Learning and Joint Deliberation through Argumentation in MAS

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Outline

- Introduction
- Justified Predictions in MAS
- Arguments and Counterexamples
- Argumentation-based MAL
- Experimental Evaluation
- Conclusions & Future Work

Committee

Committee

Input
Deliberation
Aggregation
Output

Committee: (1)A group of people officially delegated (elected or appointed) to perform a function, such as investigating, considering, reporting, or acting on a matter.

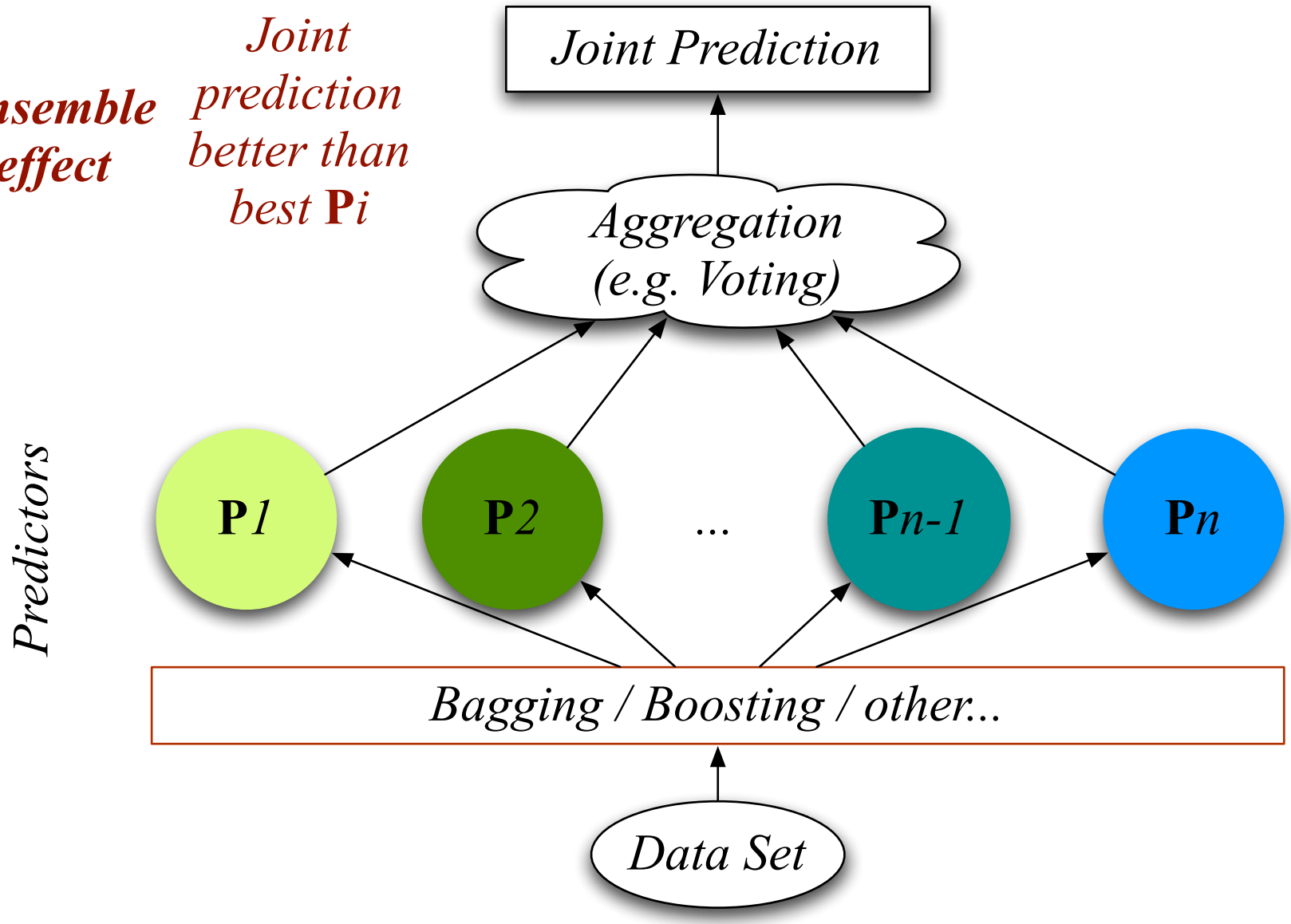
Team: A number of persons associated in some joint action. A group organized to work together.

