept search’ has more specific meaning than phrase ‘semantic search’ and that Trento is a city which is located in Italy. Furthermore, faceted search is used to specify two constraints on the paper entity, namely topic: ‘semantic search’ and author.affiliation: ‘Italian universities’.

Semantic search on individual attribute names and values is implemented by using the Concept Search approach [12]. Concept Search is an information retrieval approach which extends syntactic search with semantics in order to address the problems related to the ambiguity of natural language (e.g. the problems of polysemy and synonymy) by substituting words, when possible, with concepts. The main idea behind concept search approach is to reuse highly optimized retrieval models and data structures of syntactic search and preserve their efficiency while allowing for improved results when high-quality semantic information is provided. For instance, the semantic matching ([13] and [14]) of complex concepts, i.e. the core building block in the concept search approach, is implemented by using the inverted index technology.

Both features are specially useful for providing accurate results during exploratory search (allowing users to discover entities and knowledge that they did not know but that are interesting to them) and also for recommendation purposes (by performing a searches with parameters related to the active user).

8.4 User-Centric Services

The user-centric functionalities are implemented by building highly-refined user interfaces on top of one or more of the back-end services from Section 8.3.

8.4.1 Information display and Navigation

The main objective of this service is use the power of the semantic services to offer a seamless and effective entity navigation interface through a web interface. For example, Figure 8.2 shows a webpage (from our live demo of the platform) displaying the list of papers presented for IJCAI11.

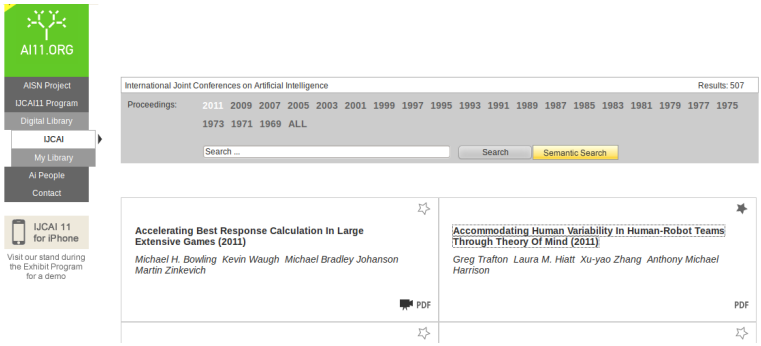

Fig. 8.2: Paper search and browsing interface.

The screen showed in Figure 8.2 offers several options to help the user find the information he is looking for:

- *Semantic search bar*: used to perform conventional and semantic search as described in Subsection 8.3.2.
- *Entity Navigation*: the following elements in the page can be clicked:
  - *Title*: this would take the user to the paper profile page where all the metadata of the paper can be viewed and edited (provided the user has the permissions to do so).
  - *Authors*: when clicked takes the user to the Author profile page.
  - *PDF icon*: this would take the user to the actual full-text of the paper by downloading the pdf file from the IJCAI servers.
  - *Video icon*: this would take the user to a page where he can have access to a video of the that paper's presentation during IJCAI11.

Figure 8.3 shows am example of a person entity profile, this displays not only the metadata related to the person (e.g. name, contact informa-

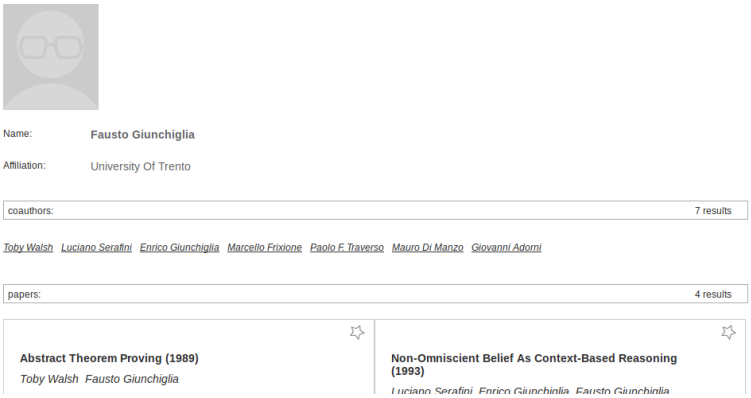

Fig. 8.3: Person profile example.

tion) but also the relations that this person has with other entities in the system (e.g. co-authors, published papers). These relations are displayed as links that can be, in turn, clicked to seamlessly continue the navigation of all the entities in the platform.

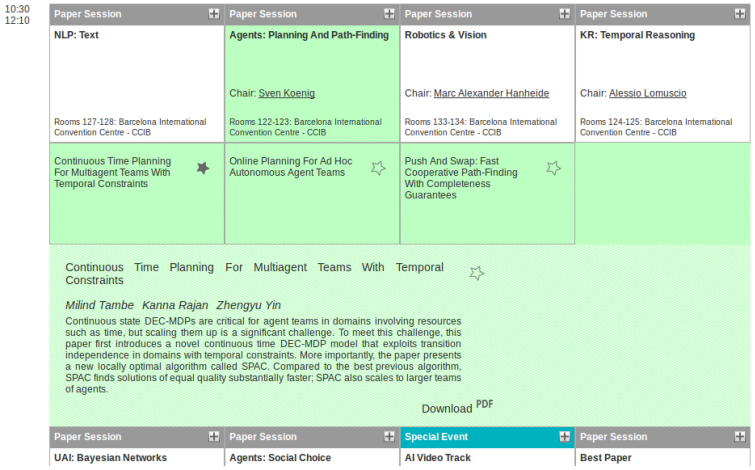

Fig. 8.4: Current version of the platform displaying a webpage with event information.

Figure 8.4 contains an example of a screen, from the current version of the platform, displaying the events of a conference. The main interface shown in Figure 8.4 is based around the idea of a expanding/contracting calendar that shows, according to the user's input, different levels of information about the conference and its sub events. Furthermore, links offering navigation to all the related entities (persons, papers, sub-events) are also made available for the user. These hundreds of interconnected entities queried and processed into rendering this webpage, are all easily findable and accessible to the user by seamless link navigation or by using the power of semantic search.

8.4.2 Favourites and Personalized Entities

As a way to assist the users remembering and following their personal interests, this feature allows to define 'favourite entities' (i.e., the papers, persons and events that have a special meaning or importance for the user). As it can be noticed in Figures 8.2, 8.3 and 8.4 a small star icon appears at the top right side of each entity. Clicking on this star icon marks that entity as a favourite for the current user.

The meaning and purpose the platform gives to defining an entity as a favourite is slightly different according to the entity type:

- *My Agenda (events)*: the purpose of this page is to show a calendar with the day and time of all the favourite events of the current user.
- *My Library (papers)*: displays all the favourite papers of user in a single list, allowing for easy reference, reading of the pdf or viewing of the associated video presentation.
- *My Contacts (persons)*: shows a list of all persons marked as favourite by the current user. Future extensions include extending the My Contacts page to include and capture the different relations that may exist between researchers (e.g., is my collaborator, co-author, advisor).

Besides defining which entities are important for the user, the system also has plans to allow the user to add their own private annotations and tags to the entities. This personalization augments the ability to define favourites by also allowing the user to capture the particular reason of interest in the target entity (e.g., A user adds the 'I need to read later'

annotation to paper in its favourite list and a ‘I really liked the abstract’ to other).

8.4.3 Mobile Support

Continuing with the objective of providing assistance to the members of the community, the mobile client of aims to offer key functionalities from the platform in a ubiquitous manner. More specifically, it’s objective is to provide support to manage the almost chaotic event of attending to a big scientific conference like IJCAI. The mobile client is mainly focusing on managing events and helping the user build his own personalized program of the conference. Figure 8.5 shows an example of how the different sub events of the conference are displayed in the mobile client. In a similar fashion to the web interface, the mobile client allows to browse the different events in a conference, having access through them to the papers (which can be comfortably read on the tablet version of the mobile client) and their authors. Thanks to these features the mobile client acts almost as a ‘digital brochure’ of the conference, assisting the users to make the best of their limited conference time by allowing to quickly find the talks and persons they are interested in.

8.5 Platform

This section will present the general architecture and some details of the most important subsystems of the proposed community platform.

The diagram at Figure 8.6 shows the general architecture of the scientific community platform.

More specifically, in Figure 8.6, the following macro-elements may be identified:

- *Server A - Content*: the actual content (papers, presentations, etc.) are left in their original content servers and linked through URLs. In the current version Server A is managed by the IJCAI itself, it is completely independent and external to the rest of the platform. This

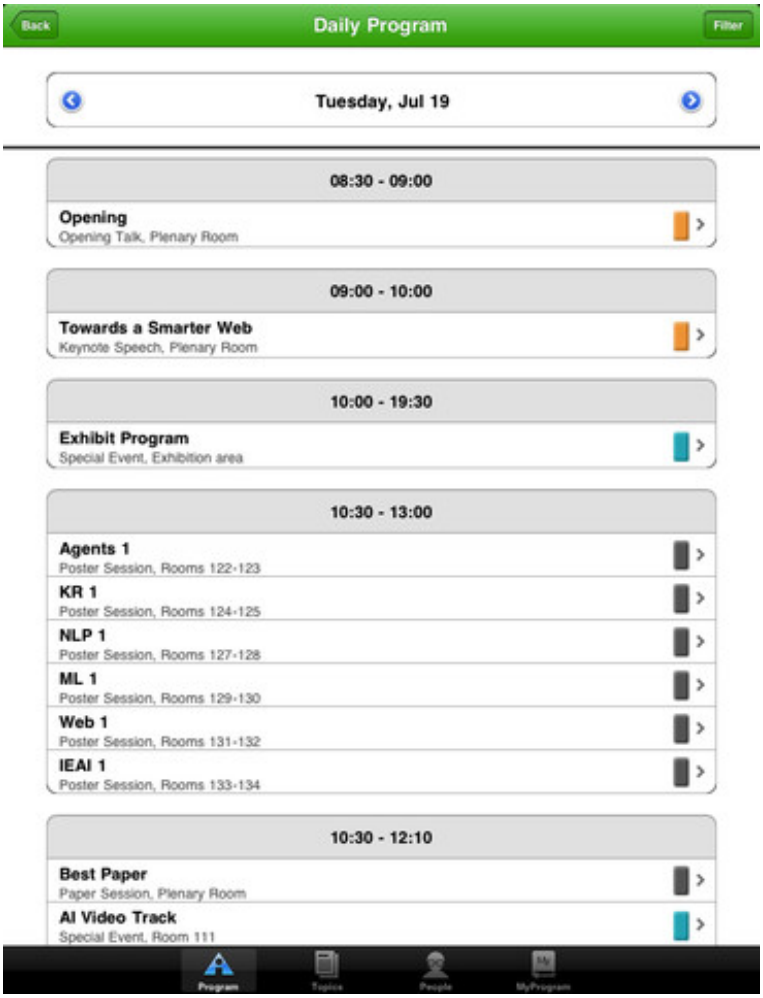

Fig. 8.5: Mobile client displaying the program of a conference day.

server is also being used at the same time to serve the current IJCAI website[12].

[12] http://ijcai.org

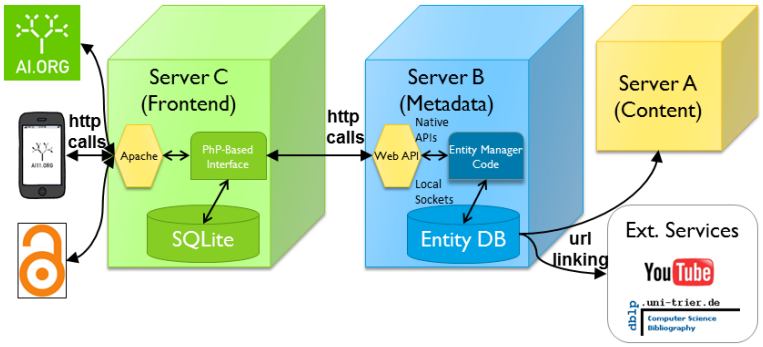

Fig. 8.6: Community Platform General Architecture.

- *Server B - Metadata*: metadata is stored in the back-end metadata server. The server B is considered the backend of the platform as it offers both conventional and semantic-based structures management and services for the metadata. This allows the platform to avoid any copyright or licensing complications that may arise when handling and duplicating the actual content to be discussed, while still being able to refer to the actual content by the use of URLs.
- *External Services*: using the same URL linking, materials from all over the Internet (e.g. videos, profiles on other sites) can be referenced from within the platform. This external content complements the core content from Server A and their links are added to the metadata in Server B.
- *Server C*: this component mainly in charge of taking the information from the metadata server and generating the web pages/data structures that will ultimately be displayed in the clients.
- *Clients*: these are in charge of rendering forms for users and processing their inputs. Thanks to the underlying architecture, clients are allowed to be machines with a modest processing power (e.g. mobile devices) as the more hardware-intensive processes are carried out in the servers.
  There are currently three clients in development:
  - *Web Client*: the browser receives enriched html pages to display and sends back the user input.

- *Mobile Client*: the mobile receives specifically formatted data structures from Server C, that the native application in the mobile device uses to build and render the pages shown to the user.
- *Open Access Client:* to comply with the Open Access Metadata Harvesting [13] Protocol, we have created a separate Open Access server that contains the subset of all the available metadata necessary to comply with this standard. By complying with this standard all of the papers managed in our platform would be indexed by the major scientific search engines.

The current architecture and the underlying model make that the resulting platform to be easy to extend and manage both in its data-based services (e.g., extension of entities, implementation of new services) and in user-centric services (e.g., new clients like Android mobile devices easily added).

8.6 Related Work

The main part of the conceptual groundwork for the community platform presented in this paper is based on the SKO (Scientific Knowledge Object) model introduced in [15]. The creation of this still upcoming SKO model, has also taken into consideration several semantic-enabled scientific discourse models covered in [16].

As an example of similar approaches, the following are some of the services and platforms that have already been created to aid scientific production:

- *Search engines*: a search engine specifically tailored for scientific papers, persons and events (e.g. Google Scholar[14]).
- *Conference websites*: these sites contain announcements and concrete information about the venue and event of a conference. They are also mainly used to register (and pay) for participation (e.g. the ESWC2011 site[15])

[13] www.openaccess.org

[14] http://scholar.google.com

[15] http://www.eswc2011.org/

- *Conference series websites*: these types of sites contain proceeding (i.e. collections of papers), give various announcements and offer special pages for the organizers to share information (e.g. the JCDL conference series site[16]).
- *Submission management*: used to manage the submission process of papers to a conference (e.g. Easychair[17]).
- *Social Networks*: like Facebook[18], almost unchallenged as a recreational and commercial social network. We would also want to offer scientific-related resources and content as the very center of the social network (e.g., Academia.edu[19]).
- *Digital Library Portals*: like ACM's[20] include several of the features we are interested in (albeit sometimes in a reduced or more basic manner).

The wide variety in the approaches and services mentioned shows that many of the functionalities and services that are considered interesting for scientific research are still somewhat dispersed. It would be normal for a researcher, for example, to first search for a paper in scientific search engine, then find it in the proceedings of a conference site and finally resort to email communication to comment or discuss.

Besides the minor inconvenience of using multiple sites, the main problem is that no explicit tracking is kept over the whole process or even the interactions or discussions that are taking place. A platform used to capture and enrich the interactions that happen inside the research community has yet to appear, that is able to manage a large body of new and legacy papers while also for aggregating useful information and services related to persons and events from the community.

8.7 Conclusions

Our proposal integrates the information services related to Digital Libraries (papers), Social Networks (persons) and Conference-aid systems

[16] http://www.jcdl.org/

[17] http://www.easychair.org/

[18] http://www.facebook.com/

[19] http://www.academia.edu/

[20] http://portal.acm.org/

(events) into a novel platform with the objective of bridging the distance between the conventional and the web-based scientific discourse. The advantages of said coherently integrated platform include:

a. Offer improved ways for helping the users find conventional content, persons or events they are looking for (through semantic search and navigation) along with the context and relations that these may have. The specific improvements will be based on the ability to search for title, authors, keywords and even key concepts related to what the user wants to find and to aid the search based on the navigation of the "related items". Search, access to information and interaction with results, will all be integrated in the same platform and aided by it.
b. Offer a way of introducing new web-based interactions like commenting, tagging and creation relations for all the content in the site in a certified (i.e. approved and validated by the management of the site) way.
c. Provide ubiquitous/live services during conferences that, through the use of portable devices, would help attendants to find, keep track and take notes about the events happening. All this integrated into the main platform, which would both keep track of this for the user and for computing meaningful statistics about the conference. While similar services to these already exist, they are fairly localized endeavours proving a sort of "your guide during the conference" services. By integrating with the social network we want to also achieve "your preparation to the conference" and "this conference continues online" services that have yet to be coherently presented.
d. Reformat the vast volumes of legacy information into a reusable and easily citable format. This would allow the users to browse information from conference that happened over 30 years ago and also have access to information and services similar to the recent conferences (that were specifically tailored for the platform).

After a successful preview of a prototype during the IJCAI11 conference, the next version of community-platform is being developed to to accommodate the useful feedback received during the conference. To solve issues of data completeness and accuracy, the metadata of the platform was cross-checked and linked with DBLP[21] and new data sources are being considered tøadd to the already significant amount of information in it (around 5 thousand papers and around 8 thousand authors).

[21] http://dblp.uni-trier.de

Future projected features work include annotation of the PDFs from legacy papers, crowdsourcing features used to improve the accuracy of the information in the platform, more social interaction features, creation of categorizations of the sub fields in the AI field (to facilitate finding papers relevant to particular subjects) and more fine-grained organizations and affiliations. (i.e., supporting the differentiation between university, department, research group).

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Chapter 9
Music Expressivity through Case-Based Reasoning

Josep Lluis Arcos

9.1 Introduction

The purpose of this contribution is to explain the relationship of Ramon with Music, Case-Based Reasoning, and the direct influence he has had in my research. First, although we share our passion for music, I will not focus on his skills as a jazz pianist. However, this common, personal interest was probably the seed of our fruitful collaboration. Second, the story started at a time when science was still not strongly influenced by the need of short-term results or by the prevalence of bureaucratic regulations. Finally, to convince the reader about the influence of his research on the artificial intelligence field, the reader can simply consult "una casa de citas de Philadelfia".

The research interest on music expressiveness comes from different motivations: to understand or model music expressiveness; to identify the expressive resources that characterize an instrument, musical genre, or performer; or to build synthesis systems able to play expressively. These challenging goals have attracted several researchers to propose AI solutions.

The first approach to tackle the problem was to try to make explicit this knowledge, mainly designing rule-based systems, using musical experts. One of the first expert systems developed was a rule-based sys-

Josel Lluis Arcos
IIIA-CSIC, e-mail: arcos@iiia.csic.es

tem able to propose tempo and articulation transformations to Bach's fugues [7]. The rules of the system were designed from two experts. The transformations proposed by the system coincided with well-known commented editions but the main limitation of the system was the lack of generality. Another successful research was the system developed by the KTH group from Stockholm. Their effort on the *director musicies* system [4] incorporated rules applied to tempo, dynamic, and articulation transformations to MIDI files. Also related to knowledge-based systems, the long-term research led by G. Widmer [16] applied machine learning techniques to acquire rules from a large amount of high-quality classical piano performances. Interested readers will find a more complete survey on the design of systems using explicit knowledge in [9], casually written by Ramon.

The main drawback when using rule-based systems is the difficulty to find rules general enough to capture the diversity present in different performances of the same piece, or even the variety within the same performance. An alternative approach, much closer to the human observation-imitation process, is to directly work with the knowledge implicitly stored in musical recordings and let the system imitate these performances. This was our starting question: could we adopt this approach to overcome some of the existing drawbacks ?

This alternative approach, also called Case-Based Reasoning, focus on locally approximating a complex target function when a new problem is presented to the system. Case-Based Reasoning (CBR) [1, 10] is a methodology that exploits prior experiences (called cases) when solving new problems by identifying relevantly similar cases and adapting them to fit new needs. CBR is appropriate for problems where either (1) many examples of solved problems are available or (2) a main part of the knowledge involved in the solution of problems is implicit, difficult to verbalize or generalize. As we will present in this chapter, music expressiveness presents the two characteristics described above.

CBR inference consists of four 'R' steps: *case Retrieval*, which determines which cases address problems most similar to the current problem; *case Reuse*, which forms a new solution by adapting/combining solutions of the retrieved cases; *case Revision*, which evaluates and adjusts the adapted solution; and *case Retention*, in which learning is performed by storing the result as a new case for future use.

In CBR, previous experience may be used to speed up the learning of novices. For instance, a young PhD student may exploit the experience

of a consolidated researcher to become a new researcher. To be honest, I should add a fifth 'R' to my personal relation with CBR.

Below, I will describe how the CBR methodology has been successfully used to design two computer systems for expressive musical performance: *SaxEx* and *TempoExpress*.

9.2 SaxEx

The first child we jointly developed is *SaxEx*. The goal of the *SaxEx* system [2, 3] was to generate expressive melodies by means of performing transformations on non-expressive recordings. That is, to add expressiveness according to user's preferences. *SaxEx* was applied in the context of saxophone jazz ballads. Specifically, *SaxEx* manages five different expressive parameters: dynamics, tempo, vibrato, articulation, and note attacks.

SaxEx was designed with the claim that the best way for a musician to elicit her expertise is to directly provide examples, i.e. playing her instrument. Then, *SaxEx* was designed as a CBR system where the cases hold the implicit knowledge collected in human recordings. To achieve its task, *SaxEx* uses a case memory containing human performances (ballad recordings), the scores associated to these performances (containing both melodic and harmonic information), and musical knowledge used to define similarity among melodic fragments.

The information about the expressive performances contained in the examples of the case memory is represented by a sequence of *affective regions*. Affective regions group (sub)-sequences of notes with common affective expressiveness. Specifically, an affective region holds knowledge describing the following affective dimensions: *tender-aggressive*, *sad-joyful*, and *calm-restless*

These affective dimensions are described using five ordered qualitative values expressed by linguistic labels as follows: the middle label represents no predominance (for instance, neither tender nor aggressive), lower and upper labels represent, respectively predominance in one direction (for example, absolutely calm is described with the lowest label). For instance, a jazz ballad can start very tender and calm and continue very tender but more restless. Such different nuances are represented in *SaxEx* by means of different affective regions.

Additionally, expressive performances (recordings) are analyzed using spectral techniques using using SMS [15] and annotated using fuzzy techniques. The advantage of using fuzzy techniques is that we can abstract numerical features provided by a low level analysis by a collection of fuzzy labels with associated membership degrees. This approach facilitates the reasoning process without losing information.

A new problem for *SaxEx* is a musical phrase, described by its musical score and a non-expressive recording, together with a description of the desired affective expressiveness for the output. Affective information can be partially specified, i.e. the user may only provide values for some of the three affective dimensions. Values of desired affective expressiveness will guide the search in the memory of cases.

The two main inference processes in *SaxEx* are the retrieval and the resuse steps. The goal of the retrieval step is to select, from the case memory, a set of *similar* notes to the current problem (input musical phrase). To do that, the similarity criterion is the key factor. *SaxEx* uses Narmour's Implication-Realization (IR) model [13] for similarity assessment. IR model is based on a perception and cognitive approach to analyze the structure of a musical piece. Specifically, IR models the patterns of expectations generated in people when listening a melody. It follows the approach introduced by Meyer [12] that applies the principles of *Gestalt Theory* to melody perception.

