Exploiting Context Awareness in Information Agents

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1. INTRODUCTION

We present a society of personal information agents that work for a community of users and that are aware of the physical and social context of their users. We show how context-awareness is a feature that allows the agents to improve their performance when they work with limited resources in information spaces with a large amount of information. The use of context information allows the agents to focus their information search and, as a result of this, increase the quantity and quality of information delivered to the user. Moreover, we present an agent architecture with context-aware capabilities used in the COMRIS project [4] for assisting people attending to big conferences and fairs.

The research on context awareness is also increasing and is encouraged by the new possibilities that offers the mobile communications [2].

2. CONTEXT-AWARE FRAMEWORK

Our framework is composed by a collection of context-aware personal information agents (CAPIAs) working in an information space and a collection of human users interacting in a physical space. Moreover, we have two *mediation services*, namely an *awareness service* and a *delivery service*, connecting the information space of agents and the physical space of human users. The *awareness service* takes charge of pushing information from the physical space to the information space. Specifically, the awareness service provides to CAPIAs a real-time information about the physical location and movements of users. For instance, in the conference application the awareness service provides a real-time tracking of users location as well as the group of other users nearby a given user. The *delivery service* offers mediation and brokerage capabilities for delivering the information gathered by the CAPIAs to their users. For instance, in the conference application the information is sent as audio output by means of a wearable computer and as HTML pages by means of screen terminals scattered through the conference.

The society of agents communicates among them using a common ontology and a collection of interaction protocols. Our approach is to use the notion of *agent-mediated institution* [3] to specify the ontology and interaction protocols to be used by a society of agents for a particular application. In addition, agents should be able to manage with context awareness information. That is to say, a context-aware agent should be able to react dynamically when a new physical context information is received from the awareness service. Moreover, since the future physical and social context of the user is not known, a desired feature of CAPIAs is the capability of gathering information that may become relevant in a future context. For instance, in the conference application, when a user is at a specific exhibition zone the CAPIAs use the knowledge provided by the conference about the physical distribution of booths for trying to anticipate the next movement of the user.

In our framework, CAPIAs are based on the distinction between two kinds of information valuation, namely *interestingness* and *relevance* (see [1] for a detailed description). The *interestingness* of a given information is estimated by its intersection with the user model. For instance, in the conference application, a preliminary criterion for determining the interestingness of a given paper presentation is performed comparing the user interests (described as a collection of topics with different weights) and the keywords associated to the presentation (also described as a collection of topics with different weights). Then, other criteria such as the knowledge about the speaker or the users agenda increase or decrease the initial assessment.

However, depending on the physical and social context of the user and on the time some information may be more or less *relevant* for the user on each particular point of time. Information *relevance* measures this intersection of a given information with the time and the context of the user. For instance, in the conference application, when a user is nearby to an exhibition booth, the information related to the booth is estimated as more relevant.

We can say that, basically, the CAPIA go on their tasks, interacting with other agents (and other accessible information resources), to gather information that is *interesting* for their users. Concurrently, each CAPIA uses an *awareness service* to keep track of the whereabouts of its user and decides which information is *relevant* for her in a particular physical and social context.

3. CONTEXT-AWARE AGENTS

The architecture of CAPIAs has to fulfill adequately the requirements posed by context awareness. Essentially, the fact that an agent is aware of the context implies that i) the changes in the context cause immediate changes in the

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internal inference, and ii) some activities the CAPIA is pursuing cannot be completed until a satisfactory context is reached. On the other hand, it's not possible for an agent to wait until a context is reached and then start the relevant activity. Since the CAPIA needs to perform some interaction with other agents, and those agents may delay too much their answers, the agent could have to wait too long and see the context change again, losing its window of opportunity. Because of that, the CAPIAs has to anticipate the work on activities that can arise as future candidates. Thus, the architecture of CAPIAs has been designed for dealing with a high number of concurrently competing activities focusing on the most promising activities at any point in time. The architecture of CAPIAs consists on five components:

The *Communication Component* is responsible of communicating the agent with the society of agents.

The *Awareness Component* is responsible of processing the messages incoming from the awareness service and provide the *context model* to the agent. The context model holds the information provided by the awareness service and information elaborated by the agent from this basic context information. For instance, in COMRIS the physical location of the user and the current time is used, with the schedule of the conference, for inferring the social activity of the user. Moreover, the context model stores the history of context changes. This context trace is used in COMRIS agents for changing dynamically the relevance of an information and for generating the information to be delivered to the user. For instance, the second time a user coincides in a paper presentation her relevance is increased. An example of using the context trace in the information delivered to the user is the use of sentences such as "... also present in the robots demonstration".

The *Delivery Component* is responsible of generating the information to be presented to the user in the format adequate to the functionalities provided by the delivery service. In COMRIS the users receive information in two ways: by means of a wearable computer and by screen terminals scattered through the conference.

The *Agent Model* is the component that holds i) the user's interests and instructions and, ii) the interest landscape—i.e. the models about the other users. The interest landscape stores the profiles and interests of other users and a record summarizing the history of the interaction with their CAPIAs. The models about the other users are built from the interaction with the other CAPIAs and are influenced by the decisions taken by the user when she accepts or declines the suggestions received from the CAPIA.

The *Decision Component* is responsible of performing the tasks on behalf of user's interests. The Decision Component manages the collection of ongoing activities by dividing them in three groups: *Focused* activities pursued in an interleaved mode; *Pending* activities waiting for the answer of another CAPIA or waiting for a specific user's context; and *Candidate* activities competing for promotion to the focused group.

Given a set of activities, the goal of the decision component is to decide which candidate activities have to be promoted to the Focused group and which focused activities are demoted to Candidates. The decision component uses the context model provided by the awareness component to make those changes. We have associated to each activity a status record $\rho = \langle T, S, eI, eR, eC, aV \rangle$ where T is the type of the activity (information gathering, appointment, proximity, or reminder); S is the starting time (the time when the activity started); eI is the estimated interestingness of the information the activity is elaborating; eR is the estimated context relevance of the information; eC is the estimated confidence that the activity will succeed; and aV is the activation value.

The estimated confidence eC is a number that assesses the possibilities to succeed (for instance, for an appointment proposal activity the confidence that an agreement can be reached). eC is calculated using features such as the time delay in receiving answers or the flexibility in accepting counter-proposals.

The activation value aV of a given activity is a number that aggregates 1) the interestingness of the information eI with 2) the relevance of the information eR (given the current context and the activity type T) and 3) the estimated confidence eC that the activity will succeed. The activation values of all ongoing activities are used by the decision component, with a threshold mechanism, for determining which activities are promoted to Focused and which other are demoted to Candidates.

4. EXPERIMENTATION RESULTS

We performed experiments with populations of 2.000 users and their corresponding 2.000 CAPIAs participating in a conference with 420 different locations, during 6 hours, and where each user changes physical location (on average) every 10 minutes. Notice that users only visited 40 different locations as average. For our experimentation purpose we have used a context simulator that provides context information about users movements without requiring the existence of users physically walking around a conference building. Using this experiment setting, the amount of different information an agent handled during the 6 hours of the conference was limited to the 40 % of the total amount.

The experiments shown that the use of context awareness allows CAPIAs to deal with high amount of potential information without degrading significantly their competence. When an agent fully uses the awareness service to guide its work it's less affected by size problems since it can dynamically adapt its focus to those CAPIAs that are relevant given the concrete surroundings of its user's activity. Specifically, when the interest intersection of users decreases the use of context information arises as a crucial capability of the agents for focusing the information search.

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