Coalition: A combination or alliance, esp. a temporary one between persons, factions, states, etc. An alliance for combined action, especially a temporary alliance of political parties.

Ensemble Effect

Ensemble effect

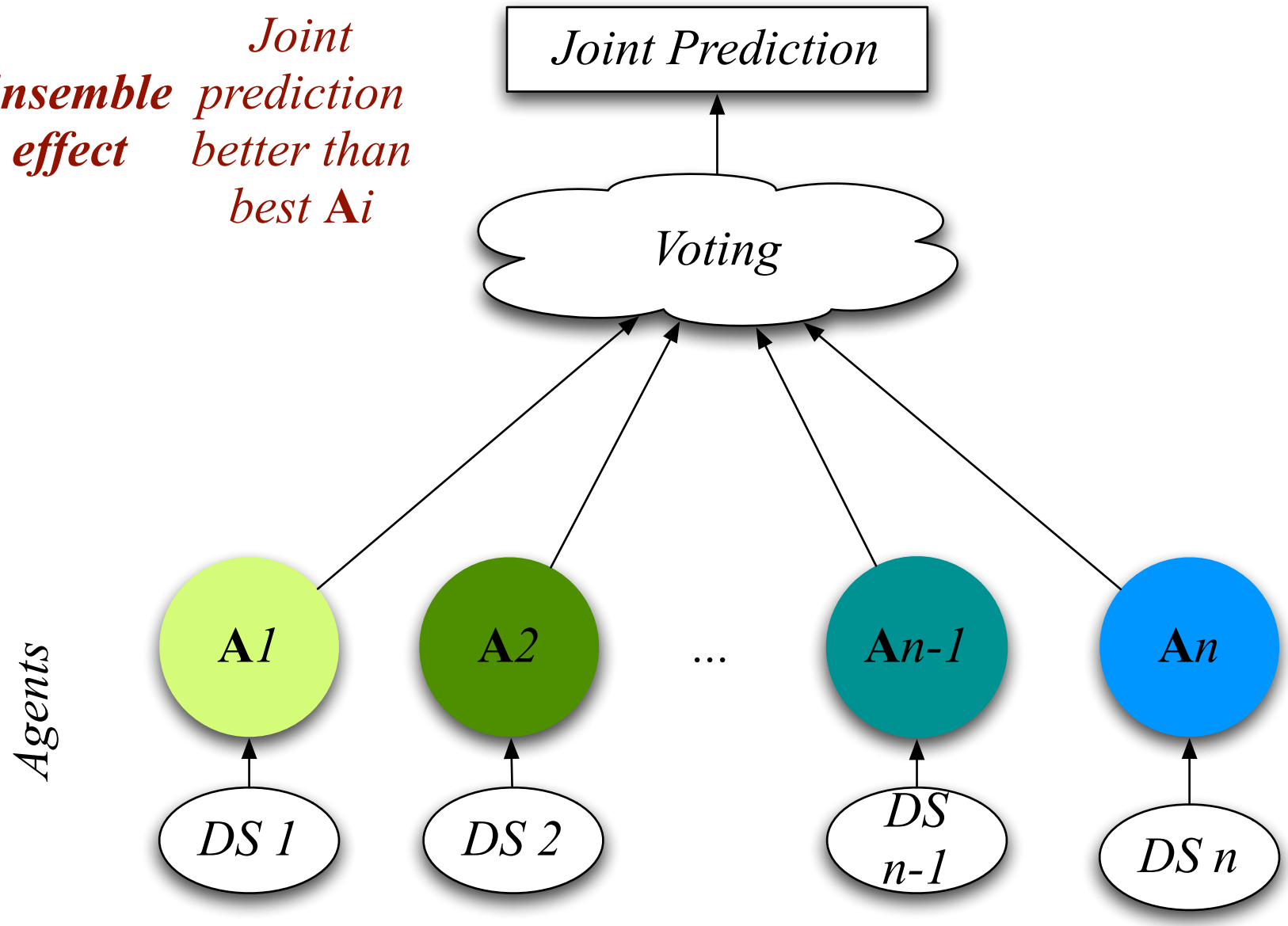
Joint prediction better than best **P***i*