After the retrieval of the notes more similar to the current problem, the role of the reuse step is to determine the expressive transformations to be applied to each note. That is, for each note in the problem melody, a value for each of the five expressive parameters (dynamics, tempo, vibrato, articulation, and note attacks) must be determined. To determine expressive transformations, the first step is to inspect the solutions given in the cases retrieved (the values chosen in each similar note for each expressive parameter). Notice that these values are represented as fuzzy labels with associated membership degrees. Because these values are never exactly the same, *SaxEx* has a collection of adaptation criteria that can be selected by the user. For instance, the *majority* criterion will choose only the values belonging to the linguistic fuzzy label applied in the majority of cases. Next, these values are combined by applying a fuzzy aggregation operator.

Expressive examples generated by *SaxEx* contained some interesting results such as: crescendos placed in ascending melodic progressions, accentuated legato in sad performances, staccato in joyful ones,

and "swingy" rhythmic patterns. Readers are encouraged to judge *SaxEx* results at
`http://www.iiia.csic.es/Projects/music/Saxex.html`

9.3 TempoExpress

The second system, developed in the context of the PhD of Maarten Grachten, is *TempoExpress*. *TempoExpress* [5] is A CBR system for realizing tempo transformations of audio recordings at the musical level, taking into account the expressive characteristics of a performance. Existing high-quality audio algorithms are only focused on maintaining *sound* quality of audio recordings, rather than maintaining the *musical* quality of the audio. In contrast, *TempoExpress* aims at preserving the musical quality of monophonic recordings when their tempo is changed.

Because expressiveness is a vital part of performed music, an important issue to study is the effect of tempo on expressiveness. An study conducted by H. Honing demonstrated that listeners are able to determine, based only on expressive aspects of the performances, whether audio-recordings of jazz and classical performances are original or uniformly time stretched recordings [6]. The goal of *TempoExpress* is to transform audio recordings in a way that (ideally) listeners should not be able to notice whether tempo has been scaled up or down.

TempoExpress performs tempo transformations by using a case-based reasoning approach. The design of the system was similar to the *SaxEx* system: a case memory storing symbolic descriptions of human performances, the scores associated to these performances, and musical knowledge used to define similarity among a new problem and the cases. Human performances are analyzed using audio analysis techniques [11] and a symbolic description of each performance is automatically calculated.

Analogously to the *SaxEx* system, IR model is used to calculate melodic similarities. However, the structure of the case memory in *TempoExpress* is more complex than in *SaxEx*. First at all, in *TempoExpress* an input problem is now an expressive performance. Moreover, available performances may become part of the problem description or a solution because source and target tempos vary.

Thus, the pairs of problem-solution are generated dynamically according to the characteristics of a new problem. First, performances with tempos very different from the source and target tempos are filtered out. Next, IR similarity is applied as a second retrieval filter. Finally, a pool of cases are constructed as pairs of problem performances (those with tempo close to the source tempo) and solution performances (those with tempo close to the target tempo).

The first consequence of dealing with input expressive performances is that *TempoExpress* must include a similarity measure among performances. It is common to define musical expressiveness as the discrepancy between the musical piece as it is performed and as it is notated. This implies that a precise description of the notes that were performed is not very useful in itself. Rather, the relation between score and performance is crucial. *TempoExpress* uses a representation of expressiveness that describes the musical behavior of the performer as performance events. The performance events form a sequence that maps the performance to the score. For example, the occurrence of a note that is present in the score, but has no counterpart in the performance, will be represented by a deletion event (since this note was effectively deleted in the process of performing the score). A key aspect of performance events is that they may refer to particular notes in the notated score, the performance, or both.

Similarity among performances is calculated using edit-distance techniques [8]. The edit-distance is defined as the minimal cost of a sequence of editions needed to transform a source sequence into a target sequence, given a predefined set of edit operations (classically deletion, insertion, and replacement of notes). The cost of a particular edit-operation is defined through a cost function for that operation, that computes the cost of applying that operation to the notes of the source and target sequences.

Case adaptation is performed by a set of defined adaptation rules. Adaptation rules capture the perceptual similarity of two performances. See [5] for a detailed description of the adaptation process.

9.3.1 Evaluating the quality of tempo transformations

To evaluate *TempoExpress* four different jazz standards were recorded at various tempos (about 12 different tempos per song). In total 170 inter-

pretations of 14 musical phrases were recorded (corresponding to 4.256 played notes).

The methodology conducted was to compare results from *TempoExpress* with results from a uniform time strecthing algorithm. The quality of a tempo transformation was calculated as the distance to a human performance. The key aspect of this approach was that results are very sensitive to the distance metric used to compare performances. It is conceivable that certain small quantitative differences between performances are perceptually very significant, whereas other, larger, quantitative differences are hardly noticeable by the human ear.

To overcome this problem, the distance measure used for comparing performances was constructed by human similarity judgments. Specifically, a web based survey was set up to gather information about human judgments of performance similarity. Survey questions were presenting to subjects a target performance A (the nominal performance, without expressive deviations) of a short musical fragment, and two different performances B and C of the same score fragment. The task of subjects was to indicate which of the two alternative performances was perceived as most similar to the target performance. Thus, subjects were asked with questions of the form "is more similar A to B or more similar to C ?".

A total of 92 subjects responded to the survey, answering on average 8.12 questions (listeners were asked to answer at least 12 questions, but were allowed to interrupt the survey). Only those questions answered by at least ten subjects and with significant agreement between the answers were considered.

A leave-one-out setup was used to evaluate *TempoExpress*. Each of the 14 phrases in the case base was segmented into 3 to 6 motif-like segments generating 6.364 transformation problems from all pairwise combinations of performances for each segment. Experiments demonstrated that *TempoExpress* clearly behaves better than a Uniform Time Stretch when the target tempo is slower than the source tempo. When the target tempo is higher than the source tempo, *TempoExpress* behaves similarly as UTS (the improvement is not statistically significant). Readers are encouraged to judge *TempoExpress* results at `http://www.iiia.csic.es/Projects/music/TempoExpress.html`

9.4 Conclusions

In this chapter I have presented two successful systems that, using a CBR approach, have had an influence in two fields: sound and music computing and artificial intelligence. In both, Ramon has been one of the main contributors. Nevertheless, the Ramon's contributions related to CBR are not restricted to the musical domain. At least, we should mention the research with the Aibos [14], one of the preferred pictures of the journalists.

Finally, the good news are that you are only sixty and, taking into account current political trends, we will have a long time to continue working together.

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Capítol 10
Projectar el futur per afrontar el present: com promoure equips de recerca de gran qualitat humana

Jaume Agustí Cullell

10.1 Introducció

Aquesta és la situació de la cultura en les societats dinàmiques contemporànies. Hem de projectar el futur per afrontar el present. O el que és equivalent, les societats desenvolupades viuen en contínua innovació. D'aquí sorgeix el seu factor competitiu. La innovació constant com element competitiu a escala global i que avui defineix la recerca. Aquestes són unes reflexions evidents per als investigadors, malauradament no tant per a massa polítics, que m'han portat a mirar endavant i no enrere. La intenció? Participar en un extraordinàriament merescut homenatge a Ramon López de Màntaras. El motiu no és solament pels 60 anys que fa (encara recordo el mal humor que tenia en el seu 40è aniversari) sinó per la seva dedicació, tan plena com productiva, al nostre institut. Els records d'aquests últims 27 anys s'acumulen a la ment i truquen. Assumint el risc que comporta apuntar al futur, he decidit reflexionar-hi.

Sóc conscient que mirar al passat, àdhuc als seus èxits, no resulta de massa ajut en una societat dinàmica; pot ser més aviat una rèmora, sobretot en un temps de crisi. Sempre, les possibilitats d'errar parlant del futur són aclaparadores, i tant més quan hom s'aventura trepitjant terreny desconegut, però cal fer-ho. Avui, més que mai, sabem que no podem repetir

Jaume Agustí Cullell,
IIIA-CSIC, e-mail: agusti@iiia.csic.es

res, ni tan sols recolzar-nos en el passat. Dit en altres termes: la recerca és una necessitat, i no pas un luxe, per a la supervivència de la nostra societat. Per tant, promoure la recerca és un dels grans serveis a la societat. I impulsar recerca ha estat una de les activitats que millor ha fet el Ramon dins l'IIIA. Permeteu-me fer aquí un intent per mostrar, breument, unes possibles bases teòriques sobre la promoció de la recerca mitjanccant la creació d'equips de gran qualitat humana. Més endavant especificaré el sentit precís que dono a l'expressió "qualitat humana". De rebot, i implícitament, donarà el context per apreciar la gran tasca del Ramon, no només com a investigador, tasca prou reconeguda, sinó com a impulsor de la recerca i del reconeixement internacional de l'IIIA. Aquest escrit, forcca teòric i abstracte, és d'alguna manera complementari a l'article, més concret, il·lustratiu, vital i amè, que ha escrit el nostre ex-director, Francesc Esteva, amb motiu de la mateixa celebració.

10.2 Necessitat d'orientació axiològica en les tecnociències

La reflexió que plantejo aquí no pretén ser tecnocientífica, ans ambiciona fer una reflexió axiològica sobre què motiva i orienta la recerca, especialment allò que cohesiona els seus equips. La hipòtesi que defenso és la conveniència de complementar els projectes tecnocientífics amb elements axiològics. L'objectiu és explicitar tot allò que motiva, orienta, dóna sentit a la recerca plantejada, i la fa socialment atractiva. També, i molt especialment, m'aturaré a assenyalar què cohesiona i què fa eficaços els equips de recerca, tot dibuixant la figura de l'impulsor de la qualitat humana dins els equips.

En un article recent (Agustí, 2012), he intentat explicar les diferències i relacions entre dues maneres de representar, o millor, de modelar la realitat. Primerament, tenim el modelatge primordial, concret, qualitatiu, motivador i orientador de tota activitat. Per exemple, els models del món en la nostra vida quotidiana. Aquest modelatge va més dirigit als sentits que a la raó, i és anomenat coneixement axiològic en l'article esmentat. Un coneixement que gairebé resulta imprescindible per sobreviure, resultat natural de les diverses formes de supervivència en un entorn donat.

És un coneixement immediat, amb origen en els sentits i no en la raó. És aquell que crea els models primaris, el món d'objectes i subjectes, els valors que ens motiven i orienten, el món en què ens movem. Així doncs, a la base de tot coneixement hi ha el coneixement axiològic. Coneixement que fou gairebé hegemònic en totes les societats preindustrials, quedant en segon terme altres formes de coneixement, entre elles el coneixement tècnic i el conceptual.

En segon lloc, i derivativament, existeix el coneixement conceptual, metòdic, dirigit a la raó, àrduament adquirit en un llarg procés d'abstracció que Bachelard anomenà la formació de l'esperit científic (Bachelard, 1973). És el coneixement filosòfic i especialment el tecnocientífic, que s'ha convertit en el vehicle per al progrés de les societats desenvolupades. Però a tal vehicle li cal un bon combustible, i encara més una millor direcció, això és, motivació i orientació axiològica per a funcionar adequadament. Quan manca, el vehicle és impulsat pel mer instint de depredació. Avui veiem com les tecnociències generen contínuament nova informació, nous models de la realitat, i obren noves possibilitats d'acció. Aquestes, per si mateixes no poden, ni els pertoca, motivar i guiar la nostra acció. No ens poden dir què hem de fer o deixar de fer amb les noves possibilitats tecnològiques. Aquest és el paper del coneixement axiològic abans esmentat, el dels sistemes de valors. D'aquests valors, a vegades en som explícitament conscients, però sovint els obviem. I són justament els valors allò que ens mou, allò que ens desperta l'interès, ens porta cap al compromís, ens condueix cap al lliurament o el rebuig. Establir motivacions i jerarquies de valors sempre havia estat la tasca primària de les religions. Més tard, i breument, ho van ser de les ideologies, una tasca que ara (després del declivi ideològic) ha de fer l'axiologia. I això, entre altres motius, perquè davant la rapidesa i continuïtat dels canvis tecnològics i els corresponents canvis socials, ja no ens serveixen les formes religioses d'establir els valors a través del sotmetiment a creences. En les societats estàtiques preindustrials que havien de fixar les seves maneres de viure, el sotmetiment a unes creences era necessari, imprescindible, segons com es miri. Ara, les creences, tant les religioses com les ideològiques o laiques, poden resultar un impediment per a la necessària dinàmica dels valors en una societat en canvi constant. Les ideologies, com a doctrines axiològiques autoritàries que pretenien ser alternativa a la religió durant la primera industrialització, tampoc no han funcionat. D'elles ens queden alguns valuosos postulats com ara la

igualtat, la llibertat i la justícia social. També, un conjunt de qüestions, més de mètode que de principi, com la democràcia, la competitivitat i el lliure mercat, entre d'altres.

Resumint: les actuals societats dinàmiques industrials no es poden guiar sotmetent-se a creences, ni religioses, ni ideològiques, ni laiques, tal i com feren els nostres avantpassats. Avui els valors i patrons de comportament fixos i fixadors no serveixen en una societat que viu dels canvis i que, per tant, s'enfronta contínuament amb problemes nous. I comença a ser clar que la marxa actual de les tecnociències, no dirigida per elles mateixes, està posant en perill la vida sobre la Terra. D'aquí ve que parlem de crisi axiològica de les societats dinàmiques industrials contemporànies. Aquestes no haurien d'estar orientades principalment en benefici del capital, que comporta l'explotació de recursos i persones. Dit altrament, no podem deixar que aquest desenvolupament de les societats dinàmiques i les seves corresponents tecnociències estiguin controlades per un instint depredador individual o col·lectiu. Un instint clarament manifest avui en el neoliberalisme capitalista. De tot plegat en resulta la no sostenibilitat manifestada en una crisi ecològica greu i, sobretot, en una creixent injustícia social. Per això és tan necessari enfortir l'axiologia i, en el cas que aquí ens ocupa, crear equips de recerca de gran qualitat humana, tot acompanyant els projectes tecnocientífics amb elements axiològics que motivin els equips i orientin la recerca cap a bon port. Aquí hi tenen un paper clau els impulsors de la recerca, investigadors atents a la qualitat humana dels equips de recerca, als aspectes axiològics dels projectes de recerca. En el nostre cas, el Ramon ha exercit aquest rol vetant sempre qualsevol col·laboració de l'IIIA amb la recerca armamentística, malauradament tan grassa.

10.3 La qualitat humana dels equips de recerca

Ens cal ser molt conscients que la recerca es fa i es farà cada cop més en equips d'especialistes molt diversos, però cohesionats al voltant d'un problema atractiu a resoldre. L'objectiu és conjugar la màxima creativitat individual amb la màxima col·laboració vers un propòsit col·lectiu acceptat pel conjunt de l'equip. Conjuminar els propòsits com equip amb

els propòsits privats és clau. És a dir, els problemes i innovacions importants solament són abordables per equips, i ho seran encara més en el futur. Aquesta tendència ha estat comprovada empíricament. A (Wuchty et al., 2007) es basen en l'anàlisi de 19,9 milions de treballs científics escrits durant 50 anys per a concloure que, si segueix la mateixa tendència, vers el 2020 tota la innovació tecnocientífica es produirà en equips formats per especialistes diversos. La cohesió i motivació dels equips, les seves relacions internes i externes, són complexes i vitals, i no es poden deixar implícitament a mercè de les circumstàncies. S'ha escrit molt sobre l'esperit de la recerca individual, però no tant de la col·lectiva, del funcionament dels equips. Crec que tot institut de recerca hauria de tenir algú que pensés en aquests temes en benefici del seu bon funcionament, un ajut i complement a la direcció. Per a tot institut de recerca realment competitiu no n'hi ha prou amb pensar en publicar, la salut dels equips també s'ha de cuidar i cultivar; una qualitat que no es dóna espontàniament en l'actualitat, i menys encara en el futur. Caldria considerar la figura de l'impulsor i gestor de projectes amb contingut tècnic i axiològic com veurem més endavant. Sortosament, a l'IIIA el Ramon ha exercit amb èxit moltes d'aquestes funcions axiològiques que caldria generalitzar i potenciar en un futur.

Els postulats axiològics són l'eix dels equips i de llur eficàcia. El que fan és formular en nivells de generalitat les seves necessitats. Aquí solament podem donar-ne alguns de molt generals i a tall d'exemple. Els postulats i la seva concreció detallada en projectes han de ser acceptats lliurament sense imposicions de cap classe. Seguint el principi de contraposició propi de la formalitat axiològica, en proposar un postulat cal considerar la seva alternativa contraposada. És així com són implementats: hom adopta un postulat negant l'alternativa. Però per copsar la viabilitat dels postulats axiològics que presento, cal que consideri, encara que sigui breument, la qualitat humana que n'és la base.

10.3.1 La qualitat humana

La qualitat humana té el seu fonament en la nostra capacitat de distingir, gràcies al llenguatge, entre el significat que les coses tenen per a nosaltres i les coses en elles mateixes, independents de les nostres ne-

cessitats i expectatives sobre elles. És la capacitat de distanciar-se, de desenganxar-se (D) d'expectatives, desitjos, temors i prejudicis propis de la nostra condició necessitada. I això fins a silenciar (S) el jo i les seves interpretacions i valoracions. Solament a través del silenci podrem conèixer les coses; no per imposició dels meus patrons mentals, sinó en el silenci en què es troben, en la realitat de les coses.

Aquesta capacitat de distanciar-se fins a silenciar la necessitat no es dóna sense un interès (I) incondicional sempre renovat, per persones i coses sense exclusions ni discriminacions. Aquesta universalitat de l'interès no impedeix el discerniment sobre persones i coses, sinó tot al contrari. Les tres actituds (IDS) són de fet buides de contingut, no són un conjunt de normes o virtuts fixes; per tant són aptes per prendre la forma que calgui en cada nova situació, tal com cal en una societat en canvi continu. A més, s'impliquen mútuament, si nÕapareix una sorgeixen les altres dues i si no n'apareix una, no sorgeixen les altres dues. I això perquè les tres neixen d'aquesta qualitat humana de reconèixer la realitat independentment de les necessitats, desitjos i temors.

IDS és l'únic que pot sostenir la dinàmica pròpia del coneixement en una societat en canvi continu. IDS ens dóna la flexibilitat per modelar creativament la realitat. Afegim-hi que IDS no exclou la possibilitat d'un mal ús, ni tampoc un ús limitat que no condueix a la qualitat humana. De fet, IDS té dos vessants, un de pràctic per resoldre tot tipus de problemes i per crear noves possibilitats d'actuació de forma adequada i sàvia. Així, sovint IDS es practica implícitament dins una activitat creativa restringida, com pot ser la creació artística o científica. L'altre vessant d'IDS és la gratuïta, la que porta a reconèixer i viure la unitat de l'existència. Aquest és l'ensenyament de totes les grans tradicions de saviesa que l'actual societat ha de saber heretar per afrontar els difícils reptes que té al davant.

10.3.2 Tres postulats generals dels equips de recerca

De manera semblant a IDS per les persones, la desitjada qualitat humana de l'equip d'innovació es podria resumir en tres actituds que també s'impliquen mútuament: investigació, comunicació i servei mutu (ICS).

A continuació considero breument aquests tres tipus de postulats axiològics contraposant cadascun d'ells amb la seva alternativa. No sempre faig explícita l'alternativa, però implícitament procuro que quedi clara.

10.3.2.1 I- Investigació en equip i graus d'implicació en l'equip

La primera condició per a la formació d'un equip és identificar un problema inatacable individualment. Això, com he dit abans, és característic dels problemes importants actuals. L'enfocament dels problemes en equip, contràriament a l'enfocament individualista on cada investigador va a la seva, significa centrar tothom sobre el mateix problema, cada membre des de la seva perspectiva, competència i interessos; és compartir una finalitat en lloc de tenir diferents finalitats particulars. Tots els membres comparteixen un sentit d'urgència per resoldre el problema i no hi anteposen els problemes, interessos i urgències particulars. Resumint, als membres d'un equip de qualitat els preocupa resoldre el problema que comparteixen, tot bandejant l'afany de protagonisme, l'interès propi i les expectatives particulars.

10.3.2.2 C- Qualitat de la comunicació

Com més comunicació hi ha entre els membres d'un equip més creativitat investigadora es dóna en cada un d'ells i en l'equip. Si falla la comunicació fallarà la investigació. I a la inversa. La comunicació depèn de l'interès en un mateix tema de recerca. Cal, doncs, una consciència clara de la necessitat d'una comunicació no tan sols fluïda, sinó sense cap mena de reserva. Si hi ha reserves motivades per manca de confiancca mútua, si per interessos individuals no hi ha plena comunicació, es fa difícil avançar, sobretot pel caràcter polifacètic del problema a resoldre. En la comunicació cal superar l'afany de cultivar la pròpia imatge, el protagonisme, així com tot intent d'amagar els propis errors o no acceptar-los mostrant solament els èxits, ja que tot això dificulta la plena comunicació i fusió entre els membres de l'equip.

10.3.2.3 S- Servei mutu

En un equip de gran qualitat cal servir la finalitat de l'equip i, per tant, a cada membre, en lloc de servir-se de l'equip i dels altres membres per a les pròpies finalitats. Cal sentir-se també responsable del progrés de tots els membres de l'equip i per tant, servir-lo. Això evita la competitivitat dins l'equip i disminueix l'estrès de la recerca. El veritable servei és incondicional. Si servim solament en la mesura que ens serveixen, o preservant interessos particulars per sobre dels de l'equip, no donarem tota la nostra capacitat i compromís a l'equip. Contràriament, com més donem a l'equip, més en rebrem individualment. Cal comprendre que la realització com investigador es fa en equip i no individualment. Posar per davant les finalitats individuals a les de l'equip destrueix les darreres. Hi afegeixo, finalment, que aquests tres tipus de postulats axiològics s'impliquen i es necessiten mútuament.

A l'IIIA, gràcies a tots, però especialment a la direcció que tant contribuí a donar-li en Ramon des del comenccament, estem força ben servits en investigació, comunicació i servei mutu. Tenim força experiència d'equip interdisciplinari ben coordinat, aquest fou un dels primers grans èxits del Ramon. Ell mateix ha impulsat reunions col·lectives de discussió del futur i ha participat en moltes comissions de recerca. La regularitat dels seminaris, el doctoral consortium, l'activitat en transferència de tecnologia i un llarg etcètera. Sense oblidar les festes: als Graners del Montseny, al començament; a la masia d'en Carles Sierra, que encara duren, i les trobades a casa d'en Ramon, on la Joelle prepara unes creps delicioses. En definitiva, a l'institut es respira un encoratjador ambient d'ICS.

10.3.3 L'impulsor i gestor axiològic de l'equip

L'impulsor i gestor axiològic dins un equip és l'especialista en els aspectes axiològics de l'equip, tot coordinant-los amb els científics i els tècnics.

No es tracta del líder en sentit jeràrquic, ja que en un projecte format per una diversitat d'especialistes, cadascun d'ells és líder en la seva àrea. Per tant, l'estructura dels equips no pot ser jeràrquica sinó més aviat

una xarxa. A continuació, considero breument la tasca de l'impulsor en referència als tres postulats bàsics ICS. Evidentment, l'impulsor ha de tenir en bona mesura la qualitat humana IDS de què abans hem parlat. S'ha comprovat empíricament que la qualitat en l'impuls i la gestió de projectes és un factor clau per al seu èxit i que una figura com la de l'impulsor axiològic és la més difícil de cobrir (Freeman, 1974).

10.3.3.1 Investigació

L'impulsor fomenta l'interès, l'adhesió voluntària per la tasca a fer, motivant-la adequadament; fomenta la responsabilitat individual i col·lectiva, la cohesió de l'equip i la relació amb altres equips, l'entorn social i el medi natural. L'impulsor no decideix les tasques de l'equip, sinó que les proposa conjuntament amb els altres especialistes. Contribueix decisivament a conjuntar esforccos. Ell no mana, sinó que motiva, suggereix, cohesiona. Aquestes actituds contrasten amb la seva alternativa. Un líder d'equip que exigeix submissió a la tasca que ell proposa; i que recompensa o paga aquesta submissió. Aquest líder jeràrquic exigeix en lloc de fomentar. Deixa clar que ell mana i es fa responsable únic del projecte.

10.3.3.2 Comunicació

Per a fomentar la comunicació sense reserves, l'impulsor ha d'eliminar qualsevol tipus d'autoritarisme; organitzar l'equip per competències i complementarietats. Fomentar la confiança mútua per tal d'eliminar la competitivitat dins l'equip. L'alternativa seria l'organització de competències i de la comunicació de forma jeràrquica. El líder jeràrquic fomenta la competitivitat dins l'equip per tal de mantenir la subordinació i la productivitat a curt termini.

10.3.3.3 Servei mutu

L'impulsor fomenta el servei mutu dels membres de l'equip. Això implica fomentar la seva qualitat humana. També fomenta el sentit de servei als altres equips i a la societat a través de la qualitat dels resultats de la recerca. L'alternativa és el servei del subordinat al seu cap dins l'estruc-

tura autoritària piramidal. Amb això es sacrifica la qualitat dels resultats, car es mutila la creativitat.

Concloc, deixant constància que tot això que he exposat aquí és una teoria que s'està elaborant dins del grup de recerca del Centre d'Estudi de les Tradicions de Saviesa (CETR.net) dirigit per Marià Corbí (Corbí 2012), amb el qual col·laboro regularment. Tot i que li manca rodatge empíric, crec que és un punt de partencca seriós, sobretot per a millorar la qualitat dels equips de recerca. A més, estic convenccut que l'IIIA, amb en Ramon al capdavant, s'ha mogut gairebé sempre *avant la lettre* en aquesta direcció. És per això que confio que acollirà amb simpatia aquest primer intent d'explicitar la qualitat en els equips de recerca.

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Part II
Personal Contributions

Chapter 11
My Appreciation of Ramon
A personal note

Wolfgang Bibel

My first encounters with Professor Ramon López de Màntaras were virtual ones and took place around 1983. My group was a subcontractor in one of the first ESPRIT projects[1] funded by the Commission of the European Union (then EC). I was happy to get Christian Freksa (now a Professor at the University of Bremen) join our group as a researcher in the project.

Christian had received his PhD from the University of California at Berkeley (on the cognitive topic of eye movements) and was heavily influenced there by Professor Lotfi Zadeh and his fuzzy logic. He had made the acquaintance of Ramon who got his Masters in Computer Science there as well. Already in 1981 the two had published a paper together.[2] Ever since the two have shared a passion for studying and representing imprecise, incomplete, qualitative, fuzzy, conflicting knowledge.

My own background is in classical logic, a field which grew out from mathematical reasoning and thus focused on precise and complete knowledge to begin with. You can imagine that this discrepancy in background led to numerous engaged and fruitful discussions between Chris-

Wolfgang Bibel
Darmstadt University of Technology, e-mail: bibel@gmx.net

[1] 'A logic oriented approach to knowledge and data bases supporting natural user interaction' (LOKI)

[2] R. López de Màntaras, C. Freksa, J. Aguilar-Martín. Algorisme d'adaptació recursiva de funcions de possibilitat per a l'aprenentatge de la significació de conceptes imprecisos. Convención de Informática Latina, pages 250–257, Barcelona 1981

tian and myself. In these discussions often the name Ramon (with the stress on the second syllable) was mentioned by Christian, quasi as a witness supporting his opinions. I liked this name for his harmonic sound and therefore, due to the well-known halo effect in psychology, I started associating a sympathy with the person behind the name without ever having seen him.

The mid-eighties were an extremely hectic time for anyone working in Artificial Intelligence (AI), and for me in particular, for various reasons. As president of ECCAI, the European organisation for AI, and later as president of IJCAII, the international AI organisation, I met so many people in these years that my memory failed to store every encounter correctly. Therefore it is perhaps understandable that I do not recall place and time of my first real encounter with Ramon. Perhaps he does? It must have been during these years after 1983 and before 1987. The upper limit can be inferred from the fact that Ramon invited me to give an invited talk on "Advances in Automated Deduction" on 11 June 1987 at the Workshop on Artificial Intelligence which took place in Blanes.

My recollection of this event is that I envied Ramon for the research environment which was provided to his institute by the CSIC (the Spanish National Research Council). He told me that the person in charge of the foundation of the institute held a conviction that researchers in an area like our's profit from an environment like a monastery. I loved the place and did not really understand the rationale when I later learned that the institute had moved into Barcelona. The other recollection of this visit is the observation of the Catalonian pride and sense of independence within the state of Spain.

As I indicated the focus of Ramon's research differs from mine. Also, academically he represents a generation after mine. This is why we never published anything together nor did we ever collaborate in a joint project. But otherwise we share many preferences and roles.

To begin with, we both love music and are practicing amateurs for musical instruments. Ramon plays the piano, me the violin. He prefers jazz, me classical music, which in a psychological analysis might turn out as reflecting the fuzzy vs. the classical logic background.

More to the point, both of us have devoted our entire career to promote the scientific field of Artificial Intelligence which has revolutionized our thinking in the past half century, perhaps more so than any other field before. Ramon shares the conviction that AI has still a great potential to make fundamental contributions to the beneficial development of

future societies and their understanding of each other. This conviction has driven him to take on the burden of numerous positions from which he could exert great influence and responsibility, whereby many of these remind me of my own career.

Professor López de Màntaras was founding member and former Vicepresident (1987-1993) of AEPIA (the Spanish AI Association) which immediately after its foundation became a member of ECCAI. In fact he was one of the first researchers in AI holding offices in Spain, a country which entered rather late into this field. Like me he became an Associate Editor of the leading journal in our field, the Artificial Intelligence Journal. He served as president of IJCAII exactly 20 years after my service in this position. He has served in the TC12 of IFIP as I did two decades ago.

The most important contributions of Ramon are of course his outstanding scientific results in knowledge representation with the mentioned bias on fuzzyness and uncertainty, in case-based reasoning, machine learning, music and many others. His contributions have had a great impact on our field, as can be seen from the high citation indices of some of his papers. His scientific competence and energy also impressed his many students and colleagues so that he enjoys a high standing at his home institution IIIA-CSIC in Barcelona, at the national CSIC, within the European as well as the international AI community, and beyond. This high standing was made especially visible by the honor of becoming the recipient of the prestigeous 2011 AAAI Robert S. Engelmore Award.

While I forgot when exactly we first met, I vividly recall when we last met, namely in Lisbon during ECAI 2010, not to mention the many encounters between these two time points. And I much hope that there will be many of these always agreeable and pleasant encounters with Ramon in the future.

On the occasion of your 60th birthday I wish you, Ramon, all the best for the years to come. For a mature scientist like you these are rich years which can be made to bear fruit for the benefit of society. In this sense we trust on your ongoing engagement and energy.

Capítol 12
Intel·ligència, Art-i-sidral

Carme Torras

Carme Torras
IRI-CSIC, e-mail: torras@iri.upc.edu

Intel·ligència, Art-i-sidral

Intel·ligència
en la recerca, la formació d'investigadors,
la gestió, les relacions institucionals...
Més Intel·ligència (emocional) en les relacions personals,
la generositat professional, el compromís social...

Art
al piano,
en la poesia,
el patinatge...
també pintes?

sidral
(o era sideral?) companyia en reunions plumbíferes,
divertit i simpàtic de mena, conversador àgil,
i amb el somriure sempre a punt.

Si n'hem viscut d'aventures i
experiències compartides
des d'aquell 1984 de Buitrago,
l'Escola d'Enginyers, i
l'"A ciencia cierta"!

Tot i que tri-partit **(I-A-s)**,
ets un bon partit, Ramon.
Per molts anys!


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Capítol 13
Nota Personal

Gonzalo Escalada-Imaz

Benvolgut Ramon,

M'han dit que puc escriure algunes frases que descriguin la repercussió que has tingut sobre mi, tant en el plan personal com en el professional, i que aquestes frases seran incloses en un llibre que et regalarem el dia del teu 60è aniversari.

La veritat, no sóc capaç de redactar tal text, per que necessitaria fer una llista que, sense pretendre ser exhaustiva, em portaria pàgines i pàgines. Així que, no em queda més remei que fer un esforç titànic de sintetització per poder escriure quelcom, que en el millor dels casos, només s'aproparà una miqueta a l'objectiu.

La veritat, què puc dir-te? He après a escriure articles tècnics, però això és molt més senzill comparat amb el que estic tractant de fer ara, és a dir, tractant de plasmar en poques paraules (per què poques? bé, a aquestes alçades, ja deus haver comprovat que sóc parc, no?) totes les repercussions que has tingut sobre mi, tant en el plan professional com personal.

Des del punt de vista professional, has estat la persona més influent, sense cap mena de dubte, perquè gracies a tu, tinc una vida professional

Gonzalo Escalada-Imaz
IIIA-CSIC, e-mail: gonzalo@iiia.csic.es

molt més que digna. Des del punt de vista personal, he après moltes coses de tu i m'has recolzat en els moments més durs, de l'esdevenir de la meva vida. Si haguès tingut fills, els hauria parlar de tu, i també als fills dels meus fills. En aquesta reencarnació, això no podrà ser. No obstant, a les persones que m'envolten i que m'envoltin en el futur, sí els he parlat, els parlo i els parlaré de tu. Per exemple, la meva família d'Euskadi et coneix.

Rebobinant, intentant recordar moments molt llunyants en el temps, crec que l'origen de la teva influència positiva en mi, és a dir, el moment que et vas creuar en la meva vida, fet que ho considero com una mena de regal diví, hauria de tornar al curs acadèmic 1980/81.

Eren els temps en el que jo era estudiant i tu professor de la escola de Mondragón. Vas ser el millor professor que teníem, aquesta percepció era compartida per tots els meus companys estudiants. Amb tu, van adonar-se que era possible aprendre i al mateix temps, aconseguir bones notes.

És molt llarga la llista d'ajudes que he rebut de la teva part, des d'aquell curs acadèmic a Mondragón. No he oblidat cap detall. Mai et podré retornar la teva ajuda, només m'he de contentar dient-te que t'estic molt, molt agraït.

Només voldria acabar dient-te que, em sento com un immens afortunat a l'haver pogut venir a Blanes i sobretot, tenir ara un despatx a l'IIIA. Això és un altre regal diví. El nostre institut no està repetit en el món, enlloc no han aconseguit reunir tan alta competència/professionalitat amb ètica. Això passa aquí, a l'IIIA, i en gran mesura, és degut a tu.

Actualment tinc dues llengües amb les que em sento identificat. Tu m'has ensenyat un munt de paraules d'una d'elles, ara permet-me que utilitzi l'altra llengua per acomiadar-me de tu en aquesta carta, i al mateix temps, que t'ensenyi un parell de paraules d'ella.

Nik zure laguna naiz, beti, betikoa. Bitzes mila ezker. Iñoiz es zaitut astuko. Betirako.

En d'altres paraules: Ramon, moltes gràcies de tot cor.

Capítol 14
Ramon: una visió des de més enllà dels 60

Francesc Esteva

14.1 A tall d'introducció

El vaig conèixer amb barba tipus "Guadiana" (tan aviat la veus, com desapareix) i cabells llargs, dues coses que s'han anat emblanqueint i reduint. La barba perquè ara que sembla més permanent se la retalla curteta i ja hi abunda més el blanc que el negre, el cabell s'ha tornat blanc i més escàs per raons òbvies que no entraré a detallar. Quan el vaig conèixer acabava d'arribar de Mondragon (després de les seves estades a Toulouse i a Berkeley) i va venir per treballar a la UPC de la mà de l'Enric Trillas, però on l'he conegut de veritat és a Blanes al CEAB i després a l'IIIA. Essent President l'Enric, es va crear el CEAB (Centre d'Estudis Avançats de Blanes) i allà va anar en Ramon amb en Jaume Agustí que, amb l'ajut d'en Josep Aguilar i en Settimo Termini (deixats temporalment pel CNRS i el CNRI), tenien la tasca de crear un grup d'IA acompanyats d'uns quants jovenets com l'Enric Plaza o en Carles Sierra i algú més senior com jo mateix que vàrem dir que col·laboraríem amb el projecte a distància perquè el nostre lloc de treball el teníem en una altra institució. El dinamisme i la intel·ligència d'en Ramon varen ser un factor essencial perquè la idea fructifiqués. Va ser poc després de la seva creació quan, per un atzar i una proposta d'en Jaume Agustí en un congrés català de lògica (què tindrà a veure el català amb la lògica?)

Francesc Esteva
IIIA-CSIC, e-mail: esteva@iiia.csic.es

al Museu de la Ciència, que jo vaig acabar a la direcció del CEAB. I mai me n'he penedit, al contrari, acceptar la direcció del CEAB ha sigut una de les decisions més encertades de la meva vida. Tot i les excursions que cada dia fèiem des de Barcelona per anar al centre, la vida científica creixia, teníem visitants, seminaris molt seguits i un ambient de treball envejable i el nom del grup d'IA del CEAB sonava cada cop amb més força fins aconseguir que el CSIC, l'any 92, decidís posar en marxa un nou institut dedicat només a la IA. L'hi posárem el nom d'Institut d'Investigació en Intel·ligència Artificial, IIIA, nom que tenia una relació de simetria amb el de l'associació americana d'IA, la AAAI. El nou Institut va funcionar primer com a rellogat a l'edifici del CEAB i després en un edifici propi al campus de la UAB on som ara. I, si el CEAB va ser l'inici d'un camí en el què en Ramon ha ocupat un paper essencial, la creació de l'IIIA el va portar a fer més visible el seu paper de líder del grup i, de forma natural, va ser el subdirector durant la meva època de director i des del 2007 n'és el director sense que ningú discuteixi el lideratge que exerceix de forma natural, sempre disposat a trobar i proposar sol·lucions i idees engrescadores però també a recollir i donar suport a les dels altres. I durant tots aquests anys s'ha anat forjant una llarga amistat confegida en dinars on es sol·lucionen tots els problemes del món, en xefles a la masia d'en Carles on menjant alimentem els nostres cossos i gaudim de les amistats però també en iniciatives, reunions i discussions científiques que ens han enriquit a tots.

14.2 Amic i company

Per poder parlar d'un amic un ha de ser capaç d'allunyar-se i veure les coses en perspectiva, ha de ser capaç de fer una recerca que el situï en el seu lloc i això no és fàcil però ho intentaré. Haig de dir d'entrada que en Ramon és una personalitat polièdrica (queda bé la parauleta i a sobre està de moda però si he entés bé el seu significat s'escau d'allò més amb la persona), interessada per múltiples coses, des de la música i el ball passant pel cinema, l'art, la política o els bons vins fins, és clar, per la ciència en general i la IA en particular. És a dir, és tafaner de mena (en el bon sentit de la paraula que vol dir no quedar-se en la superfície de les coses i anar al fons a buscar les causes reals dels problemes), una condició necessària però no suficient per ser un bon científic. I dit això

deixeu-me desgranar algunes de les seves qualitats i algun defecte que, com no, també en té.

És un excel·lent investigador que té un coneixement ampli dels temes i que té la capacitat per investigar des d'una vessant que valoro especialment, que m'agrada molt. Agafa un tema, sigui teòric o aplicat, i estudia la seva sol·lució amb una mirada àmplia, té la capacitat i la força d'estudiar com resoldre el tema sense constrenyir-se a cap tècnica sigui ja coneguda per ell o nova de trinca. Aplica les tècniques que coneix o en busca de noves i utilitza la que li sembla més adient pel problema que té entre mans i això l'ha portat a ser pioner en Fuzzy, en arbres de decissió, en sistemes experts o en CBR i aprenentatge i dissenyar aplicacions a temes tan allunyats com poden ser la medicina, la música o la robòtica. Per mi el seu CV, on es barregen la teoria i les aplicacions, demostra el seu ampli coneixement i és un model per investigadors que vulguin tenir presència real al món de la recerca. I més si es vol fer recerca en una disciplina com la IA que té una certa transversalitat, on s'ha de fer recerca sobre maneres d'afrontar problemes que tenen aplicació a un ampli ventall de temes. I amb aquestes condicions, no és estrany que en Ramon tingui molts deixebles, que hagi format en la recerca molts investigadors (recordeu la famosa foto de familia, de la geneologia d'investigadors per la relació "haver dirigit la tesi a" feta a l'escala de l'institut on la jerarquia venia representada pel graó on se situava cadascú?).

És, sens dubte, un gran treballador i un gran lector. Està al corrent de moltes coses, les llegeix amb avidesa, les assimila i les sap arxivar al lloc adequat. Sempre recordo que un dia que li preguntaren al malaurat Ernest Lluch si era una cosa innata això de llegir i treballar molt va respondre sense pensar-s'ho, "no, no, això és una cosa que es cultiva i sols s'adquireix amb disciplina i molt d'esforç". En el nostre cas tots sabem que en Ramon és un esforçat treballador, que no és estrany veure'l treballant al despatx fins tard, arribant de casa amb feina feta, o enviant mails en hores . . . intempestives. I tots sabem que quan es tracta de saber quins són els darrers avenços en IA, en Ramon és una font fiable en la majoria dels casos. I això, com deia en Lluch, no és una cosa innata. En Ramon hi ha dedicat molt temps i esforços per aconseguir-ho i tots els que hem gaudit de la seva amistad o hem col·laborat amb ell ens hem aprofitat d'aquest esforç i dels seus coneixements i idees. I més que ningú els seus estudiants . . .

En Ramon és un líder natural, li surt de dins. Ningú a l'IIIA li discuteix el seu lideratge i no perquè tingui cap mà "oculta" (secretari d'orga-

nització, policia secreta o similar) que faci callar els possibles opositors, sinó, perquè tothom reconeix en ell la persona que aporta idees, que escolta les dels demés, que té capacitat per lluitar pel que es necessita, per defensar el treball dels investigadors de l'IIIA on calgui. Però també per no defensar lo no raonable o indefensable cosa que també s'agraeix i, almenys a mi, m'agrada que un director ho tingui clar i ho faci així, sense estridències però amb fermesa. És clar que ell i jo mateix ho hem tingut, i encara ho té, fàcil en aquest aspecte perquè la majoria dels investigadors de l'IIIA són raonables i fan propostes sempre positives i defensables. Mireu sinó alguns exemples com la UDT o les spin-off que han sortit d'idees del personal de l'IIIA que la direcció sols ha hagut de recolzar. Una altra cosa és la tasca de relació amb el CSIC i l'administració, aquí sí que cal lluitar i de valent!!! No és estrany que alguns parlem de la burrocràcia, amb honroses excepcions que, si bé encomiables, no deixen de ser excepcions. I aquí ve a to una anècdota de quan encara érem un grup molt petit al CEAB. En Ramon es va prendre seriosament lo de "tirar del carro" per crear un grup conegut d'IA i va acceptar estar en moltes comissions a la UE, a l'ECAI, al board de AI communications (la revista de l'ECAI), etc. Viatjava continuament de forma que un cop vàrem decidir posar-li a la porta un dibuix d'un avió i un cartell que deia més o menys "hem fet el que hem pogut perquè no et trobis estrany al despatx, volíem decorar-lo de cabina d'avió però no ho hem aconseguit". La veritat és que aquells viatges i activitats que va frenar quan un metge li va dir que ho havia de fer si no volia tenir problemes, ens varen anar molt bé a tots plegats.

És un bon venedor. Deixeu-me que arribat aquest punt us expliqui una altra anècdota. Un dia parlant d'aquesta vessant de marketing d'en Ramon, l'Enric Trillas quan jo encara era director de l'IIIA, em deia: "Francesc tu segueix de director, en Ramon ven molt bé el vostre treball però tu garanteixes que en Ramon no es vengui un dia l'Institut i això també és important". La frase té la seva gràcia però la realitat és que en Ramon és director des del 2007 i, per ara, encara no s'ha venut l'IIIA. És clar que estem en període de crisi i això dificulta la cosa ... S'ha de reconèixer que és cert que en Ramon ven i ven bé i ho pot fer sense través, perquè no dir-ho? Perquè l'IIIA, sense passar-se, és un bon producte ... I aquí no cal dir que un xic de raó tenia l'Enric Trillas quan insinuava que en Ramon de vegades va passat de voltes ... i si no recordeu els somriures d'alguns i com varem haver de matitzar algunes frases del primer plà estratègic, per citar el cas que més recordo ... Entre ell i en Carles

a vegades podrien cantar allò de "som els millors" (recordeu l'obra de l'Espriu?). Per posar sols un exemple, l'altre dia un va dir que havia vist que un article en el que havien col·laborat gent de l'Institut era el més citat entre els publicats durant un període d'anys en una bona revista i va trigar uns 3 segons a apareixer la notícia a la pàgina de presentació de la web de l'IIIA ...

En Ramon és, a més a més, una gran persona, un amic dels amics en qui sempre es pot confiar. Avui us vull explicar una cosa que crec exemplifica més que moltes paraules, el que vull dir. Fa poc, com sabeu, el meu fill Marc va decidir abandonar-nos. Podeu suposar l'impacte que això va tenir en mi i en bona part dels membres de l'IIIA. Al cap de poc de saber-se la notícia vaig rebre una trucada d'en Ramon que estava fora. Crec que no sóc indiscret si us explico el que em va dir i espero que en Ramon no se senti malament per fer-ho però és que representa tan bé el que vull expressar. Resumint va dir, "Francesc jo us he vist amb els fills molts cops des de petits, he vist com els tractàveu i no puc dir res que no sigui coses bones del vostre comportament. Mai, mai, t'has de sentir responsable de res". Va trigar uns minuts a trucar-me després de saber la notícia però el primer que el va preocupar va ser no afegir problemes, que el seu amic sentís que els amics estaven aprop, que mai tindrien el més petit retret ... Vull dir que va ser, sens dubte, una de les converses que més em va frapar i, de veritat, em va fer molt de bé tot i que no he tingut mai la temptació de sentir-me responsable dels actes del meu fill passada certa edat i menys de la seva darrera decisió.

També voldria dir que és un vitaliste, sempre inquiet i, com ja he dit, interessat per tot. El podeu trobar tocant el teclat en el concert de Nadal de l'IIIA o en qualsevol congrés o lloc on hi hagi un teclat interessant (recordo les seves visites a una botiga de música a San Francisco perquè la noia de la botiga li deixava tocar un teclat que deia que era molt bo i que consti que, en aquest cas, no era un problema de públic -que no n'hi havia més que jo ocasionalment- sinó de gaudir de la música) o a qualsevol concert de jazz i d'aquí al sistema **SaxEx** que és capaç d'imitar uns concertistes i donar expressivitat a una balada de jazz inexpressiva, sols hi ha el pas d'usar el CBR, el fuzzy, tenir una base de balades de jazz interpretades per diferents concertistes i un cap clar capaç de barrejar-ho tot amb sentit i treure'n conclusions. O, per continuar amb la música, el podeu trobar ballant qualsevol ritme especialment si té salsa. O potser us agrada la poesia i podeu trobar les seves poesies en alguna revista o sentir-lo parlar de la poesia que llegeix. O potser sou amants de l'art i

podeu parlar amb ell de temes d'art (no conec que s'hagi dedicat especialment a la vessant artística com autor però com podria, sense tenir una sensibilitat important pel tema, donar una xerrada a ARCO, la fira d'art de Madrid?). Fins i tot, no sé si és molt positiu, li agraden els esports de risc i patina que patinaràs (va formar part d'un equip que va competir en unes 24 hores de patins per afeccionats) es recórre el passeig de Calafell i rodalies amb un equip multiedat de lo més divertit. Però si pels patins és capaç d'aixecar-se aviat no li demaneu que vagi aviat a la Masia quan hi ha xefla perquè prefereix arribar quan el menjar ja està fet (que en això de la cuina prefereix que treballi un altre) això sí portant el vi i el cava perquè no falti el bon beure.