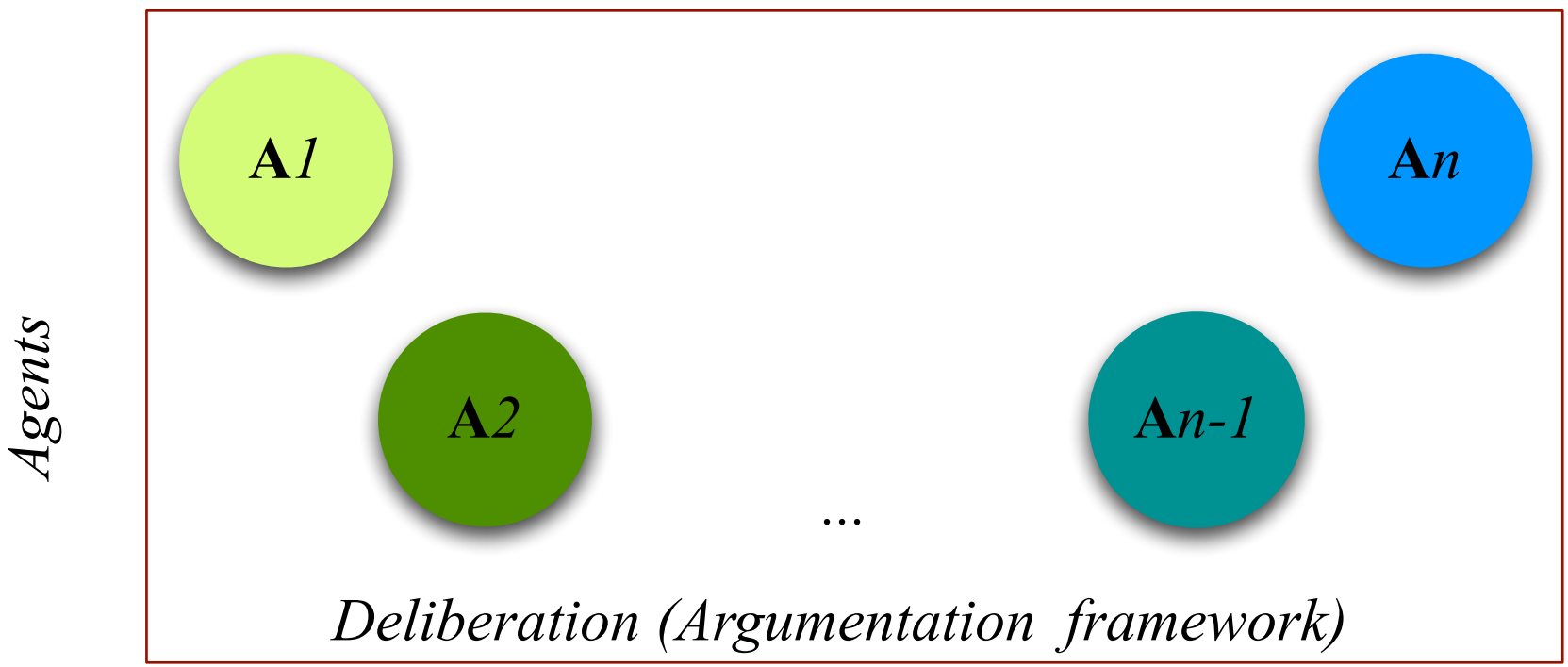
Committee of agents

Ensemble effect