I, per acabar aquest apartat deixeu-me citar el que menys m'agrada d'en Ramon. I això és quan s'embala, quan una cosa el posa a cent i aleshores costa raonar amb ell. S'ha d'esperar que li passi i aleshores tot torna a la normalitat. El problema és si durant el temps de l'embalament passa algú per allà, sobretot si té a veure amb el tema motiu de l'embala-ment. Aleshores es pot emportar un ruixat important, sense dret a rèplica, almenys fins que acaba la diatriba. De vegades això ha estat útil, de vegades ens ha tocat a altres fer el que cal per refer uns lligams que en un moment s'han trencat i potser convé tenir-los. Però que mai s'oblidi que en la majoria dels casos, almenys des de la meva perspectiva, en Ramon s'embala i s'empipa per coses que a mi casi sempre em semblen raonables. Potser en aquests moments perd les formes però, en el fons, casi sempre que ha passat en la meva presència he compartit el fons. I com jo també de vegades m'embalo (en fer-me gran i veure les coses més tranquil·lament, aquests tipus de reaccions disminueixen) potser l'entenc i el disculpo. O potser simplement sóc amic i, com a tal, disculpes moltes coses, l'acceptes com és. De totes maneres tractant-se d'en Ramon si poso en una balança les coses positives i negatives, no ting cap dubte de que les positives guanyen per molt.

14.3 Una aportació científica: el cas del MILORD

En aquest apartat voldria parlar d'una aportació d'en Ramon que va mobilitzar tot l'IIIA (en els moments inicials) i que va impulsar la recerca. Podria triar altres casos però n'he triat un que m'agrada i en el que vaig col·laborar. Quan va començar l'aventura de Blanes en Ramon va im-

pulsar l'ús de la teoria dels fuzzy sets als sistemes experts. D'això en sortiren les tesis d'en Carles Sierra, l'Albert Verdaguer, parcialment la d'en Lluís Godo la qual cosa va donar lloc al shell de sistemes experts anomenat MILORD. Aquest shell va ser la base de partida d'una sèrie de tesis com la d'en M.A. Belmonte sobre reumatologia, la de na M. Domingo sobre classificació d'esponges, etc. Durant un temps una bona part de la recerca que es va fer a l'IIIA va girar entorn d'aquests sistemes sigui per definir-ne el llenguatge, sigui per modoluritzar-lo, sigui per millorar la seva heurística, sigui per fer aplicacions bàsicament a la medicina (sistemes d'ajut al diagnòstic o de suport a la decisió) o per afegir-hi aprenentatge que millorés la seva eficiència. El sistema consistia en una base de regles fuzzy, un motor d'inferència i un sistema de meta-regles que conduïa la cerca. Els valors de veritat associats a les regles eren un sistema finit d'etiquetes lingüístiques modelitzades per unes funcions (fuzzy sets) valorades a [0,1] que suposaven una "partició" de l'interval unitat. La composició d'aquestes etiquetes es feia de forma funcional però d'una forma bastant complicada. S'operaven els fuzzy sets per medi d'una t-norma i després s'aproximava el fuzzy set resultant pel de la família que més se li acostava. Més tard es va observar (crec que va ser en Lluís Godo) que, de fet, aquestes etiquetes lingüístiques es podien substituir per noms qualsevols i que operar-les entre elles d'acord amb el procés abans esmentat donava una taula de veritat u operació en un conjunt finit. Així, de fet, el sistema expert es convertí en un sistema que tenia un motor d'inferència multi-valuat. D'aquí es va pasar a modularitzar el sistema i definir per cada mòdul o conjunt de regles que deduïen un mateix resultat (sigui el diagnòstic final o algun esgraó intermig) una lògica multivaluada diferent depenent de les etiquetes lingüístiques que el metge o expert que estudiava el problema feia servir. Així un especialiste que ens havia de donar el resultat d'unes proves (per exemple unes plaques de raig X per un malalt de pulmó) potser només feia servir tres etiquetes com "està molt infectat", "està poc infectat" i "no té infecció" mentre que un que parlés del diagnòstic final podia fer servir un número més gran d'etiquetes per dir, per exemple, si era segur, molt, poc o gens possible (4 etiquetes en aquest exemple) que fos infecció per un virus o un altre o una altra causa. El tema va continuar i molts hi vàrem treballar, en Jaume Agustí va ser l'ànima per fer el sistema modular, en Lluís en Pere i jo mateix vàrem veure quines condicions s'havien de donar perquè el traspàs d'informació entre mòduls (que podien tenir lògiques multivaluades amb diferent nombre de valors

i diferents operacions per modelitzar les operacions lògiques) preservessin certa forma d'inferència. Finalment en Josep Puyol va fer un estudi pormenoritzat del llenguatge del shell ja enriquit i que ja tenia el nom de MILORD II i va ser qui el va mantindre i va ajudar a fer moltes de les darreres aplicacions. L'explicació potser no és massa "científica" (l'espai i el lloc potser no és l'adequat a una explicació massa tècnica que es pot trobar en els articles) però si que fa veure com en Ramon va produir una idea que va ser motor de bona part de la recerca que es va fer al grup d'IA del CEAB i que encara va continuar donant temes de recerca quan ja erem a la UAB, al nou edifici de l'IIIA. Una idea científica brillant i una capacitat per desenvolupar-la i usar-la per fer al voltant seu un estudi de diferents aspectes que donaren lloc a recerques interessants.

Agraïments.- Arribat a aquest punt l'article s'acaba i quina millor forma que essent agraïts. Gràcies Laura Curto, la meva veïna i amiga, per la curosa correcció del català. Gràcies Ramon per ser com ets. Esperem poder gaudir molts més anys de la teva amistat, de la teva intel.ligència y de la teva vitalitat. Que la nova dècada et porti molts èxits i sobretot la felicitat que et mereixes.

Figura 14.1: FuZZ-IEEE de Barcelona

Figura 14.2: St Francisco

Capítol 15
Per molts anys company de viatge !

Josep Amat

Per molts anys company de viatge!

Anem al mateix tren des de ja fa molts anys. Jo hi vaig pujar unes estacions abans, i et vaig veure per primera vegada en un dels compartiments reservats per la FIB. Poc després vaig veure com canviaves de compartiment per anar-te'n a un altre de més ample: el reservat a l'IIIA. Però de fet, crec que sempre hem anat en el mateix vagó, encara que en compartiments diferents.

En aquest vagó es passen molt bones estones, d'altres de només bones i també de no tan bones. Una bona estona que recordo haver compartit amb tu, varen ser les sessions organitzades per un entranyable club que es va formar, constituït per gent d'altres compartiments i d'altres vagons, l'anomenda Associació per la Tecnologia, Informació i Comunicacions (ATIC). L'ATIC organitzava, ara ja fa més de 25 anys, unes notables sessions monogràfiques sobre aquestes temàtiques. Aquestes sessions recordo que acabaven en uns col·loquis que tenien per títol Les TIC: Per bé o per mal? Uns col·loquis que donaven molt de sí i sempre eren seguits per uns llargs sopars. En aquests sopars, en que els temps ja no eren controlats per cap moderador, els debats resultaven més lliures i aquí tu n'eres sempre un dels principals animadors.

Josep Amat
UPC, e-mail: josep.amat@upc.edu

Figura 15.1: Com a atent observador de l'evolució i del progrès, sempre busques la millor finestra per no perdre't cap detall de l'entorn.

Altres sessions en que sempre has estat fixe i jo sols un convidat més ocasional, són les Jornades sobre Intel·ligència Artificial que m'han permès compartir també de tant en tant compartiment en aquest tren que mai para, i poder comptar amb el teu suport. En el projecte que vaig engegar, el dels robots mòbils cooperatius, les formigues, que va ser possible amb la teva col·laboració. Va ser un bon exemple de saber aprofitar dos dels teus múltiples aspectes, ho recordaré: quan vàrem obtenir uns prou bons resultats (un dels aspectes). Ho vàrem portar al Forth International Symposium on Experimental Robotics, (lISER'95) a Stanford. Era el juny del 1995. Jo volia poder portar aquest congrés algun dia a Barcelona, per això abans de sortir vàrem preparar una presentació de la candidatura. La presentació, que evidentment vas fer tu, va ser en el sopar de congrés a un restaurant de Sausalito, al costat del pont de Sant Francisco. Aquesta presentació va ser tan brillant (un segon aspecte), que no hi va haver color, l'ISER'97 va ser a Barcelona!

Que per molts més anys doncs puguis seguir desenvolupant aquestes múltiples facetes que ajuden a que aquest tren del progrés científic i tecnològic, pugui anar avançant cada cop més ràpidament. I esperem que entre tots sapiguem fer-lo anar cap a uns paratges millors.

Figura 15.2: Després d'atenta observació i anàlisi, tots pendents a les teves reflexions i opinió

Chapter 16
Memories of Ramon

Maarten Grachten

My connection to Bellaterra

The snowy landscapes of Austria are passing before my eyes as I organize my memories of Ramon. I am on my weekly train commute between Vienna, where I live, and Linz, where I work as a post doctoral researcher at the Johannes Kepler University, in the department of computational perception, headed by Gerhard Widmer. My work there is on the analysis and modeling of music by means of machine learning, and that topic forms a direct link to Ramon.

My first acquaintance with Ramon was in the year 2000, after my Master's thesis supervisor Rineke Verbrugge in the Netherlands had told me about her research visit to the *Institut d'Investigació en Intel·ligencia Artificial* (IIIA), in Bellaterra. Although the purpose of her visit was to discuss matters related to agent systems with Carles Sierra, she told me there were other interesting things going on further down the white corridors of the institute — the enchanting saxophone melodies of SaxEx had caught her ear. That research, dedicated to designing a computer system to play music expressively, was exactly the mix of music and artificial intelligence that I was looking for.

Maarten Grachten
Johannes Kepler Universität Linz, e-mail: maarten.grachten@jku.at

Pastís de poma

In the e-mail correspondence that followed, after clarifying that unfortunately there was no funding for an internship from their side,[1] Ramon insisted that I was very welcome to visit the IIIA to work with him and Josep Lluís Arcos, in order to realize my Master's project. Excited with this opportunity to visit Barcelona and work in a research institute, I was at the same time slightly uneasy. I had never spoken a word of Spanish, nor any other Roman language, apart from some basic French. However, Rineke argued that the language would definitely not be a problem, since Català, due to its similarity to French, was very easy to learn. As a proof of this statement (and to whet my appetite, I suppose), she pointed out that the Catalan expression *pastís de poma* is very similar to the French *pastis aux pommes*.

You only have one chance to make a first impression

My first impression of Ramon, before meeting him, was by a visit to his web page.[2] That page was then as it still is today, free from any type of layout, to avoid distraction from content. On Ramon's home page the important things in life go first: hobbies! Besides his published poetry, there is plenty of footage of Ramon during long-distance (and high-speed!) rollerskating. After the hobbies section, there is politics and opinion. As any good citizen, Ramon takes his responsibility to speak out against the evils of this world: AI for military purposes, and religion. With the important things out of the way, at last there is a long and impressive list of academic achievements and publications on Ramon's home page.

[1] I guess we were all told this once, before we have to tell the same to others many times...

[2] `http://www.iiia.csic.es/~mantaras/`

Feet on the desk

Needless to say, this first impression was utterly sympathetic, and that impression was confirmed when I met him in person — short in stature, but highly energetic, with twinkling eyes. During my stay at the IIIA in the months that followed, I got to know Ramon's great enthusiasm for anything that has to do with music. As a piano player, Ramon always had interesting ideas and suggestions on how to model musical improvisation.

After finishing up my Master's degree in the Netherlands, I joined the IIIA a second time — this time *with* funding, thanks to the efforts of both Josep Lluís and Ramon. Under their supervision, I enrolled as a PhD student in a research project on musical expression. As I spent more time at the IIIA, I discovered that Ramon's enthusiasm is not limited to music, but that it is a fundamental part of his personality. Whether it is about an algorithm for computing melodic similarity, or about a *gran reserva* during some *pica-pica*, Ramon will tell you about it with a contagious excitement.

I remember that at the professional level, his interest in things took the shape of piles of papers on his desk. These papers were not just decoration — visiting Ramon in his office, I commonly encountered him reading some article or other, feet on the desk, glasses parked on the forehead, and his nose close to the paper.

As a student you might fear that Ramon, being the director of the institute, is too busy with other things to give you occasional feedback, or any useful advice about your research. But that is not the case! If you send Ramon some text and you ask him for his thoughts about it, he is surprisingly fast, and his feedback usually invites you to rethink your ideas in a constructive way.

Collonut

For a foreign student, the IIIA is not only a great place to learn more about artificial intelligence, it is also a perfect place to learn Catalan. During the first years of my stay, my Spanish and Catalan were so rudimentary that I was forced to speak English, and I was happy to find

everybody willing to speak English to me. But the weekly seminars, and Enric Plaza's course on artificial intelligence were great opportunities to pick up Catalan.

In addition to that, the corridors of the IIIA provide occasional opportunities to learn new Catalan words. In a conversational context that I don't recall, I remember Ramon giving voice to his characteristic enthusiasm: *¡ Collonut !*

Ramon, it is due to these learning opportunities that now I can tell you (*en la teva llengua*): *¡ Ets un tiu collonut !*

Capítol 17
Implicancias*

Jesús Cerquides

> "Debe entenderse que todos somos educadores. Cada acto de nuestra vida cotidiana tiene implicancias, a veces significativas. Procuremos entonces enseñar con el ejemplo."
>
> René Gerónimo Favaloro

La meva relació amb en Ramon comença quan amb vint-i-dos anys, vaig rebre una beca d'introducció a la investigació, les conegudes com a beques de la bicicleta. Era l'any 1995 i l'edifici de l'IIIA estava molt nou i lluent, això que tot just arribar jo estava molt impressionat i mentre pujava escales amunt no deixava de mirar de cua d'ull darrera les portes no fos cas que trobés algun Terminator o algun ordinador jugant al tic-tac-toe contra ell mateix. Quan vaig arribar al despatx d'en Ramon vaig veure que a la porta tenia una foto amb la Margaret Thatcher. "Comencem malament. Com a mínim té també el póster del Jazz" vaig pensar. I en girar la porta vaig veure'l llegint amb els peus recolzats sobre la taula. Això em va trencar una mica els esquemes perquè el poc que m'havia mogut professionalment ho havia fet en entorns molt més formals. Després me n'adonaria que ho feia sovint i finalment ho acabaria copiant. Ara me'n recordo cada cop que els meus estudiants se'n foten de mi quan m'ho veuen fer. Em va rebre amb un somriure i vam començar a parlar ràpidament sobre el que m'agradava i les coses que

* En América: consecuencias, secuelas.

Jesús Cerquides
IIIA-CSIC, e-mail: cerquide@iiia.csic.es

podia fer en els mesos que estaria a l'institut . . . i encara que he voltat per diversos llocs, després de disset anys continuo (i molt orgullós) a l'IIIA. Des d'aquell primer dia, en Ramon m'ha acompanyat en les etapes més importants de la meva vida científica. Durant aquest temps, m'ha aportat molt: la seva intel·ligència, simpatia, bonhomia, però ara en destacaré breument tres de les coses que m'ha ajudat a aprendre, com defensava Favaloro, mitjançant els seus actes i potser sense saber-ho.

En començar a treballar amb ell, em vaig adonar que mai acabava de dir-te clarament el que esperava que fessis. Més aviat et donava una idea general que després havies de treballar fins que esdevenia quelcom més concret, més tangible i, molt més important, quelcom teu. I és que quan treballes en quelcom que sents teu, ho fas molt més motivat, i la motivació és el combustible del científic, que per altra part, si alguna cosa ha de saber fer, és trobar les seves pròpies preguntes i definir el seu propi camí.

Ara bé, obrir un sender per on cap altre ha trepitjat mai i gaudir mentre ho fas, que al cap i la fi és del que es tracta aquest ofici, no és mai fàcil. I quan comences, ho és encara menys. Tenir algú al costat que et recolzi i et doni reforç positiu és molt important. Si recordo alguna frase sortint de boca del Ramon és sempre un "ets un màquina" o un "això està molt bé", que quan es refereixen a l'IIIA es transformen en un "som collonuts" o un "som millors que l'MIT" (que malgrat ser obvi, no deixa d'ésser positiu).

Quan ja sabem trobar camins, de vegades els busquem més curts del que toca, i sucumbim a la pressió d'aquest entorn que ens exigeix producció científica sense valorar la seva qualitat, per cap altra mètrica que no siguin les dels senyors JCR i ISI. Des que vam començar a treballar plegats, el Ramon sempre m'ha deixat ben clar que, encara que fer articles i llibres és important, donat que és el resultat fonamental del nostre treball, encara ho és més que els treballs que fem siguin de qualitat.

Aquestes virtuts: autonomia, reforç positiu i treball de qualitat són les que també ha aconseguit transferir a l'IIIA com a institució, en la seva etapa com a vicedirector primer i ara com a director. Per això jo mateix i crec que tots els que diàriament hi treballem, i ens sentim a gust, li estem agraïts.

Chapter 18
Working with Ramon

Anthony G. Cohn

I think I first met Ramon in 1992 before the *Institut d'Investigació en Intel·ligència Artificial* moved from Blanes to Bellaterra. He invited me to visit him in Blanes and I was, as always, made to feel so very welcome. On entering his office, it was already decorated with many years of conference name badges, hung in vertical strips down the walls – I wished I'd had this idea, though it does require a sufficiently large office, particularly given Ramon's very wide ranging interests and hence the large number of disparate events he attends.

Over the years, I have interacted with him many times, and the experience has been universally joyful. I chose him an as one of my area chairs for ECAI-94 in Amsterdam where his wide ranging knowledge, expertise were very useful. Ten years later, I very much enjoyed attending the ECAI-04 conference in Valencia for which he was conference chair – apart from the academic programme, I particularly remember the largest paella I've ever seen cooked – one single paella pan for all the hundreds of conference attendees at the banquet.

In 2003 Ramon was elected to the IJCAI Board of Trustees (see Fig. 18.2), to serve as conference chair for IJCAI-07 in Hyderabad, a position for which he was clearly very well suited. The conference was a fantastic success, very well attended, and organised, with an excellent social programme (Fig. 18.1). Ramon will go down in history as the longest serving IJCAI President – since IJCAI-07 was unusually held

Anthony G. Cohn
School of Computing, University of Leeds, e-mail: A.G.Cohn@leeds.ac.uk

Fig. 18.1: A Conference Chair's wide ranging duties.

in January, following his election to President immediately after serving as Conference Chair for IJCAI-07, he then served around 2.5 years, half a year longer than normal, until IJCAI-09 in Pasadena. We shared some six years on the IJCAI board, and Ramon was always a fount of well considered advice and knowledge – not to mention a very sociable colleague!

Since I left the Board of Trustees, I have continued to work closely with Ramon since I invited him to become an Associate Editor for the AI journal starting in 2007 at the same time as I became Editor-in-Chief. His very broad expertise has been very helpful, able to cover areas as diverse as agents, fuzzy systems, AI and Music, CBR – and indeed on occasions those papers for which I was unable to find any other Associate Editor! As in all his duties of this kind he undertakes, he is efficient and very insightful in his analysis of the papers he oversees.

So, to conclude, I wish Ramon the very best for the future, and maybe some relaxation after his many services to the field of Artificial Intelligence. He has always been a pillar of strength (Fig. 18.3) and extremely enthusiastic and committed in all the activities we have been mutually involved in. I'm sure he will continue though to pursue his many and varied research interests, and I can look forward to more talks such as the excellent one I recently heard when he gave his Robert S Englemore Memorial Lecture Award address at AAAI-11.

(a) 2004

(b) 2006

Fig. 18.2: Trustee meetings in 2004 and 2006.

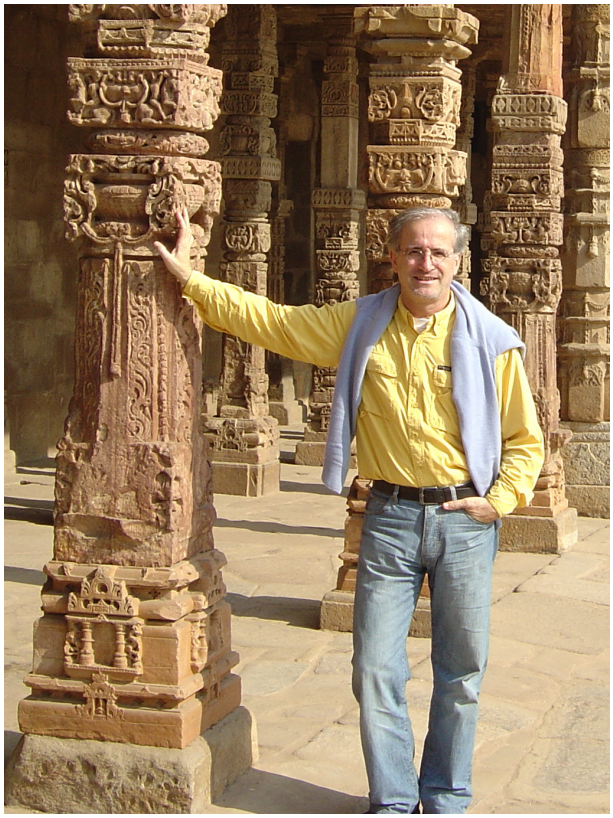


Fig. 18.3: A pillar of strength.

Chapter 19
From music to agents

Jordi Sabater-Mir

Every story has a beginning. It was July 1996, place: the Costa Brava. While being at my parents place for holidays, that day I had to phone call a researcher at the Artificial Intelligence Research Institute. That researcher was Ramon Lopez de Mantaras, my former teacher of Expert Systems during my degree of Computer Sicience at the Autnomous University of Barcelona. I had to chose a topic for my final degree project and Ramon had commented to us the possibility to do a project about artificial intelligence and music. Only three years before I had decided to renounce to my career as a musician to start computer science and now Ramon was offering me the possibility to join my two passions: music and computers. I remember being very nervous since the night before. That was a unique opportunity.

However after talking with Ramon that day he told me that I still had too many courses pending to start the final degree project and that another guy, with less pending courses, already had applied for the position (by the way "that guy", Marti Cabre, is one of my best friends now!). He was right, I knew it was probably too soon to ask for a final degree project, but I wanted so much that opportunity! He however told me that perhaps the next year there would be another chance for a similar project.

Jordi Sabater-Mir
IIIA-CSIC, e-mail: jsabater@iiia.csic.es

So after one year I tried again, and that time Ramon accepted me as a final degree project student. I spent almost one year at the IIIA working with him and Josep Lluis Arcos on GYMEL, an automatic harmonizer of melodies. The system developed was able to take a simple melody and, by using case based reasoning and general knowledge about harmonization, to suggest a sequence of accompanying chords. The project obtained the maximum qualification that was giving the university.

At the end of the project, Ramon called me to his office and suggested me to prepare and article based on that work to be submitted to the AAAI Spring Symposium on MultiModal Reasoning. That year the AAAI Spring Symposium was to be held at the Stanford University. Of course my initial thought was "come on, Ramon don't know what he is saying, nobody will be interested on this work". But I trusted him and we prepared and submitted the article. And the article was accepted. I remember the day I received the acceptance from the organizers. I felt a cold sweat coming, followed by a sense of fear. Well, at the end the paper was presented at the Spring Symposium and till now it has received 21 cites, not bad for my first incursion in the scientific world :)

The year spent at the IIIA working with Ramon and Josep Lluis made me realize what I wanted to do the rest of my life. I wanted to do research on AI. Unfortunately there were no projects at the IIIA about music at that time and to follow my scientific career I had to change to a different topic. I managed to get a grant in a IIIA project named SMASH about autonomous agents and Medicine, paid half by the CSIC and half by the Consorci Sanitari de Mataro. After one year I was able to start a thesis following the research I started in the SMASH project in the topic of autonomous agents with Carles Sierra (by the way, one of the "scientific childs" of Ramon), but that is another story.

But with Ramon we have not shared only work. Since my arrival to the IIIA we have organized every year a Christmas concert. Of course, Ramon has been one of the regular participants, demonstrating every year his musical talent. His performances playing guitar as part of the "Three Mariachis" (with Pablo Noriega at the voice and Carles Sierra at the "ai-ai-ais"), his solos playing a piano jazz improvisation or his interpretation at the piano of "Alfonsina y el mar" together with myself at the violin, are already part of the musical memory of the IIIA(the proof in figure 19.1).

What started as a dream one summer in 1996 has become my life. Now, 26 years later I'm a tenured scientist at the IIIA. If that summer

someone had told me that now I would have my office not far from Ramon's office I would not have believed it. As we said every story has a beginning and in my case (and also for many, many others) that beginning is Ramon.

Fig. 19.1: The Christmas concert at the IIIA.

Capítol 20
Nota Personal: Petits records personals on hi surt en Ramon

Josep Aguilar

El mes de juny de l'any 1977, del segle passat, va ser molt important per mi: aquell dia un estudiant que m'havia creat alternativament enrabiades i satisfaccions, finalment llegia la seva tesi a la sala de conferències del LAAS.

No recordo si, abans d'acceptar-lo al meu equip de recerca vaig consultar el seu historial acadèmic, crec que només sabia que havia estat estudiant a Mondragón, al País Basc, però que era català. El professor Yves Sévely, que tots hem apreciat i respectat l'havia tingut com alumne i no me'n va dir res de dolent, tot al contrari, el considerava com un dels bons candidats per un doctorat.

De bon principi les nostres relacions varen ser amistoses com poden establir-se entre un professor d'uns 35 anys i un alumne que no devia arribar als 25. Era l'època de la famosa i esperada transició a la península i les nostres opinions sobre el nostre país comú eren similars. Del punt de vista acadèmic, els seus primers treballs em varen donar ràpidament la impressió de que havia fet un excel·lent fitxatge pel meu equip. Vaig pensar que, després d'haver trobat un tema per a la tesi, no calia que em preocupés gaire; durant un temps relativament llarg no me n'hi vaig ocupar. Greu error! Quan li vaig demanar d'explicar-me on havia arribat, vaig constatar que la recerca estava terriblement endarrerida i vaig agafar el que col·loquialment se'n diu un cabreig. He de reconèixer que en Ramon tenia una excusa: entre tant s'havia casat!

Joseph Aguilar-Martin,
LAAS, Toulouse, e-mail: aguilar.josep@gmail.com

A partir d'aquesta anècdota, tot va anar molt millor: vàrem començar veure'ns sovint i a treballar junts sobre un algorisme d'aprenentatge que jo havia proposat uns anys abans, en un congrés, sense creure-hi realment i que, gràcies al seu treball va sortir d'unes aplicacions poc significatives que jo havia fet. En Ramon va obtenir resultats interessants amb els nous algorismes, que varen ser comparats amb altres mètodes existents, particularment en la separació de poblacions Gaussianes; com de costum les revistes científiques varen tardar quasi 10 anys a publicar el resultat.

No he comptat el nombre de publicacions que hem fet junts, però penso que, entre revistes i congressos, passen de les 20. Els resultats publicats no han caigut en el pou sense fons habitual de les revistes científiques que ningú llegeix, tot al contrari, han servit de llavor d'un gran nombre de treballs de tesi i d'aplicacions industrials en el marc de projectes europeus i a certs països de l'Amèrica Llatina.

La nostra col·laboració en la recerca ha estat completada d'una amistat permanent que ha estat consolidada per la nostra estada comú a la universitat de Califòrnia a Berkeley, i a la meva participació en la creació de l'equip d'Intel·ligència Artificial al Centre d'Estudis Avançats de Blanes, embrió de l'actual IIIA, que és ara sota la direcció d'en Ramon.

No puc acabar aquesta curta ressenya històrica de les relacions que he mantingut amb en Ramon, sense citar certes persones que han estat uns amics comuns i que ens han ajudat a prosseguir en els nostres projectes; en primer lloc he de recordar la memòria de na Núria Piera, desafortunadament desapareguda en plena activitat de recerca i d'apropament entre Tolosa de Llenguadoc i Barcelona, en segon lloc, no puc passar sota silenci el professor Enric Trillas qui em va introduir a la Lògica Difusa i que tant ens va ajudar a crear aquell equip de Blanes del que he parlat. M'aturo aquí perquè la llista dels nostres amics comuns seria molt llarga.

Josep Aguilar Martin
Tolosa de Llenguadoc
diumenge, 26 de febrer de 2012

Capítol 21
La doctorand núm. 6

Maite López-Sánchez

Vaig conèixer a en Ramon López de Màntaras l'any 1993 com a professor de teoria de l'assignatura de sistemes experts a la UAB. Vaig escollir sistemes experts sense saber el que eren, simplement havia sentit parlar bé de l'assignatura. Va resultar ser cert, i de fet, aviat em va agradar prou com per fer el Treball Fi de Carrera (TFC) amb el professor de pràctiques. Com a professor recordo al Ramon com una persona experta en el seu tema i amb facilitat per a fer assequibles els coneixements que vol transmetre. El Ramon no va necessàriament de "profe enrotllat"però tampoc no marca les distàncies amb els alumnes, simplement fa bé les seves classes amb un posat proper i relaxat. Així que no és d'estranyar que el vegem tantes vegades en actes públics tant de caire divulgatiu com científic.

No recordo exactament com vaig quedar per parlar amb en Ramon per tal que fos el meu director de tesi. El que sí recordo és com el meu director de TFC em va comentar la possibilitat i a mi se'm va obrir el món: "ah! –vaig pensar– però això de fer recerca està al meu abast?"Havia estat una bona estudiant durant la carrera, però no vaig ser primera de promoció ni tampoc ningú mai ens havia parlat de la carrera acadèmica. Tampoc no m'havia parat a pensar que els científics (aquells senyors grans savis, amb bata blanca i aspecte descuidat que tenim a l'imaginari col·lectiu) també havien començat de joves. Em podria arribar a fer científica? Encara a hores d'ara em costa identificar-me com a tal i m'és més

Maite López-Sánchez
Universitat de Barcelona, e-mail: maite@maia.ub.es

fàcil dir que dono classes a la Universitat. I no és que en Ramon complís exactament amb aquest estereotip, però en aquella època rondava els 40 (ara que jo ja els tinc em sembla que no és tant, però en aquells moments casi em doblava l'edat), així que ni les seves idees progressistes, ni el cotxe esportiu vermell i ni els cabells una mica llargs, eren prou per evitar-me el pensar que com a referència, en Ramon no estava tant lluny de ser un senyor gran savi (la bata blanca no li calia, doncs a la nostra àrea ningú la fa servir).

La següent cosa que recordo és anar a Blanes, a visitar a en Ramon al centre de recerca. Em va impressionar força aquell entorn de treball tant maco i aïllat, en el que es respirava i compartia ciència (es convivia amb recercaires d'oceanografia i altres àrees que a mi em semblaven igualment fascinants). Recordo com en Ramon m'ensenyava el seu embrió de biblioteca i em deixava un llibre per llegir (i tornar). També vaig dinar amb ells a Blanes... llavors jo no bevia pràcticament res d'alcohol i ja vaig intuir que inexorablement em caldria fer un petit esforç d'integració! Malauradament mai he arribat a trobar-li el gust al cava que tant li agrada a ell, però almenys sí que vaig aprendre a gaudir d'un bon vi negre!

Li vaig tornar el llibre al seu nou despatx de l'IIIA al campus de la UAB al setembre, i li vaig portar també el meu treball final de carrera (que va resultar ser el primer d'una enginyera informàtica a la UAB). En Ramon em va ensenyar convocatòries de beques i vàrem fer els papers. Mentre esperava, vaig començar a treballar als matins com a programadora en una empresa a la Zona Franca i per les tardes passava per l'IIIA. Ironies de la vida, el meu cap a l'empresa també es deia Ramon (que a més coincideix amb el nom del meu pare!). Per mi la recerca era una aposta vital i implicava renunciar a un sou competitiu. Pel Ramon imagino que era un moment per fer créixer l'IIIA: érem tres estudiants demanant beca i ell va haver d'anar a Madrid per a aconseguir una del CSIC. El tall per nota em va permetre celebrar amb una ampolla de cava (modest) l'inici de beca. També vaig poder celebrar la inauguració oficial de l'edifici (tenint una placa amb el meu nom a un despatx!). I ho vaig fer ja amb la sensació de que ja formava part de la família de l'IIIA: aquesta que tant li agrada esmentar a en Ramon i que ja llavors es transmetia als nouvinguts (veieu, per exemple, la foto 21.1).

Em vaig introduir a la recerca llegint la tesi doctoral de la Beatriz López i en la meva línia de que tot em semblés interessant vaig començar simultaniejant arbres de decisió i robòtica autònoma. Però la meva

Figura 21.1: Celebració (en família) d'aniversari a l'IIIA (any 1995?).

capacitat és limitada. En Ramon ho va entendre i em va deixar escollir. El relleu als arbres de decisió, les hores de calor insuportable i màquina sun suposadament potent però a on t'havies d'esperar per a refrescar les finestres d'interfície (potser seria la calor? ;o)) el va agafar el Jesús Cerquides. També per aquella època em vaig trobar amb un conegut, el Juan Antonio Rodríguez (jar), que s'havia assabentat de que en Ramon era el meu supervisor i em va preguntar com estava per entrar a l'IIIA. En jar tenia clar que era un bon centre i que en Ramon era un investigador de prestigi, i encara va dubtar menys que havia d'entrar quan va veure la seva secretària! Aquell següent any van tornar a haver tres candidats a beca (el Francisco Martín era el tercer), però aquesta vegada tots van guanyar beca directament. Diuen que el talent atrau el talent, i no tinc cap dubte de que aquella situació força extraordinària va ser un bon exemple de l'expressió. Crec que tots ens vàrem entendre força bé.

En aquella època, quan portaves un temps a l'IIIA podies anar descobrint que, ben mirat, la combinació de caràcters de l'institut era força heterogènia i curiosa. En Francesc Esteva i en Ramon eren capaços de fer que l'harmonia i familiaritat impregnessin l'ambient de l'institut. No obstant eren remarcables tant les discussions científiques dels seminaris com les banals (però força acalorades) de l'hora del cafè. Al principi, jo (jove, visceral, dona, enginyera i fent servir PC!) m'hi afegia sense pensar-m'ho... el temps em va fer anar aprenent i acceptant algunes co-

ses però també a distanciar-me d'algunes altres. No obstant van quedar algunes invariants durant els prop de cinc anys que vaig estar a l'IIIA: sempre vaig córrer pel passadís per anar a l'impressora (si senties a algú derrapar en arribar a la porta de ben segur era jo! en Ramon devia estar ben fart dels cops de porta...) i quasi bé mai vaig gosar posar-me faldilla (m'abstindré de reproduir els comentaris). Ben és cert, però, que en Ramon es mantenia al marge de tot això amb una discreció que sempre li he agraït profundament. Tampoc no recordo tenir discussions de cap tipus amb ell. El seu caràcter conciliador, i suposo que la relació de director-doctorand (cordial, però amb una distància raonable que sempre he trobat necessària) ho evitaven.

Figura 21.2: Celebració a la masia del Carles i la Carme l'any 1996. A l'extrem dret en Ramon està al costat de la Joel i en Marc.

En qualsevol cas, totes les discrepàncies s'oblidaven en les celebracions: els berenars de crêpes a casa d'en Ramon i la Joel o els dinars (sempre excessius però bonissims) de la masia d'en Carles Sierra i la Carme permetien mantenir cohesionada la família (Fig 21.2). En aquelles ocasions en Ramon (com tots) es deixava anar incitant per en Carles, tothom ho celebrava i la Joel ho acceptava amb una naturalitat que he anat entenent amb els anys. Anecdòticament, he de dir que va ser amb el Ramon a un dinar de la masia la primera i única vegada en la meva vida que he preparat all-i-oli. Qui m'havia de dir que el meu director de

tesi també m'ensenyaria això! tothom va fer broma del tema veient-nos treballar mà a mà... malauradament no tinc fotos del moment, el més proper és pelant patates amb altra gent (Fig. 21.3), però no té ni de lluny la mateixa gràcia.

Figura 21.3: Pelant patates a la celebració de la masia (abans havíem fet l'all-i-oli amb en Ramon).

El dia a dia de l'IIIA era tranquil. Jo tenia un despatx al mateix pis d'en Ramon i em donava la confiança per anar a fer-li consultes sempre que tingués la necessitat. Els articles havien d'estar escrits uns dies abans per enviar-los per missatger. A més, passar el text de PC a Mac era més complicat que ara, però tampoc no recordo un estrès insuportable pels deadlines: anàvem a un ritme de treball força constant (tots els dies de 10h a 20h) i mai vaig tenir la sensació de que en Ramon m'estrenyés (si ficava jo l'alarma de l'IIIA a la nit o si venia algun cap de setmana a treballar ho vivia com autoimposat). Moltes vegades vàrem fer reunions de recerca o vaig fer consultes amb altres investigadors (en Carles Sierra, amb qui vàrem fer la majoria d'articles, en Lluís Godo, en Francesc Esteva, en Josep Amat i l'Antonio Martínez, en Thomas Dietterich, la Lola Cañamero, la Carme Torres i l'Enric Celaya entre d'altres) i sempre va ser amb un esperit constructiu i receptiu a les propostes dels altres. Certament, però, era la primera i única persona de l'IIIA treballant en robots autònoms, i això em feia sentir una mica aïllada. D'això el Ramon poca

cosa podia fer tret d'enviar-me a treballar amb gent de fora. I així ho va fer: al principi vaig anar a picar codi per robots físics amb els estudiants d'en Josep Amat a la UPC, i prop d'acabar la tesi vaig fer una estada de recerca amb el professor George Bekey a la USC.

L'acompanyament i la guia per part d'en Ramon durant tot el temps del doctorat van ser una constant, però just abans d'acabar la tesi una combinació de circumstàncies em van fer "matar al pareï dir que no a l'oferiment del Ramon per a continuar com a becaria postdoctoral a l'IIIA (i això ho vaig fer a pesar d'haver rebutjat uns mesos abans l'oferiment del Gaurav Sukhatme de la USC a quedar-me allà per tal de tornar a l'IIIA a acabar la tesi). Era l'època del boom d'Internet, alguns becaris de l'IIIA teníem inquietuds de transferència de tecnologia difícils de canalitzar dins les dinàmiques clàssiques de recerca... el resultat es va acabar cristal·litzant en l'inici d'una empresa: iSOCO, intelligent Sotware Components S.A. En aquells moments en Ramon va ser tot un pioner anant al CSIC a Madrid a explica'ls-hi el pla de negoci que havia fet en Francisco (escrit en LaTeX, per cert). Va aconseguir que el CSIC el reconegués com a spin-off, signar un conveni i la cessió d'espais per a treballar (veure foto 21.4). Per la meva part, l'absorció al nou treball era tant brutal que recordo detalls com que l'IIIA va haver d'encarregar-se unilateralment de publicar la monografia de la meva tesi.

Els inicis d'iSOCO al 1999 i els anys posteriors van ser una etapa extremadament intensa. En Ramon assistia a la majoria de juntes generals i sempre que li va ser possible va recolzar l'empresa. Entre d'altres, va mediar per a tenir a la Ministra de Ciència i Tecnologia (Anna Birulés) a la inauguració dels nous espais a Sant Cugat al 2001. Tots vàrem estar formals aquella tarda. En Francisco em va assignar el rol de "mestre de cerimònia"així que vaig aprendre protocol per a presentar-la. Al seu discurs va dir "*iSOCO es además una empresa nacida en el mundo de la investigación y a partir de científicos, [..] y además en un centro de científicos, en el Instituto de Investigación de Inteligencia Artificial...*". També vaig acompanyar-la per les instal·lacions. Em va cridar l'atenció que dins d'una conversa informal em remarqués com d'afortunada havia estat de tenir a en Ramon com a director de tesi. No em va fer l'efecte de que ho digués per a quedar bé (òbviament, tampoc li calia fer-ho), simplement semblava haver conegut bé a en Ramon. Malauradament a vegades son els altres els que t'ensenyen a valorar el que tens o has tingut... i la veritat és que he necessitat molt de temps per a aprendre a fer-ho per mi mateixa.

EL PAIS, jueves 10 de febrero de 2000

INNOVACIÓN

Un centro de investigación incuba iSOCO, una empresa para Internet

La compañía crea aplicaciones de inteligencia artificial y reúne ya a 40 jóvenes profesionales

Todo en Internet va a una velocidad que asusta. El último ejemplo: iSOCO. Esta empresa la crearon seis ingenieros informáticos en julio de 1999 en un rincón del Instituto de Investigación en Inteligencia Artificial (IIIA), en las afueras de Barcelona. Apenas medio año después reúne ya a 40 trabajadores, ha cerrado su primer ejercicio con beneficios y cuenta entre sus clientes con empresas del calibre de General Electric, Nokia y Jazztel. ¿A qué se dedica? Diseña y desarrolla aplicaciones para comercio electrónico utilizando técnicas de inteligencia artificial.

Figura 21.4: ciberp@is (EL PAIS, 10 de Febrer 2000).

Fins fa poc, si algú em preguntava que volia ser jo de petita o de jove, no li sabia donar una resposta clara. M'agradaven moltes coses i algunes se'm donaven bé però crec que no destacava especialment en res. De fet, per diferents circumstàncies tant podria haver escollit estudis universitaris d'informàtica (que vaig fer) com de veterinària, dret, belles arts, biologia o matemàtiques. No obstant, molt recentment em vaig adonar de que, tot just quan anava a l'institut i ens van fer rodar un curt de tema lliure, jo em vaig preparar un personatge d'una científica que feia meditació. . . i vet aquí on soc un quart de segle després: fent recerca i classes durant el dia i practicant ioga algunes nits. . . tot plegat, jo diria que s'assembla bastant a la consecució d'un somni (un futur que jo mai havia gosat de demanar-me conscientment). Jo he posat molt d'esforç pel camí, però és indubtable que en Ramon va ser el primer que ho va fer possible: MOLTES GRÀCIES RAMON.

Però tampoc no em voldria quedar amb les gràcies i prou. Han passat els anys, i no puc deixar de reflexionar sobre allò que en Ramon ha significat per a mi (si no deixo de mirar-me el melic) i per a la comunitat.

A més de les nombroses aportacions científiques que ha fet, el Ramon, amb tenacitat, ha estat capaç d'aixecar un centre de recerca que és de referència internacional, tant pels resultats com per la formació que reben els que s'hi acosten. I així i tot, no és una persona perduda entre els grans nombres: a cada estudiant ens ha dedicat l'atenció que ens ha calgut. De la mateixa manera ha fet un esforç envers la transferència de tecnologia: ha fet tasques divulgatives, va ser clau en l'inici d'iSOCO i en la creació de l'Unitat de Desenvolupament Tecnològic (UDT) de l'IIIA. I és que, més enllà dels premis i reconeixements que ha rebut al llarg de la seva carrera, en Ramon segueix sent una persona accessible, apassionada per la ciència i la seva transferència a la societat. Per un nouvingut no és trivial valorar en la seva justa mesura la manera que té d'aproximar-se als nous coneixements un professor d'investigació. L'albirament des de les alçades pot malinterpretar-se com una certa pèrdua d'interès o de no voler entrar en certs detalls, però en realitat es tracta d'un procés d'abstracció. Haver vist molts treballs de recerca abans no et fa valorar-los menys, sinó situar-los millor i relacionar-los més fàcilment amb d'altres. I per això tampoc no cal conèixer tots els detalls, ben sovint hi ha prou amb entendre bé la idea subjacent i saber-li trobar el sentit (o simplement la coherència). En Ramon segueix organitzant i assistint a tots els seminaris de l'IIIA. Quan seu a la cadira (o més ben dit, s'hi col·loca) amb aquest posat relaxat, ben lluny de per fer una becaina, és per agafar aquesta alçada de vol i és per veure-hi més enllà. En el meu cas, sempre recordo el "*symbol grounding*". Durant la tesi, mentre jo estava embardissada en intercanviar comportaments bàsics per tal de que els meus robots (simulats) seguissin parets o detectessin cantonades, en Ramon parlava del "symbol grounding": un concepte molt més abstracte que no pas l'operativa per detectar les coses (els símbols) que envoltaven als meus robots... doncs això és abstracció, això és mirar més enllà. En definitiva, això és ser un científic (o dit d'una altra manera, un senyor gran savi).

Chapter 22
Ramon López de Màntaras

Ulises Cortés

The past is ours, and there is nothing more secure for us than that which has been. We are ungrateful for past gains, because we hope for the future, as if the future–if so be that any future is ours–will not be quickly blended with the past.
SENECA

I have known Ramon López de Màntaras, *aka* Ramon, since late 1982 when I began my doctoral program in Computer Science at the Universitat Politècnica de Barcelona (today Universitat Politècnica de Catalunya (UPC)). After 8 months he became my PhD advisor, I was his first PhD student also his first overseas student. This was quite serendipitous as he was, at the time, among the few researchers at the Barcelona School of Informatics who had an international experience. In two years, under his advise, I wrote and defended my PhD Thesis (1984), my first paper and we were together at my first presentation in a congress (see figure 22.1. At that time he was also creating his own research group to work on Expert Systems: Carlos Sierra[1] came with me to join Ramon and, late 1983, Enric Plaza[2] came along and since then we all have been together in many adventures.

Ulises Cortés
LSI-UPC, e-mail: ia@lsi.upc.edu

[1] Carlos was his third PhD student

[2] Enric was his second PhD student

I got married in the summer of 1984. As my parents were unable to attend the ceremony he and Joëlle, his lovely wife, where at the ceremony representing them. We were young and crazy and I remember that things were happening very fast. Since we met we forged a long standing friendship that still strong and we share not only academic enterprises but many memorable times. Today, I am sitting trying to recall memories, ordering and selecting photographies of that period to start this essay in his honor. Thirty years have passed like a thunder in front of my eyes. He is about to make sixty years old but he still young at heart.

Fig. 22.1: Ramon in 1985 at FISAL, Porto Colom

My contribution to this collection has turned out a rather strange hybrid of reminiscences and an short essay about Ramon's influence on our Catalan Artificial Intelligence community, on the creation of the Artificial Intelligence Ph. D. Program and on the constitution of the Catalan Association of Artificial Intelligence which are some of steeping stones of this collective achievement where Ramon was and is a principal actor. I am more than sure that other of his *alumni* and colleagues will talk about Ramon's contributions to Artificial Intelligence at large and

about his great ability to discover new paths of research to transform his work to novel ideas and applications. I am not seeking to repeat that inhere. Still, I was a privileged witness of Ramon's contributions helped to transform a Fuzzy Sets community into a Machine Learning – a lot of efforts remain in this area – to an Autonomous Agent community.