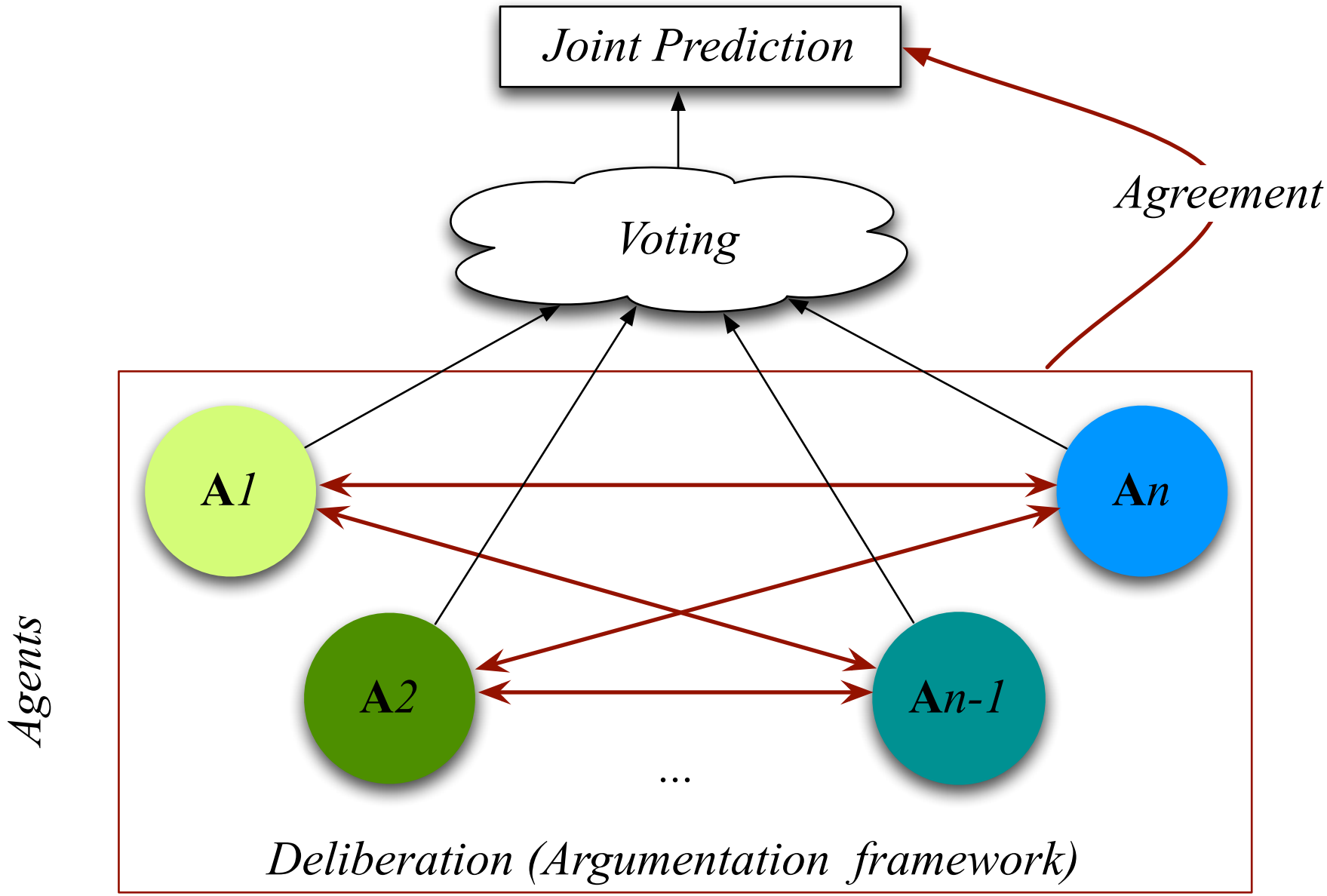
Joint prediction better than best **A***i*



Deliberation + Voting



Deliberation + Voting



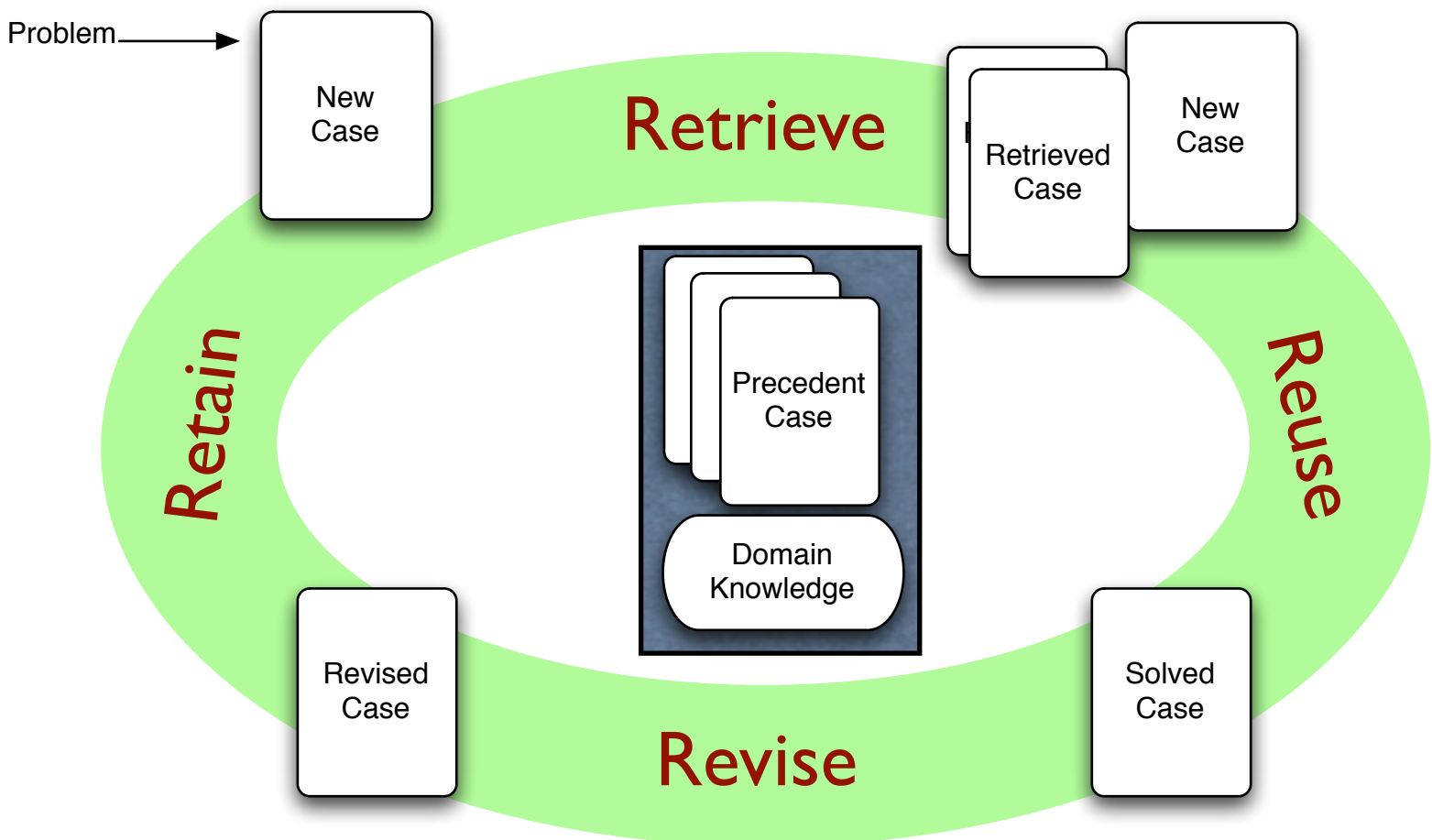
Introduction

- CBR agents
  - solve problems and learn from them
- How could CBR agents collaborate?
  - solving and/or learning from cases
- Argumentation process
  - to mediate agent collaboration
  - achieving a joint prediction

Learning vs Cooperating

- Why to learn in problem solving?