Ramon *Pontifex*

If I have to define Ramon's most prominent social characteristic with a single word I would use, no doubts, *pontifex*. He has been always very active in creating the conditions for having the best possible atmosphere to do research, in his close environment, in Catalonia, in Europe, and the world. He is a person of conviction who is concerned about the welfare of the entire AI community. He is the kind of person that sees as a problem as an opportunity to build a solution, and he contributes to have it. To give an example, in 1984, Ramon was among the participants of a seminar that was the seminal act in the creation of what today is the Spanish Association of Artificial Intelligence that was in itself a great achievement for the community in Spain. This task of building consensus implies a lot of networking and he is brilliant in getting everybody to feel comfortable. He served the AI community outside Catalonia both at the European level being the Editor-in-Chief of *AI*Communications, which is the official journal of the European Coordinating Committee for Artificial Intelligence, for almost 6 years and at a global level being the President of the IJCAI Board of Trustees.

The PhD Program on Artificial Intelligence at the UPC was created back in 1985. Ramon with other researchers like Carme Torras and Felisa Verdejo made it possible to have this academic program to give a space to growing research community open to admit people from very different backgrounds. Ramon's role was key in facilitating the participation of all the different groups in Catalonia and himself was an active Ph Advisor in this program until 2003. This program has been an essential instrument in building the actual AI research community in Catalonia. Most the ECAI Fellows in Catalonia are former graduates of this program and three among them Ramon's Phd students.

Ramon was key person in the creation of the Catalan Association of Artificial Intelligence (ACIA) and the first president. Around him was

Fig. 22.2: A wizard, a piano player

easy to build a seminal structure. The rest of the history was no easy but it is fruitful. Today, ACIA is one of the most buoyant AI research associations in Europe.

Final note

Ramon is not only always profoundly engaged in his own scientific projects and other coordination activities but also excited and intrigued by the research projects and papers of each of his students; and he always maintains an unquenchable curiosity for the Artificial Intelligence in all its manifestations. As all good graduate advisors, Ramon helps not only his students but all young researchers in his surroundings to become more critical, discerning evaluators and better persons. This has been a constant the last 30 years at UPC where I met him, Centre d'Estudis Avançtas de Blanes (CEAB) and Insitut d'Investigacions en Intel.ligencia Artificial (IIIA) the two research institutes that he created.

Ramon's own personal interests: piano (see figure 22.2), poetry, in-line skating... and areas of expertise have always been wide-ranging making him *rara avis* among researchers. A man of his times, his knowledge and love for music, specially Jazz, has also had a defining effect on his scientific and personal life. Back in 1998, during the 13^{th} European Conference on Artificial Intelligence at Brighton, he gave one of key talks under the title *It Don't Mean A Thing (If It Ain't Got That Swing)* where his renacentist knowledge was exposed to European AI community at large.

For many of us Ramon has always epitomized the quintessential graduate advisor, an excellent teacher, a friend of his friends and a great person. He is always looking to the future of the Artificial Intelligence research and its non-military applications, whit the same open spirit but wiser. I want to express with these lines my friendship and deepest respect and admiration.

Chapter 23
A free spirit

R. Uthurusamy

Fig. 23.1: A picture I took of Ramon in Vancouver, Canada in July 2007 that shows how free-spirited he is. He quickly rented the skates and went for skating in the Stanley Park for a few hours.

R. Uthurusamy e-mail: rusamy@yahoo.com

Capítulo 24
1968 - 1980: Mondragón - Toulouse - Mondragón - Berkeley - Mondragón

Pedro Larrañaga

Sirvan estas primeras líneas para desearte Ramon un feliz día de cumpleaños (¡¡los primeros 60!!), a los que llegas pletórico de entusiasmo y fuerzas, además de con un gran reconocimiento de la comunidad científica en Inteligencia Artificial, y lo que es más importante, rodeado del cariño y la admiración de tus colegas.

Cuando Carles me contactó para colaborar en tu *Festschrift*, tuve claro que mi aportación debía de circunscribirse al periodo de tu vida relacionado con la Escuela Politécnica Profesional de Mondragón. Desde el momento que te conocí me llamó mucho la atención tu manera de expresarte y relacionarte, muy cercana a los estereotipos que se nos atribuyen a los vascos. La cercanía de mi pueblo natal, Soraluce-Placencia de las Armas, con Arrasate-Mondragón, y el hecho de que varios de mis amigos hayan estudiado en la Escuela Politécnica Profesional de Mondragón, sirvió también para decidirme a conocer más acerca de tus vivencias durante estos años clave de tu formación académica y personal.

Recoger la información y documentación que se muestra en estas páginas no hubiese sido posible sin la ayuda de José Luis Flores, doctorando mío de la Universidad del Pais Vasco-Euskal Herriko Unibertsitatea (UPV-EHU) y antiguo profesor de la Universidad de Mondragón, quien me proporció el contacto de María Ángeles Iñurritegi, secretaria de dicha universidad. Maria Ángeles, además de conseguir buen número de

Pedro Larrañaga
Departamento de Inteligencia Artificial, Universidad Politécnica de Madrid, e-mail: plarranaga@fi.upm.es

los documentos que aquí se muestran, me puso a su vez en contacto con Alberto Ruiz de Olano, compañero de "muchas fatigas" de Ramon en diferentes periodos de la vida. Quiero expresar mi agradecimiento más sincero a los tres: José Luis, María Ángeles y Alberto, agradecimiento que extiendo a Concha Bielza y Pedro Luis López-Cruz por su ayuda en la preparación de este manuscrito.

24.1 1968 - 1973: Escuela Politécnica Profesional de Mondragón


Núm. 130

Instituto Nacional de Enseñanza Media
«Luis de Peguera»
MANRESA

D. Ramon López de Mantaras Badia
ha abonado la cantidad de 50 pesetas
como derechos de expedición de la Certificación Oficial de sus estudios al Escuela Profesional Politécnica Mondragon
Manresa, 14 de agosto de 1968
El SECRETARIO,

Figura 24.1: Abono de los derechos de expedición de la certificación oficial de los estudios de bachillerato (1968)

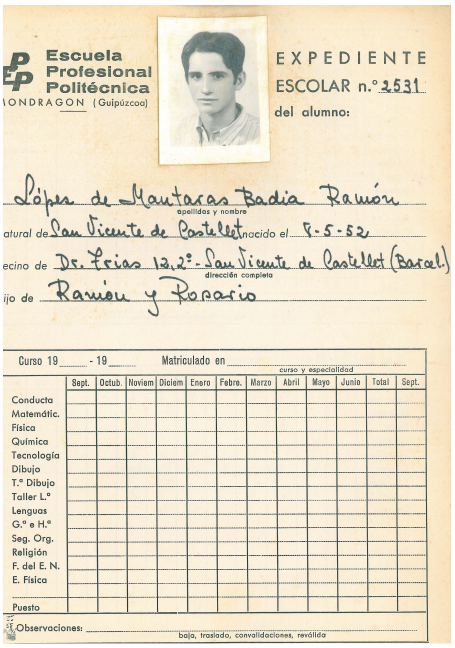
El 2 de Octubre de 1968, contando Ramon con 16 años, rellena la ficha de inscripción en la Escuela Politécnica Profesional de Mondragón, para iniciar estudios de 3^o de Oficialía Electrónica. Dos meses an-

tes, Agosto de 1968, había abonado al Instituto Nacional de Enseñanza Media Luis de Requera, en Manresa, la cantidad de 50 pesetas, como derechos de expedición de la Certificación Oficial de sus estudios a la Escuela Politécnica Profesional de Mondragón (véase Figura 24.1). Sus estudios de bachillerato superior en la Academia Joviat de Barcelona no iban todo lo boyantes que Ramon y Rosario (sus padres) esperaban, y su padre que trabajaba como delegado de Fagor (una de las empresas más prestigiosas de las Cooperativas de Mondragón, donde también se encuadraba la Escuela Politécnica Profesional de Mondragón) decide trasladar al chico desde su San Vicenç de Castellet (Barcelona) local a Mondragón (Gipuzkoa) (véase la Figura 24.2).

Figura 24.2: Desde su (A) San Vicenç de Castellet (Barcelona) local a (B) Mondragón (Gipuzkoa) (1968)

Ramon ingresa como interno ocupando la habitación 323 y con número de expediente 2531. Según fuentes de la Escuela Politécnica Profesional de Mondragón la admisión no fue sencilla, ni directa, ya que en aquellos tiempos era raro atender peticiones de fuera del País Vasco, y más concretamente de fuera de la comarca del valle alto del Deba (Mondragón, Eskoriatza, Aretxabaleta, Oñati, Bergara, Soraluce-Placencia de las Armas). La labor y entrega de su padre como delegado de Fagor en Cataluña, así como la visión de algún responsable de la Escuela Poli-

técnica Profesional de Mondragón hicieron que finalmente se tomase la decisión que tan buenos frutos dio.



Escuela Profesional Politécnica
MONDRAGON (Guipúzcoa)

EXPEDIENTE ESCOLAR n.º 2531 del alumno:

López de Mantaras Badia Ramón
apellidos y nombre

natural de San Vicente de Castellet nacido el 8-5-52

vecino de Dr. Farias 12, 2º - San Vicente de Castellet (Barcel.)
dirección completa

hijo de Ramón y Rosario

Curso 19____ - 19____ Matriculado en ____ curso y especialidad

	Sept.	Octub.	Noviem	Diciem	Enero	Febre.	Marzo	Abril	Mayo	Junio	Total	Sept.
Conducta												
Matemátic.												
Física												
Química												
Tecnología												
Dibujo												
T.ª Dibujo												
Taller L.ª												
Lenguas												
G.ª e H.ª												
Seg. Org.												
Religión												
F. del E. N.												
E. Física												
Puesto												

Observaciones: ____ baja, traslado, convalidaciones, reválida

Figura 24.3: Expediente escolar al ingresar en la Escuela Politécnica Profesional de Mondragón (1968)

En la Figura 24.3 se muestra el expediente escolar del alumno Ramon López de Màntaras Badia, incluyendo asignaturas tales como `Conducta`, `Religión` y `Fundación del Espíritu Nacional`, las cuales no nos resultan ajenas a los que ya hace muchos años pasamos por el bachillerato. Según se desprende del expediente, la evaluación se producía mensualmente, y también se contemplaba la ordenación de los alumnos en base a sus notas, asignándoles a los mismos un puesto dentro de la clase. ¡¡Que tiempos aquellos!!

En esta primera etapa de estancia en Mondragón (1968-1973), Ramon realiza durante el curso 1968-1969 los estudios de 3^o de Oficialía

en la especialidad de Electrónica Industrial, y en el curso 1969-1970 efectúa el preparatorio para el ingreso en Ingeniería Técnica. Durante el periodo 1970-1973 lleva a cabo sus estudios de Ingeniería Técnica, en la especialidad de Electrónica Industrial. En ese periodo compagina los estudios con trabajos de prácticas en el Laboratorio de Automatismos Electrónicos y en la cooperativa Fagor Electrónica. No contento con estas actividades, su energía, dinamismo y su carácter extrovertido, le llevan a hacer sus pinitos como disk-jockey, y a interpertar con la guitarra (y a veces con la compañía del "Pater") baladas y temas musicales de actualidad.

Este talante tan positivo, con el que Ramon fué capaz de compaginar estudio, trabajo y diversión, junto con el buen aprovechamiento a nivel de notas, de las enseñanzas adquiridas, no pasaron desapercibidos por la Dirección de la Escuela Politécnica Profesional de Mondragón, que según palabras del Presidente de la Junta Rectora solicita para el alumno Ramon López de Màntaras Badia, al director de la Caja Laboral Popular de Mondragón un préstamo con garantía personal para proseguir sus estudios en la Universidad Paul Sabatier de Toulouse:

> "Consideramos no sólo acertado sino necesario profundizar en el estudio de dichas materias y otras más en la Universidad francesa de Toulouse, pudiendo incorporarse, terminado el Doctorado en el cuadro docente de esta Escuela, la cual está interesada en que efectúe la formación más completa posible."

24.2 1973 - 1977: Universidad Paul Sabatier de Toulouse

A principios de los años setenta Javier Retegui (a la sazón director de la Escuela Politécnica Profesional de Mondragón y posteriormente Consejero de Educación del Gobierno Vasco) junto con Manuel Quevedo (profesor de la Escuela Politécnica Profesional de Mondragón) establecen relaciones con la Universidad Paul Sabatier, fruto de las cuales dos alumnos de la Escuela Politécnica Profesional de Mondragón se desplazan en el curso 1972-1973 a estudiar la Maitrise en Automatique a dicha universidad francesa. El curso siguiente, son seis los graduados de la Escuela Politécnica Profesional de Mondragón que comienzan sus estudios en la Universidad Paul Sabatier. Entre ellos se encuentra Ramon, matriculado en la Maîtrise en Électronique et Automatique, estudios que

Figura 24.4: Calle Malcousinat residencia en Toulouse (1973-1977)

culmina en Junio de 1974, para un año más tarde diplomarse en Études Approfondies en Automatique y finalmente defender la tesis doctoral, alcanzando el título de Docteur de Spécialité 3éme Cycle en Automatique el 21 de Junio de 1977, con una calificación de "très honorable". El título de la tesis doctoral "Autoapprentissage d'une Partition: Application en Classement Itératif de Donneés Multidimensionnelles" tiene, incluso hoy en día, toda su vigencia dentro de la rama de Inteligencia Artificial denominada Aprendizaje Automático, y nos da una idea de lo avanzado y pionero que fue el trabajo de tesis doctoral de Ramon. Repasando las publicaciones previas a la tesis doctoral, nos encontramos, entre otros, con términos como "información condicional", "algoritmo de autoaprendizaje" y "simulación" en los cuales uno puede vislumbrar el cambio de visión respecto a los trabajos más prácticos desarrollados anteriormente en la Escuela Politécnica Profesional de Mondragón.

En esta época de Toulouse, Ramon establece residencia en la calle Malcousinat (véase la Figura 24.4), y entabla una gran amistad con Alberto Ruiz de Olano, con el que llega incluso a coincidir en la fecha de defensa de la tesis, acto que rememoran 20 años más tarde junto con otros compañeros (Figura 24.5).

Figura 24.5: En la sala de lectura de tesis de la Universidad Paul Sabatier, 20 años más tarde (1997). De izquierda a derecha: Joseba Quevedo, Josu Zabala, Alberto Ruiz de Olano, Ramon y Xabier Ruiz del Portal

De aquella época es también la despedida del director del Laboratoire d'Automatique et d'Analyse des Systémes (LAAS) del Centre Nationale de la Recherche Scientifique (CNRS) de Toulouse, donde vemos a un Ramon con gafas y barba, a la derecha de la foto (Figura 24.6), al más puro estilo de los años setenta.

Como representantes del campeonato de tenis de mesa del LAAS fueron seleccionados Alberto y Ramon, honor que alcanzaron como consecuencia de sus exhibiciones entre sus compañeros de laboratorio en los partidillos que jugaban en el descanso de la comida, al estilo de lo que Google hace hoy en día en sus sedes.

Al igual que había hecho en Mondragón, también en los años de estancia en Toulouse, Ramon es capaz de compaginar sus estudios con otro tipo de actividades. Así, forma parte del programa de investigación en Robótica dentro del LAAS (Septiembre de 1974 a Junio de 1977), ocupando el último año (Enero 1976 a Junio 1977) una plaza de profesor ayudante en Automática en la Universidad Paul Sabatier de Toulouse.

Figura 24.6: Despedida del director del LAAS en Toulouse. Ramon a la derecha, con barba y gafas

24.3 1977: Escuela Politécnica Profesional de Mondragón

De vuelta de Toulouse, Ramon permanece unos meses preparando la documentación necesaria para incorporarse a la Universidad de California Berkeley. El compromiso que ha adquirido con la Escuela Politécnica Profesional de Mondragón consiste en que una vez terminado el periplo americano debe de incorporarse como docente en la Escuela Universitaria de Ingeniería Técnica de Mondragón.

24.4 1978 - 1979: Universidad de California Berkeley

Atraído por la robótica, el reconocimiento de formas y la lógica borrosa, Ramon se desplaza al Electronics Research Laboratory donde, bajo la dirección del Profesor Zadeh, ocupa plazas de Research Assistant (Enero

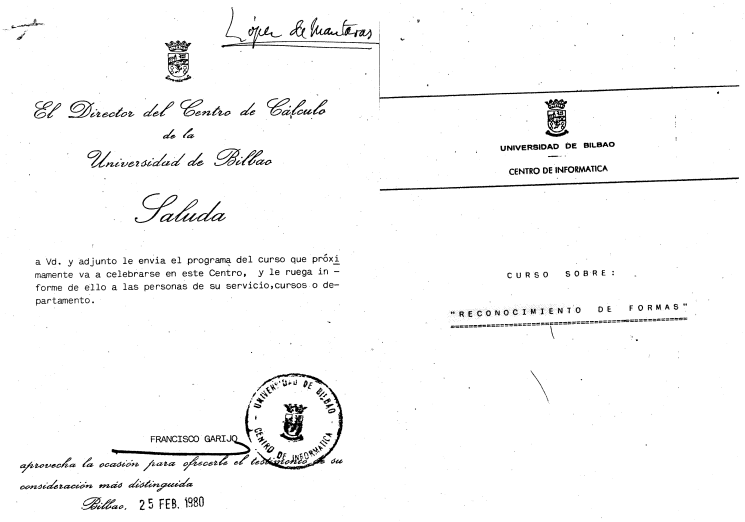
1978 a Marzo 1979) y de Research Associate (Abril 1979 a Septiembre 1979). En dicho periodo obtiene el Master of Science en Computer Science por la Universidad de California Berkeley con una muy alta calificación. El título de su trabajo fue "On Selflearning Pattern Classification".

24.5 1979 - 1980: Escuela Politécnica Profesional de Mondragón + IKERLAN

Cumpliendo con los compromisos adquiridos, a la vuelta de Berkeley se incorpora a la Escuela Universitaria de Ingeniería Técnica de Mondragón donde ejerce (al 25 %) como Profesor de Informática, y también se incorpora (al 75 %) al Departamento de Informática de IKERLAN (Centro de Investigaciones Tecnológicas) sito en Mondragón, desarrollando su investigación en Inteligencia Artificial. En ambos casos la actividad se lleva a cabo desde Octubre de 1979 a Octubre de 1980.

El centro de investigación IKERLAN cuenta en la actualidad con más de 200 investigadores, y se creo en 1974 al amparo de la Escuela Politécnica Profesional de Mondragón. Ésta inició su actividad docente en 1943, impulsada por el padre D. José María Arizmendiarrieta, fundador de la experiencia cooperativa de Mondragón. Un hito importante en la historia de la Escuela fue la creación en 1956, por cinco de sus ingenieros técnicos, de la primera cooperativa industrial del movimiento cooperativo de Mondragón: ULGOR Sociedad Cooperativa, en la actualidad FAGOR. Es también reseñable la constitución en 1977 de Mondragon Unibersitatea, que en la actualidad cuenta con más de 4.000 alumnos distribuidos en sus 22 titulaciones de grado y sus 15 másteres. Dichas enseñanzas se imparten en la Escuela Politécnica Superior, la Facultad de Empresariales, la Facultad de Humanidades y Ciencias de la Educación y en la recientemente creada Facultad de Ciencias Gastronómicas. En Septiembre de 2011 se ha inagurado el Centro en Electrónica y Sistemas Embebidos que integra la investigación y formación en los ámbitos de la electrónica, la informática y las telecomunicaciones. Sin duda el quehacer de pioneros como Ramon sirvió para aportar su granito de arena para que este Centro de Investigación e Innovación viera su luz.

Una de las actividades que Ramon realizó durante este último año fue la impartición de un curso sobre "Reconocimiento de Formas" (Fi-



El Director del Centro de Cálculo
de la
Universidad de Bilbao

Saluda

a Vd. y adjunto le envia el programa del curso que próximamente va a celebrarse en este Centro, y le ruega informe de ello a las personas de su servicio, cursos o departamento.

FRANCISCO GARIJO

aprovecha la ocasión para ofrecerle el testimonio de su consideración más distinguida

Bilbao, 25 FEB. 1980

UNIVERSIDAD DE BILBAO
CENTRO DE INFORMATICA

CURSO SOBRE:

"RECONOCIMIENTO DE FORMAS"

Figura 24.7: Curso sobre reconocimiento de formas, impartido en la Universidad de Bilbao (1980)

gura 24.7) que organizado por el entonces director del Centro de Cálculo de la Universidad de Bilbao (embrión de la actual UPV-EHU), Francisco Garijo, se desarrolló en Marzo de 1980 en Lejona. En el programa del mismo nos encontramos con temas como métodos heurísticos, matemáticos, lingüísticos, difusos, así como distintos tipos de aprendizaje (con tutor, sin tutor, autoaprendizaje), todo ello con aplicaciones en robótica y música, dos de los dominios en los que Ramon es considerado referente a nivel mundial.

24.6 Para terminar

En las líneas anteriores hemos visto algunos aspectos de la trayectoria y el quehacer de Ramon en un periodo de tiempo clave para su formación y desarrollo personal. Nos hemos encontrado con la actividad de una persona vitalista, positiva y en cierto modo visionaria, que supo conjugar

el rigor y el compromiso científico con otro tipo de actividades de ocio y disfrute de la vida.

Querido Ramon, he comenzado estas páginas felicitándote por tus 60 años. Me gustaría terminar deseándote una larga vida inspirada por los mismos valores que han regido tu existencia durante “esta primera parte”.

ZORIONAK RAMON ETA URTE ASKOTARAKO!!

Capítol 25
Nota Personal

Joëlle Rey

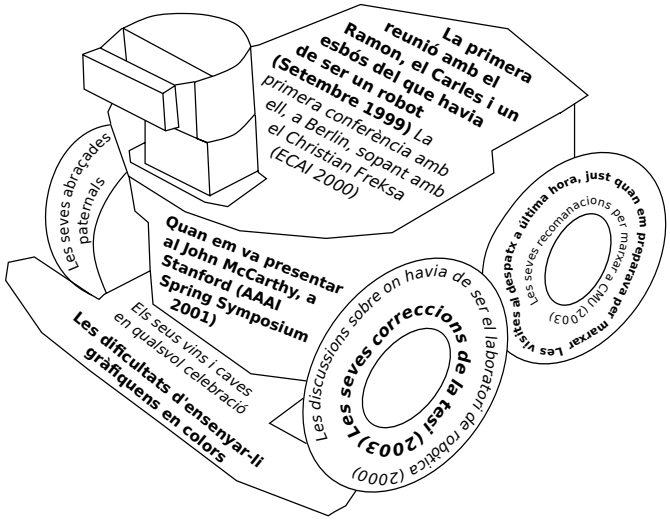
Això va passar en una època llunyana en la que els que són actualment becaris a l'IIIA ni havien nascut. A en Ramon l'havien admès a la Universitat de Berkeley i havíem marxat a Califòrnia per viure les precarietats de la vida d'estudiant. De fet, a part d'un xec que ens enviaven de tant en quant les cooperatives de Mondragón i d'uns estalvis nostres, no en teníem ni cinc. Jo intentava guanyar-me les garrofes fent traduccions, classes de francès i substitucions ocasionals als Serveis Comercials del Consulat Francès de Sant Francisco. En un moment donat, en el que estàvem en una situació de bancarrota total, em va contractar el Sr. René Verdon, propietari d'un restaurant de San Francisco anomenat "Le Trianon", per fer unes feines de traducció i de redacció de textos en francès. El Sr. Verdon havia estat el cuiner d'en John i la Jackie Kennedy quan estaven a la Casa Blanca. Després de la mort d'en Kennedy, aquest excel·lent cuiner francès, fastiguejat per la poca sensibilitat gastronòmica d'en Johnson que s'alimentava essencialment d'hamburgueses amb chili, va deixar el seu càrrec de Chef de la Casa Blanca per anar-se'n a Califòrnia i obrir el seu restaurant. La meva feina era puntual i va durar unes tres o quatre setmanes. Quan vaig acabar, a més a més de pagar-me esplèndidament, el Sr. i la Sra. Verdon, que eren molt amables i gens estirats, em van convidar a anar a sopar al restaurant amb el meu marit. "Le Trianon" era d'allò més chic amb un tio en uniforme davant la porta que es precipitava per anar a aparcar-te el cotxe quan arribaves. En Ramon i jo vivíem en el ambient mig hippy de Berkeley i teníem

Joëlle Rey
UPF, e-mail: joelle.rey@upf.edu

una furgoneta Volkswagen T2 tota abonyegada i amb para-xocs de fusta. Evidentment no ens podíem presentar al restaurant en aquest vehicle. En quant a vestuari, en Ramon només tenia texans molt desgastats i la nostra situació precària no ens permetia fer despeses innecessàries. Per sort teníem molt bons amics. Un d'ells, en Jean Lasserre, del LAAS de Toulouse ens va deixar el seu cotxe, un Ford Pinto, que no era nou però era un tipus esportiu que "donava el pego". Pel que fa a la vestimenta, en Piero Bonissone, li va deixar a en Ramon un vestit d'allò més elegant (un traje pura elegància italiana). Total, que varem anar al restaurant amb el cotxe d'en Jean i el vestit d'en Piero; quasi res era nostre, només la gana... Però el sopar va ser de primera i ens ho vàrem passar molt bé!!!