  - to improve accuracy, range, etc
- Why to cooperate in problem solving?
  - to improve accuracy, range, etc
- Learning-cooperation continuum
  - learning agents that cooperate by arguing

CBR cycle

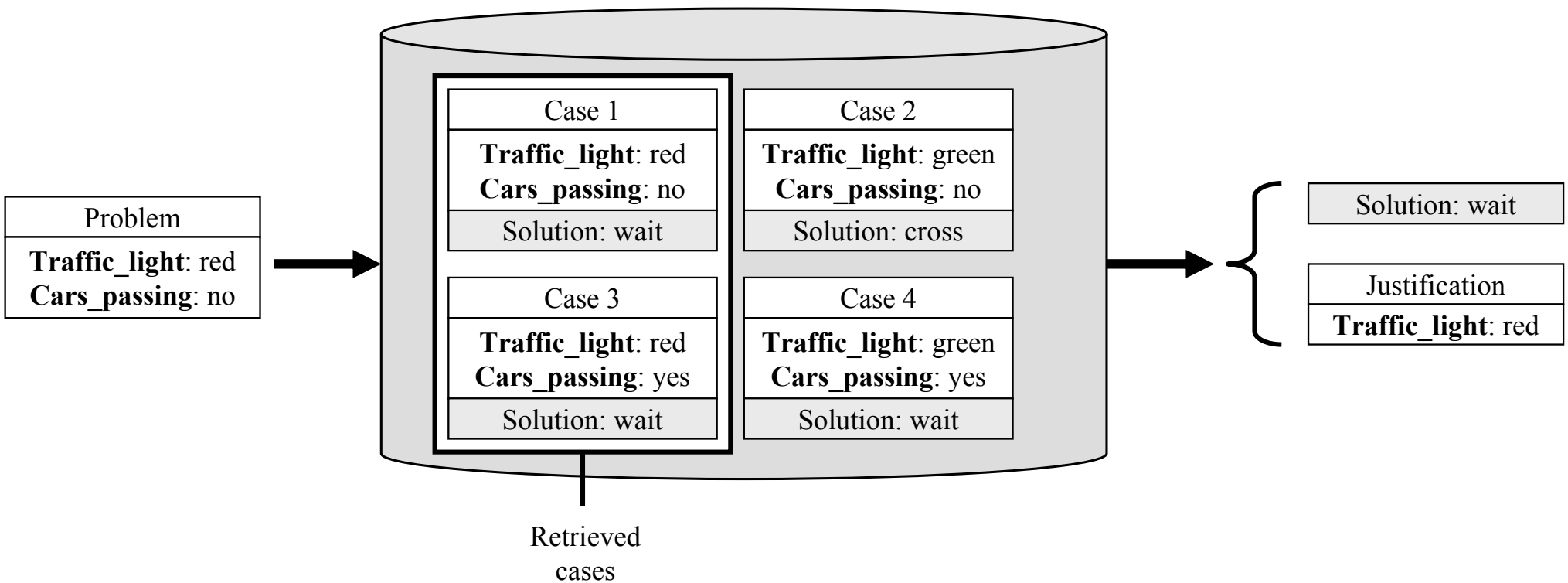

Problem
New Case
Retrieve
Retrieved Case
New Case
Retain
Precedent Case
Domain Knowledge
Reuse
Revised Case
Revise
Solved Case