Capítol 26
Records 1999-2012

Dídac Busquets



Dídac Busquets
Imperial College, London, e-mail: didac.busquets@imperial.ac.uk

Chapter 27
Ramon López de Màntaras: A Good Citizen of Science

Stan Matwin

I consider it an honour to write Ramon Lopez de Mantaras. I first met Ramon more than twenty years ago, when we were involved in the professional community fostered by the European Machine Learning workshops, which later became the European Conference on Machine Leaning and Principles and Practice of Knowledge Discovery in Databases (ECML PKDD). Ramon's presence was notable, due to his contributions to scientific presentations and discussions, his participation in community meetings and, of course, his enthusiastic involvement in the social aspect of these gatherings. As Ramon and I got to know one another better, it became apparent that we share views on Artificial Intelligence, research integrity, the importance of research in society and many other issues. As Director of the Institut d'Investigació en Intel·ligència Artificial in Bellaterra, Ramon invited me to conduct research there for a year, during which our collaboration and friendship grew stronger. It was a great opportunity to take part in stimulating discussions with Ramon and his colleagues, often over lunch, as we explored everything from technical issues and research papers, to world affairs and the news of the day.

If I could use only one word to describe Ramon, it would undoubtedly be 'integrity'. Everyone who has worked with him has benefitted from his fair and impartial reviews, opinions and advice. However, he

Stan Matwin,
University of Ottawa, e-mail: stan@eecs.uottawa.ca

is also flexible, and quite capable of changing his views when othersÕ arguments are convincing and based on sound premises. He has deep respect for those who have advanced our field; people like Lofti Zadeh, one of his mentors. Conversely, he doesnÕt have much time for people who are too invested in self-promotion and media attention.

Another word that describes Ramon is ‘ethical’. This applies to the principles of research ethics —refereeing, avoiding conflict-of-interest (or even the appearance of such) and giving credit where it is due— as well as to his strongly held beliefs in other areas. An example of this is his unequivocal stance against military applications of Artificial Intelligence research; in particular robotics, where so much modern research is driven by military needs and defense funding.

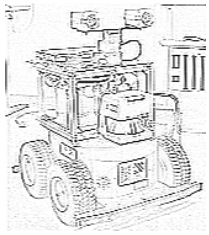
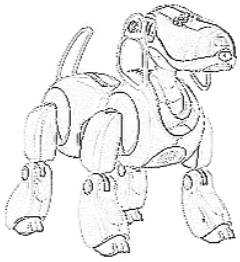
One more word to describe Ramon is ‘supportive’. He can always be relied on to take part if needed, whether as a committee member or reviewer, a referee, a guest speaker or in other cooperative roles. I especially enjoyed his support in 2006-7, when he served as Chair of ECML PKDD 2007 in Warsaw. I believe he was aware how important it was to me for my alma mater host this event, and in a true Ramon fashion he endorsed our bid, thereby increasing our chances of being selected. His participation on IJCAI and ECCAI boards, where he has always taken on important leadership roles, are examples of his interest in giving back to the community. He is always available when you need his opinion or advice, whether it is about research, the practicalities of living in Barcelona, or a good bottle of wine.

If all the lofty academic praise gives the impression that Ramon is a single-minded researcher, that is certainly not the case. His diverse interests and abilities illustrate a sophistication rarely found in this age of specialization and linear focus. He is a wine connoisseur, a poet and an expert pianist with a keen understanding of jazz. He also participates in physically-demanding, competitive roller-blade rallies. And of all my European friends, Ramon has the best understanding of North American culture, politics and music. When you discuss virtually any current topic with him, there’s a good chance you will learn something new.

I am convinced that the world would be a better and more interesting place, and Artificial Intelligence would be further advanced, if there were more people like Ramon. I also believe that whoever coined the term ‘a good citizen of science’ just might have had him in mind.

Capítol 28
De programar robots, ...a educar criatures!
A CBR-based approach

Raquel Ros


Raquel Ros
Imperial College, London, e-mail: raquel.ros@imperial.ac.uk

Retrieve	**Reuse**	**Revise**	**Retain**
Fer la comanda.	"Treballar-ho" amb la parella.	No funciona a la primera.	Provar molts cops fins a tenir èxit.
Fer seguiment de la comanda.	Visites mèdiques, cursos pre-part, exercisis (yoga, piscina, caminar...).	Hores d'espera més llargues de les previstes.	Duplicar el temps d'espera.
Construir escenari al laboratori.	Preparar la casa (habitació, zona de joc, bany).	Els canvis necessaris són més grans del planejats.	Flexibilitat a l'hora de realitzar els canvis necessaris a la casa.
Compra d'accessoris, material de recanvi i eines.	Compra de roba, joguines, medicines, productes infantils.	La gama de productes és molt gran i la tria es fa complicada.	Provar diferents marques en petites quantitats fins a trobar les més adequades.
Recollida de la comanda.	Naixement del bebè.	Pot avançar-se o endarrerir-se. Temps d'espera per l'entrega real molt variable.	Ampliar el rang de dates per la possible arribada. Comptar amb més hores extres d'espera.

Retrieve	**Reuse**	**Revise**	**Retain**
Carregar el robot.	Donar de menjar al nadó.	No és evident la quantitat de menjar necessària.	Proveïr una quantitat aproximada però amb la previsió que en poques hores pot necessitar-ne més. Amb el temps les bateries es regulen més fàcilment.
Engegar el robot.	Despertar al nadó.	No es 100% efectiu.	Ampliar l'interval de temps per assolir l'objectiu.
Apagar el robot.	Fer dormir al nadó.	Més complicat del que sembla, sobretot els primers mesos.	Fer servir diferents estratègies i tècniques fins a trobar la més adequada.
Netejar el robot.	Fer el bany del nadó.	Sovint es produeixen pèrdues de líquids no planejades.	Disposar de material de recanvi extra.
Discutir idees amb supervisor.	Discutir amb la parella, els sogres, tiets, germans....	Explosió d'opinions contradictòries.	Considerar només l'opinió de la parella i ignorar la resta.
Desenvolupar mòduls de percepció del món.	Desenvolupar tècniques per motivar l'atenció del nadó en el seu entorn.	El sistema de percepció és molt més efectiu del previst i millora en funció dels estímuls proveïts.	Incrementar els estímuls el més possible.

Retrieve	**Reuse**	**Revise**	**Retain**
Desenvolupar algoritmes de raonament.	Explicar el funcionament de les coses i ajudar-lo a comprendre-ho.	El sistema de raonament és més avançat del previst i millora en funció de la retroalimentació proveïda.	Incrementar la informació disponible el més possible.
Definició i implementació d'accions (navegació, manipulació).	Ensenyar-li a caminar i manipular.	El sistema actuador és primitiu al principi però de seguida adquireix experiència i millora ràpidament.	Ampliar la gama d'accions possibles a mesura que domina les bàsiques.
Implementació de comportament no-verbal.	Desenvolupar llenguatge no-verbal.	Rang d'expressions molt superior a l'esperat i més efectiu.	Incrementar la utilització de gestos i expressions per motivar l'aprenentatge.
Desenvolupar protocols de comunicació.	Desenvolupar llenguatge verbal	Aprenentatge exponencial.	Proveïr activitats variades per motivar l'aprenentatge el més possible.
Desenvolupar protocols de coordinació.	Desenvolupar les seves capacitats socials.	El sistema millora si és exposat a una major interacció amb els agents de l'entorn.	Incrementar el contacte amb agents fora de l'àmbit familiar.

Chapter 29
Ramon López de Mántaras

Pedro Meseguer

My name is Pedro Meseguer. Currently, I am scientific researcher at the Artificial Intelligence Research Institute (IIIA) of the Spanish Council for Scientific Research (CSIC). I did my PhD thesis under the supervision of Ramon López de Mántaras, more than 20 years ago. Here I summarize some memories of that period, as well as some points of Ramon's character.

29.1 PhD Advisor

I met Ramon first time in the late 80's in Blanes. At that time I was an undergraduate student, in the last course of the Computer Science Degree at the Technical University of Catalonia. I remember I was introduced by Carles Sierra. Soon I became engaged with the activities of the Blanes group, first producing a rule editor for the expert system shell MILORD, and secondly being involved in a european project on expert systems validation, where I realized by PhD.

In the preparation of that european project, I had the first insights of Ramon's character. I realized that Ramon was passing some of my opinions into the successive versions of the Technical Annex of the project

Pedro Meseguer
IIIA-CSIC, e-mail: pedro@iiia.csic.es

in preparation. In that sense, Ramon was not blocking my initiatives (although surely some would be too naive). The effect is that I felt personally motivated on that project because it contained my contributions uncensored by him. Over the years, I could appreciate more of this Ramon character: he does not block students; on the contrary, he accepts and encourages student initiatives to study related fields, go deeper in this or that area, meet other researchers, set up external collaborations, etc. Students treated in that way have a similar reaction to mine: they have an extra motivation to perform their duties because they feel personally involved in the research task.

In addition of supporting my initiatives, I want to underline other trend of Ramon's character which is availability. He was always available to sign administrative letters related with my status of PhD student, to have meetings on the project or on my PhD, to revise my writings, etc. I remember a Sunday evening where I went to his house in Sant Cugat, where he gave to me a preliminary version of my PhD thesis fully commented. I think he was travelling the next week, so we could not meet at the lab in Blanes. Ramon was sensitive enough to personal situations of PhD students. For instance I remember my difficulties with the English language, and Ramon was always willing to help, translation of my writings, allowing me to follow courses, etc.

Regarding guidance on the PhD topic, Ramon shared his experience as inspirator and developer of expert systems. In addition to his personal experience, he was always alert about contributions that could appear here or there. He was always bringing preprints or research reports from other labs which could have some relation with my PhD topic. The relation with Carles Sierra and Albert Verdaguer, main developers of the MILORD shell and the PNEUMON-IA application respectively, was also of great importance for me.

29.2 Scientific Leader

Ramon founded the IA group in the late 80's and he has been its scientific leader since. I joined that group as PhD student. After presenting my PhD I left the group for a few years and I came back in mid 90's.

As scientific leader of the group, one remarkable attitude of Ramon has been to allow an –almost absolute– freedom for the permanent mem-

bers of the group to do research. This freedom includes research projects, specific teams, relations with other labs, etc. This does not mean that he will not give advice or indicate directions to follow, but freedom is very much present in the daily activity of the AI group. This strategy has given very good results. A large majority of group members feel personally motivated and are very active at international level, where the name "IIIA" can be found in the most demanding AI conferences and specialized journals.

Ramon is a very dynamic person. In the early days of Blanes he was travelling a lot, with a frequency that a few people would be able to follow. From that period came the joke on Ramon quantum state, shared by PhD students and young post docs: "if you know were Ramon is, you do not know where he is going; if you know where he is going, you do not know where he is". As result of all this activity, the IA group gained visibility, establishing relations with most AI groups in Europe. Today Ramon remains extremely active. In December 2011 I met him by chance in Barcelona, a Saturday morning. He was with skate rollers and wearing a helmet, in a group with other skaters. He told me "we are doing a long distance race, now we go to the airport". Next Monday I received a picture with the travelled distance in that race: 108 km! And Ramon completed the race.

Another dimension of Ramon's character is his delegation capacity. In Blanes times, when Ramon was involved in multiple activities with very frequent trips, he showed a good capacity to delegate some of his duties in his collaborators.

On scientific achievements, Ramon did contributions in many AI fields, with special attention to approximate reasoning –he has a strong background on fuzzy logic– and machine learning –specially in induction trees and case-based reasoning–. I remember a sunny morning in his large office of Blanes, where Ramon was sitting as his table that was totally clean except for a notebook where he wrote the formula of his distance (Ramon synthesized an attribute distance for induction trees). Ramon was looking at that formula, as if he would like to see beyond the mathematical symbols and extract the secret relations among attributes in inductive tree learning.

This brings to my mind a fact: tables in Ramon offices have always been well-ordered, often with not many papers on top. Not being a formal person, I can only interpret this as an indirect sign of his internal order.

In general, Ramon is good dealing with people. He has some psychological insight, and he communicates gently with most people. This is very positive to manage a large group, with permanent researchers, post docs, engineers, PhD students, etc. Around four years ago, Ramon became director of the IIIA –task that was nicely developed up to that date by Francesc Esteva– position in which he remains. In addition to the hard task of management of the Institute in days of economical difficulty, I want to underline his efforts to keep a good atmosphere of collaboration between the different members of the AI group.

Chapter 30
Imprints of an unreliable memory from the floor of a pub under the Antipodes

Austral[i]opithecus Sydneus Bulgaricus

Writing this note has been an exciting and challenging endeavour, not necessarily because of the wooden floor. Originally, the plan was to get separate scientific and personal notes. My several attempts to follow this delineation ended up sinking into the swamps of Die unendliche Geschichte. The two aspects seem highly intertwined to me Ð too much mutually embedded to separate them. Oh, I need a good kicking bottle of red - a Pasadena 'Pony Express' Zinfandel will do.

30.1 Where, when and how ... it had started

Interactions constitute a process that unfolds. The way interactions unfold can tell us a lot about the interactions themselves. John Deb asked me whether I would like to deliver in the second half of April 2004 a one week PhD course, related to data mining as part of the joint PhD program between IIIA and UPC in Barcelona. It was a great opportunity combined with few weeks in the Free University of Bolzano-Bozen and Aalborg University. Consequently, in the second half of April 2004, I was on the way to my first visit to Barcelona (in fact, to Catalunya). Three hours after I landed at 'Aeroport del Prat' airport I was on the train

Simeon SImoff
University of West Sydney, e-mail: S.Simoff@uws.edu.au

to Portbou, looking for Hostalric. An hour later, I was looking for reaching the next goal - the cook-place of several whole pigs, in a hope to find the Master Chef steaming around! Indeed, there was such place (with some pig remnants left there) and bunch of charming hosts took control over the rest of the night - no need to mention the well-known names behind this and similar events that took place in the years to come. It was a magic jump straight into the company of a lovely bouquet of colourful personalities from two neighbouring institutes in Universitat Autònoma, whom I had seen for a first time and who already set high the standards and expectations.

Fig. 30.1: Ne-e-etworkh-kh mining

For a Libra, doing just a course on data mining sounded slightly trivial —at the time there were several classics in the field. I decided to develop a course on Network Mining, which seemed to be an emerging new area (the term was not even there yet). It was an intensive preparation and delivery, the impact of which on the deliveryman is evidenced in Fig. 30.1. In 2004 this seemed to have been a useful effort for the students, taking in account the subsequent boom in social networking

technologies and modelling at the end of the first decade of this century. I gave at UPC a seminar on smart trading systems in information-rich environments, and Carles got me for a joint Friday seminar in the neighbouring institute. The presentation was meant to introduce some speculation around the interactions between intertwinning This is when I met Ramon for a first time in the form of the first and on the spot question during the seminar with respect to Fig. 30.2 — "It a-a-a-ll looks good, but how does it actually work?". No cock-and-bull stories! This actually set the tone of our relation in the future. Later after the seminar we continued from that point. The slide presented part of the work coming out of the second year of our (John, Ian Wilkinson, a great business professor from UNSW, and myself) "Shaping the e-Markets" ARC (Australian Research Council) Discovery project. It was exactly the spot where we have focussed — what actually should be going through the little arrows to the negotiation agent in Fig. 30.2. Ramon's comments about different knowledge representations that the mining agents can use to communicate their "findings" to the negotiation agent came as an olive oil to a squeaking tap. In fact, this setup the relation

30.2 Long live CBR

In the "Curious Negotiator — committing to what is maximally non-committal" project — the visual essence of which is encapsulated in one of those nice diagrams (in Fig. 30.3) that makes you believe that it is doable, there was a space for case-based reasoning (CBR). I have developed a special relations with case-based reasoning and mixed feelings about it, prior to hitting in 2006 and 2008 the pro-CBR barrage of words from the *Big Contributor, Fan and Supporter of CBR from Bellaterra*!

A glass of Oscar Shiraz 2006 reminded me to provide a bit more history of my work. In the mid 1990s my first interaction with the practical implementation of the concept was during the early years with the Key Centre of Design Computing and Cognition at the University of Sydney. A colourful team of researchers working in a diverse spectrum of disciplines, including Mary Lou Maher, Terry Purcell, David Gunaratnam, Diella Bolzan, Fiona Kerr, Phil Tomlinson and myself developed an educational multimedia case library of structural designs, populated with buildings from Sydney [3]. The motivation for the development of

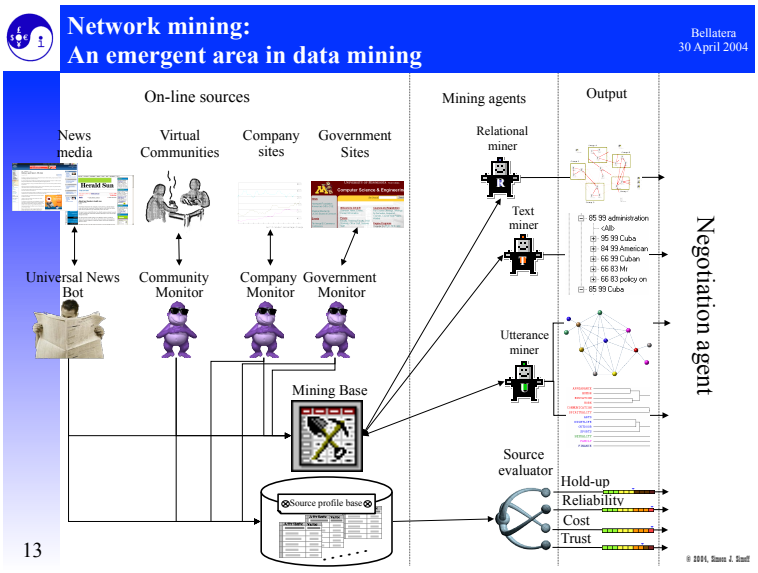


Fig. 30.2: Must be the number 13th . . .

the library was two-fold Ð represent and manage complex design cases and formalise a typically informal body of knowledge. For the user the SAM cases appeared as a collection of Web pages, structured around a hierarchy of concepts, which to some extent can be treated as sub-cases. In addition to the Web page collection, the case-library included an underlying flat attribute-value representation. Case retrieval included three strategies:

Search by (words in) the name of the building This retrieval strategy returned a list of buildings sorted according to two types of buildings: wide span and tall buildings.

Terminology and parameter search This retrieval strategy required from the user completing a (lengthy) form describing the structural design he/she was looking for in terms of the architect, engineer, types of structural system, structural materials, etc. SAM then returned a list of all buildings that satisfied a partial match with the specified terms

and parameters. The buildings were ranked according to how close the match was according to selected distance measure.

Text string search This retrieval strategy was similar to the Web search engines at the time, which looked for a user specified list of words that might be used in a case description, returning a list of cases that included the specified strings in the case text description.

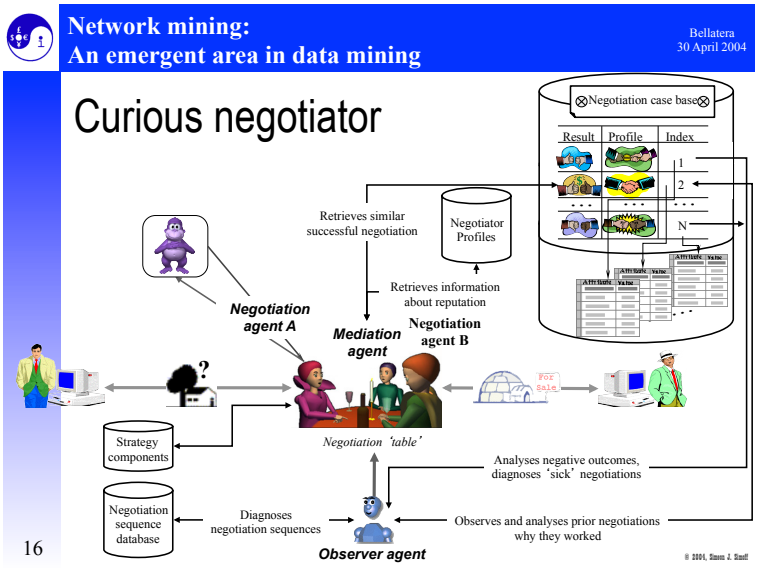


Fig. 30.3: Cases, cases, cases . . . hip-hip hooray CBR

The system did not have an automated case adaptation cycle, but included case modification and addition. Eventually, it had grown to a substantial collection of buildings. Eventually this became the platform for my first application (jointly with Mary Lou) for a large research grant from the Australian Research Council (ARC) in 1997 for knowledge discovery from multimedia case libraries. A glass of Margaret River Leewin Estate CabSov straightened what the project was about - it brought together case-based reasoning and unstructured data mining, and applied them to real-world building industry data. Funded for 1998–2000 the

project developed some text and image mining techniques that eventually fed their output into additional indexing of multimedia cases. However, when I moved to UTS in the middle of 2000, my research focus went back to mining unstructured data. Case-based reasoning went off the focus and I didn't really explore its range of problem solving capabilities.

Not until the "Curious Negotiator"! There part of the project was crying for Ramon — develop mediators that use CBR. At this point of time I came across an article [2], where the list of authors on its own looked like "The CBR Legends" (I am sure Paul Allen would have sponsored a basketball team of a similar magnitude). Going only through that list required a glass of a Glacier Sauvignon Blanc from New Zealand. After the glass — oh, what a luck to have the first author willing to get into the CBR mediation adventure.

Oh, with all those glasses behind, I shouldn't miss the moment to recollect some of the wisdom ...

30.3 The wisdom stream

Many times I have told myself to write down or record some of the steam of wisdom and humour constantly rock'n'rolling once you get in that black car ... actually, let start the small recollection from the floor with that one.

Wisdom for sunny countries Avoid owning/renting a black car in a country where the sunny hot days are dominant (The weight of this rule increases if that car is essential for the wellbeing of your mates! In the days when the topic of global warming was payed lesser attention in the media, one might have got away cooling such car with the engine on, air conditioning on maximum and the front door open).

Wisdom preventing scientific Alzheimer's Conference badges can be the aspirin for Alzheimer's in terms of (scientific) memories (Don't give up to all those appealing to your environmental consciousness and increase your collection of badges — one day that can turn vital when tracing the story of your field).

Wisdom about artificial intelligence for wine Drinking wine is not enough to develop the artificial intelligence that can start buying it for you.

This is an ultramicro sample of the volume that can be collected and published for the benefit of the humanity (there may be a certain bias towards one part of it) — again, this is just the beginning.

As an admirer of Ramon's work on AI and music, including the elegant essay [1], there seems to be an untapped area for a joint fun in the next decade — the development of the online wine buyer.

30.4 In the next decade: The Wine Smarty

Searching for a 'wine adviser' on the net will bring plenty of wine advising sites, ranging from those who offer personal and professional wine consultancy services, to independent wines and winery guides. They all provide opinions, descriptions, using a special language with metaphors, analogies, word impressions to describe the perceptions that certain wine can leave. Fig. 30.4 shows an example of such description, taken from the Australian wine auction at Graysonline. The diversity of descriptions even in the same shop or auction differs, demonstrated in Fig. 30.5. Well, what shall the Wine Smarty if my guest is a connoisseur from IIIA and we want to organise a night with Spanish wines. Shall it go for Condado de Oriza Roble available for bidding at the Australian site? Getting information on the prices from different sites, for instance from German retailer (Fig. 30.6), up-to what price it should be bidding?

Go Wine Smarty, Go!!! This can be a nice challenge for the next decade that can complement the achievements of AI in music and challenge the last wisdom in the sample.

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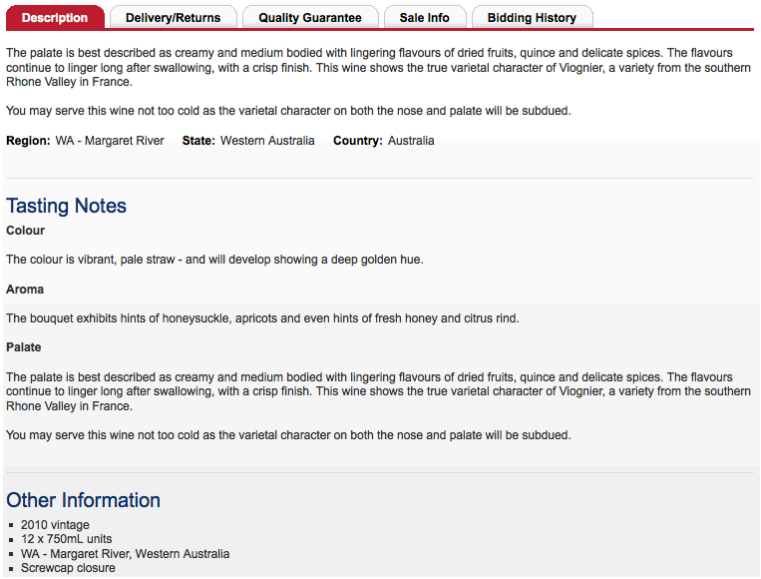

Fig. 30.4: How does this one taste?

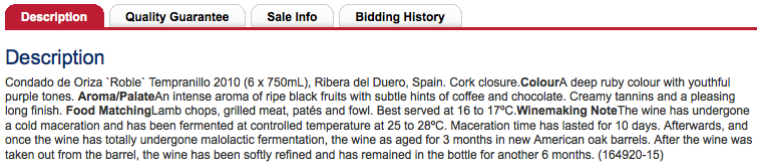

Fig. 30.5: . . . and how does this one taste?

Fig. 30.6: . . . oh, these seem to be in Aussie dollars . . .

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Chapter 31
Grande Ramon!

Hector Geffner

I cannot remember exactly when or where I first met Ramon but it was probably in the early 90's. We then met many times especially since I came to work to Barcelona in 2001. Ramon was already a well known AI pioneer in Catalunya and Europe and known world-wide for his work in Machine Learning, Case-based Reasoning, and Robotics. Yet our conversations were about everything and seldom about AI. Ramon is an athlete, a musician, a larger than life character, full of energy and warmth. He speaks clear and loud, knows everyone and everything, and radiates affection and optimism wherever he goes. I love to see Ramon at conferences, in particular when I am with my wife. We can then stick to Ramon, talk about everything human, and be sure that we will have fun and not get bored. Marina, my wife, says also that Ramon has the looks of Don Quixote and I think she is right. He is also as romantic and generous but not naive at all. What Ramon has managed to accomplish in the world of AI, and in the world of Catalan AI, would not be otherwise possible. Ramon has planted the seeds whose fruits are for all of us to see.

I'm thus happy and proud to join this celebration wishing Ramon many more years of productive work and fun.

Hector Geffner
ICREA & Universitat Pompeu Fabra, e-mail: hector.geffner@upf.edu

Happy birthday Ramon! But don't believe those who are telling you that you are now a sexagenarian. It is not true. It must be a mistake of the calendar. You are the spirit of youth.

Capítulo 32
Pimavera en el Trópico

Pablo Noriega

Era marzo del 1988. Íbamos rumbo a Cancún, seis pasajeros en una gigantesca Ram Charger". La víspera había sido la clausura de la Reunión Nacional de Inteligencia Artificial y seguramente los seis habíamos trasnochado - como todas las noches previas. Tengo la vaga impresión de que habíamos ya visitado alguna zona arqueológica y pasado por más pueblos de los que merecíamos. Supongo que padecíamos el agobio del calor que hace en Yucatán antes de la temporada de lluvias y si no éramos ya presa del aburrimiento, corríamos peligro. Tal vez fuera Santiago Negrete el instigador o quizás Pati Arévalo, y quiero recordar que algún elefante se balanceó, no estoy seguro. Pero si el sopor del trópico difuminó mis recuerdos del cómo y el cuándo, mi memoria conserva con feliz nitidez la imagen de Ramon dirigiendo de rodillas, desde el asiento delantero del coche—que corría a toda velocidad—el segundo movimiento de la Primavera de Vivaldi, con una entusiasta interpretación *a capella* de los seis pasajeros. Interpretación que si bien no desmentía la precaria formación musical de casi todos, sí que ponía de manifiesto las cualidades organizativas y de liderazgo de Ramon, así como su feliz afición por el desmadre.

He tenido la suerte de compartir un viaje de casi treinta años con Ramon y esta pertinaz experiencia me permite y me obliga a dejar constancia en este volumen de otra cualidad que lo caracteriza: la generosidad. Ese retrato del científico brillante, el maestro prudente, el administrador

Pablo Noriega
IIIA-CSIC, e-mail: pablo@iiia.csic.es

eficaz y el líder arrollador que sin duda pintarán los demás escritos de este homenaje, quedaría en vil esbozo si no se llegase a mencionar la generosidad del retratado. Una cualidad que se expresa en él a través de gestos simples como festejar una broma, que subyace a ese disculpar sin reproche los tropiezos y que se multiplica en reseñas, comisiones y consejos. Una cualidad que Ramon prodiga en familia, colegas y causas perdidas como esas festivas disputas con Enric, Carles o Pere, o en la organización semanal del seminario del IIIA. A pesar del vasto alcance de esa generosidad discretísima, quiero aquí particularizar unas cuantas ocasiones en las que el beneficiario de ella fue México: la fundación— con José Negrete y Pepe Cuena— de la Sociedad Mexicana de Inteligencia Artificial y de los congresos de Iberamia, el dictamen de aprobación del Laboratorio Nacional de Informática Avanzada, los consejos para orientar la política informática del país en el marco del Acuerdo de Libre Comercio de América del Norte (NAFTA), las numerosas conferencias invitadas en congresos y mesas redondas de estudiantes y de profesionales, así como su ahora ya inevitable membresía en la comisión evaluadora del Instituto Nacional de Astrofísica, Óptica y Electrónica. Señalo para acabar una más, la participación de Ramon en la celebración de los cincuenta años de la computación en México, no sólo por la honrosa distinción de ser el único extranjero invitado al evento sino porqué, en una demostración inequívoca de generosidad, se puso corbata. Hecho constatable en la foto que acompaña esta nota.

El viaje que mencioné al comienzo de este texto lo acabamos Ramon y yo en un autobús de tercera, que desanduvo la misma carretera a lo largo de toda la noche. Habíamos dejado a nuestros compañeros de concierto en Cancún, donde dos de ellos acabaron firmando paga y señal de un condominio en tiempo compartido del que jamás se ha sabido si acabaron de pagar. Eso fue fruto tal vez de la euforia del viaje o quizás de la otra, al fin generosa, primavera, la que la sangre altera; *i que sigui per molts anys.*

Figura 32.1: R L de M i B. Palacio de Minería. México. 13.11.08.

Chapter 33
Scholar, Engineer, Leader, Advisor, Artist, and Friend

Christian Freksa

33.1 Acquaintance

Ramon and I got connected through the unparalleled scientific networking abilities and hospitality of Professor Lotfi Zadeh at the University of California in Berkeley. I met Ramon in 1978, when he came together with Joëlle Rey from Toulouse and joined Zadeh's expert systems research group in Berkeley to work for a Master of Science degree. I also was a graduate student in Zadeh's group at the time. Ramon had interests in pattern classification and learning while my research was in pattern characterization using fuzzy sets and relational approaches. This was close enough for us to collaborate and to learn from each other through discussions, writing papers together, and jointly participating in workshops and conferences. Already at that time, Ramon was well organized and clearly structured whereas I was probably a bit more chaotic. When we met privately, Ramon often played the guitar, sang wonderful songs, or put on a record by the Catalan musician Lluís Llach.

Ramon returned to Europe in 1979 to join the IKERLAN Research Center in Mondragón, Spain, where he developed an expert system for designing electrical power transformers. Ramon arranged for me a three-month teaching appointment at IKERLAN which left me with sufficient time and lots of inspiration to write a full draft of my doctoral thesis.

Christian Freksa
Universität Bremen, e-mail: freksa@sfbtr8.uni-bremen.de

A few months later (in 1980) Ramon and I attended the International Congress of Psychology which was held behind the 'Iron Curtain' in Leipzig / East Germany. We took the opportunity of our presence in the German Democratic Republic to visit an Artificial Intelligence colleague in the nearby city of Dresden. Herbert Stoyan was a political dissident who had officially requested release from East German citizenship — an illegal act in that country. His private telephone line had been disconnected by the authorities, and he and his family waited for agents to pick them up and throw them in jail — as this was the regular punishment for this illegal act. As the Stoyans did not have a telephone (and email did not exist in Europe at that time!), Ramon and I could not announce our visit. We searched for their house and rang the bell. Two 3- and 5-year old boys opened the door, saw two strangers dressed with coats, and shouted to their mother, 'mom, they are coming'. Fortunately, neither Ramon nor I spoke in the local Saxon language, and we were easily identified as foreigners and potential friends rather than as the STASI agents they had been waiting for. They called Herbert home from work and arranged a spontaneous feast, 'the last celebration before they will pick us up'. Herbert gave us the first copy of his LISP book that had just come off the printing press plus some highly delicate personal documents that we were asked to bring to the West. [A few weeks later the Stoyans actually were thrown in jail.]

After completing my thesis in Berkeley, I moved to Munich to take up a postdoc fellowship at the Max Planck Institute for Psychiatry. Ramon joined me a bit later in Munich for an extended research visit and we wrote a paper on An adaptive computer system for linguistic categorization of "soft" observations in expert systems and in the social sciences. Over the following years we discussed on topics of fuzzy representation and reasoning, qualitative reasoning, human-computer systems, spatial competence in robotics, machine learning, case-based reasoning, and musical composition and style. We also collaborated in various committees of universities and scientific societies.

33.2 Career

For more than thirty years, Ramon has pursued an internationally highly visible scientific career in the area of Artificial Intelligence. He is a very

active, imaginative, and successful scientist who gives important impulses to the international AI community. Ramon received his academic education and training program at universities and research institutions of highest international standing. He obtained an electronics degree in Mondragón (1973), an automatic control degree in Toulouse (1974), a doctoral engineering degree in Toulouse (1977), a Master of Science degree from UC Berkeley (1979), and a doctoral degree from Universitat Politècnica de Catalunya (1981). Consequently, he has been able to participate in establishing L'Institut d'Investigació en Intel·ligència Artificial (IIIA), a research institute that has gained high international reputation. Not only is Ramon a successful director of this institute, but he also made sure that new leader personalities emerge under his guidance.

Ramon has been a scientific mastermind both in developing new research paradigms in AI and in building up this new research field in Spain 'from scratch'. From the beginning, he applied the highest international standards to his research group and thus enabled his students and researchers to be visible and to participate on the international level of competition early on. Ramon carried out remarkable pioneering work in a number of different research areas including technical and medical expert systems, formal validation systems, and cognitive robotics. His creative imagination and his multi-talented personality led him to successfully apply his technological expertise to a completely new domain, the domain of musical composition and to achieve wonderful results: he demonstrated impressive automated conversion from inexpressive to expressive music.

Ramon's contributions range from fundamental theoretical contributions to applications in domains like medicine, technical diagnosis, and musical performance. He published well above two hundred scientific articles, for the most part in highly competitive international journals and conferences, and he received numerous awards for his scientific contributions. Through his visions, through hard work, through his success in his research field, and through his ability to convey the fascination of the field to other people, Ramon has been able to attract and train highly qualified students and researchers. Meanwhile, several of his students have successfully built up new research areas themselves and also have become internationally recognized scientists.

The IIIA at Barcelona has become an internationally renowned research center for Artificial Intelligence of the highest quality; it is known as the AI center of Spain. Ramon is largely responsible for its success.

Thus it came to no surprise, that the International Joint Committee on Artificial Intelligence selected Barcelona as the site for the world conference IJCAI 2011, relying on the proven abilities of Ramon and his highly competent team.

Ramon also is a much sought-after advisor inside and outside of Spain. This is reflected in numerous invitations and honors he has received over the years. Among them are international prizes for his pioneering work and honors in recognition of his dedicated service to the international AI community. In his way of conducting research, to advise students and colleagues, to lead his institute, to serve the scientific community, to take position on societal issues, to participate in cultural affairs, and as an upright human being, Ramon is a role model for young intellectuals who will be the scientific leaders of tomorrow.

33.3 Epilogue

It is difficult for me to imagine what Spain would be like without Ramon, as I connect many pleasant and important personal and professional experiences in the Basque country and in Catalonia with Ramon and Joëlle. His advice in scientific, strategic, and ethical issues of contemporary information science and technology have been very important for me and his way of doing research and leading his institute are admirable. Ramon's judgment and opinion have influenced our research field and the attitudes of researchers in the field on an international level in a very positive and human way.

Dear Ramon, continue to progress as you have in the past, continue to enjoy research, music, poetry, skating, skiing, wine, your family, life in general for many years to come — and continue to fight for your values of humanity!

Capítol 34
Memòries

Carles Sierra

"Memory is everything. Without it we are nothing."
Eric Kandel

A mida que he anat acumulant anys, i ja en són uns quants, la figura d'en Ramon ha anat creixent. Mirant enrera, es pot apreciar el que ha construït, la visió que va tenir als anys vuitanta i com va saber jugar les seves cartes de manera intel·ligent. El que ha fet no és gens fàcil. Va crear l'IIIA i l'ha situat com un referent a nivell internacional en recerca en Intel·ligència Artificial. La qüestió és que al meu entendre ha aconseguit això sense una planificació detallada (de fet planificar és una feina difícil i feixuga al nostre país —titànica fins i tot), sinó més aviat aplicant uns principis bàsics, unes regles del joc que han funcionat molt bé: transparència, responsabilitat i voluntat de servei.

En Ramon sempre ha explicat clarament els criteris en que ha basat les seves decisions i s'ha esforçat en crear consensos. Ha demanat que la feina es fes bé i que tothom respongués de les accions fetes. I ha basat les relacions dins l'IIIA en un context de procurar pel bé comú i deixar les individualitats de banda. És a dir, ens ha transmès un cert sentit de sacrifici pels altres. Crec que això ha estat la base sòlida que ara ens manté. I que ens permetrà superar la crisis enfortits, perquè no hi han recances del passat.

Carles Sierra
IIIA-CSIC, e-mail: sierra@iiia.csic.es

He escrit molts articles amb en Ramon. Segons en DBLP vint-i-dos fins a data d'avui. Déu n'hi do! Va ser amb ell que vaig aprendre a estructurar les idees i el discurs perquè fos mínimament comprensible. He mirat els primers articles que vaig escriure amb ell cap a mitjans dels anys vuitanta, i la veritat és que em semblen tan senzills i naïfs que estic per esborrar-los del curriculum! En qualsevol cas, en Ramon m'ha ensenyat a treballar com a científic i per tant puc anomenar-lo mestre. En uns paraula maca *mestre*. Em va ensenyar l'honestedat en la feina, a ser creatiu per damunt de tot i a disfrutar de la recerca. Haig de dir que crec que la majoria dels investigadors de l'IIIA han après d'ell la passió per la nostra àrea.

En Ramon va fer que jo anés molt ràpid a la vida. Vaig acabar la tesi en una mica menys de tres anys després d'acabar la carrera. De fet tot va anar tan ràpid que vam guanyar un premi l'any 1987 per un dels nostres primers articles conjunts acabat a altes hores de la matinada —acabat igual que l'ampolla de Chinchón que ens vam beure mentre escribiem les fórmules. Jo llavors no m'imaginava que això de la recerca fos tan divertit. Els premiats estan a la Foto 34.1 esquerra i en Ramon és vitorejat a la Foto 34.1 dreta. Van ser anys molt excitants i feliços per a mí.

Figura 34.1: (Esquerra) Premiats al 1987. (Dreta) En Ramon vitorejat.

Dels inicis del grup de recerca a Blanes, al CEAB, molts n'han parlat en aquest llibre. Crec que en Ramon va ser clau en triar els investigadors per la seva vàlua científica però també humana. En Ramon sempre ha proposat com a criteri fonamental per a la incorporació de nous members que fossin persones abans que investigadors. És un criteri que com-

parteixo i que crec que ha contribuït al bon funcionament de l'IIIA tots aquests anys. Un gran encert d'en Ramon.

Figura 34.2: (Esquerra) En Ramon desmentint les males llengües que diuen que no li agrada el futbol. Cap a finals dels 80. Encara li duraven les samarretes de Berkeley, que n'és d'estalviador! (Dreta) En Ramon després de dir que per a mí tot es fa en cinc minuts, rebent el que es mereixia. Any 2000 amb motiu del congrés *Autonomous Agents*.

Al gener del 1989 em va dir: *escriu, hi ha una plaça que sortirà cap a l'estiu i t'hi has de presentar*. Dit i fet, a escriure la tesi com un boig. I de fet em vaig casar al cap de set mesos d'acabar la carrera en part perquè semblava que aconseguiria una plaça de tècnic, com va ser finalment. Quan ho penso ara em sembla que jo estava boig, casar-me amb una beca de tres mesos en el primer any de tesis. Encara riuen a Madrid quan els vaig demanar el permís de vacances per matrimoni. Però com en Ramon transmetia aquella seguretat que ens menjariem el món i que tot aniria bé, no pensaves gaire i simplement feies. Tot i que segurament la meva genètica probablement ajudi, aquesta cantarella de fer coses, fer coses, fer coses, una mica l'he après d'ell. Sempre l'he vist enfeinat, atrefegat. Va haver-hi una època en que se'l veia ben poc el pèl per l'Institut. En deiem l'electró, perque no podies saber-ne la posició i el moviment alhora.

En Ramon sempre ha tingut una visió especial per saber els temes que seran importants en la nostra àrea. Al poc de mudar-nos al flamant nou edifici de l'IIIA a Bellaterra em va dir, *Carles aquesta àrea d'agents, promet. Perquè no t'hi poses.* A mi m'adradava força el tema i vaig pensar, potser té raó que és una àrea de futur. Em vaig lligar la manta al cap

i me'n vaig anar amb la família cap a Londres a passar un any i aprendre millor que era allò dels sistemes multiagent. Una de les decisions més encertades de la meva vida. Aquell any em va obrir les portes de l'àrea, em va permetre conéixer un nombre gran d'investigadors que després han crescut per esdevenir referents. Novament en Ramon la va encertar i amb la meva modesta aportació va aconseguir que l'IIIA esdevingués conegut arreu pels treballs en multiagents.

En Ramon sempre ens ha encoratjat a complicar-nos la vida. Jo diria que he après bé la lliçó. Com ell era el primer en organitzar coses, en particular un exitós FUZZ-IEEE al 1997, els demés ens apuntavem a la moguda. En Ramon sempre estava al costat per donar un cop de mà, com l'any 2000 en el congrés d'agents autònoms (Foto 34.2 dreta), i un cop de cava! (Foto 34.3).

Figura 34.3: Moment de relax després que s'acabés el congres d'Autonomous Agents el 2000 amb en Kenneth Forbus i en Christian Freksa. En Ramon bevent una cervesa entre copa i cova de cava.

Això de beure cava li ve de lluny. A finals del 80, a més de jugar a futbol (Foto 34.2 esquerra) ja aprofitava qualsevol ocasió per obrir una ampolla de cava (Foto 34.4 esquerra). De fet, beure cava ha esdevenin-

gut el seu esport favorit juntament amb el patinatge com molt bé ens recordava en Samy a la seva nota de la pàgina 203.

Figura 34.4: (Esquerra) En Ramon donant exemple de què s'ha de beure en hores de feina. (Dreta) En Ramon menjant calçots.

Un altre camp que en Ramon ha conreuat al llarg de la seva vida, i que crec que és gran part del seu èxit com a líder de l'IIIA, és el del moviment assembleari. Suposo que li ve de les arrels anarquistes de la seva família. Ell sempre parla de la seva iaia obrera i que lluny dels estàndars morals franquistes de l'època deia amb rialla soneguera: 'on hi ha pèl hi ha alegria!' Moltes decisions a l'IIIA s'han pres com a resultat de la discusió entre pars. A la foto 34.5 es veu el personal de l'IIIA a finals dels 90 en un retir 'espiritual' a la Vall de Núria. Reunions com aquesta i les costellades familiars (vegeu foto 34.4 dreta) ajuden molt a que el grup estigui cohesionat. Això de les costellades de l'IIIA ha esdevingut una tradició molt important, jo diria que del nivell del suquet d'en Portabella. El bo i millor dels investigadors en IA s'ha trobat i retrobat en aquestes costellades que van començar l'any 1987 en una masia d'un parent d'en Jaume Agustí i van continuar des del 1990 a Mas Puig, una masia que tinc llogada a Hostalric. Crec que en Ramon se n'ha perdut ben poques. Si repassèssim els noms d'investigadors reconeguts que hi han passat la llista seria llargíssima.

Figura 34.5: L'IIIA reunit a la Vall de Núria discutint sobre el futur de l'institut.

Bé, acabo. Ramon, espero que segueixis igual durant molt anys. La teva importància per l'IIIA és tan gran que crec que fins i tot després de mort haurem de fer amb tu el mateix que van fer amb en Jeremy Bentham: embalsamar el seu cos per posar-lo al bell mig d'un passadís al University College de Londres per inspirar les futures generacions! Així des de l'entrada a l'IIIA (Figura 34.6) vigilaràs perquè els valors que ens has transmès es mantinguin per sempre.

Figura 34.6: El cos embalsamat d'en Ramon López de Màntaras inspirant les futures generacions d'investigadors de l'IIIA des de la seva cabina a l'entrada de l'institut. En Dani segueix al peu del canó.