Argumentation in Multi-Agent Learning

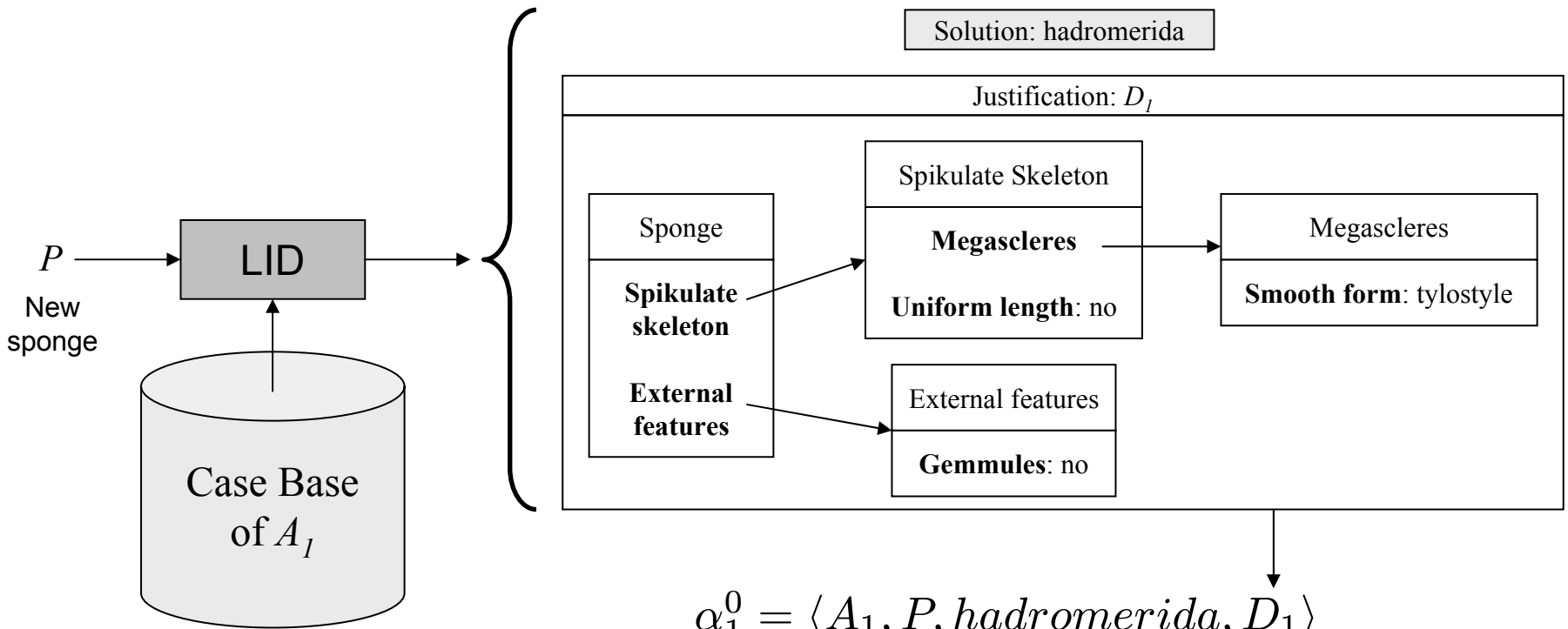
- An argumentation framework for learning agents
  - Justified Predictions as *arguments*
- Individual policies for agents to
  - generate *arguments* and
  - generate *counterarguments*
  - select *counterexamples*

Justified Prediction

Justification: A symbolic description with the information relevant to determine a specific prediction

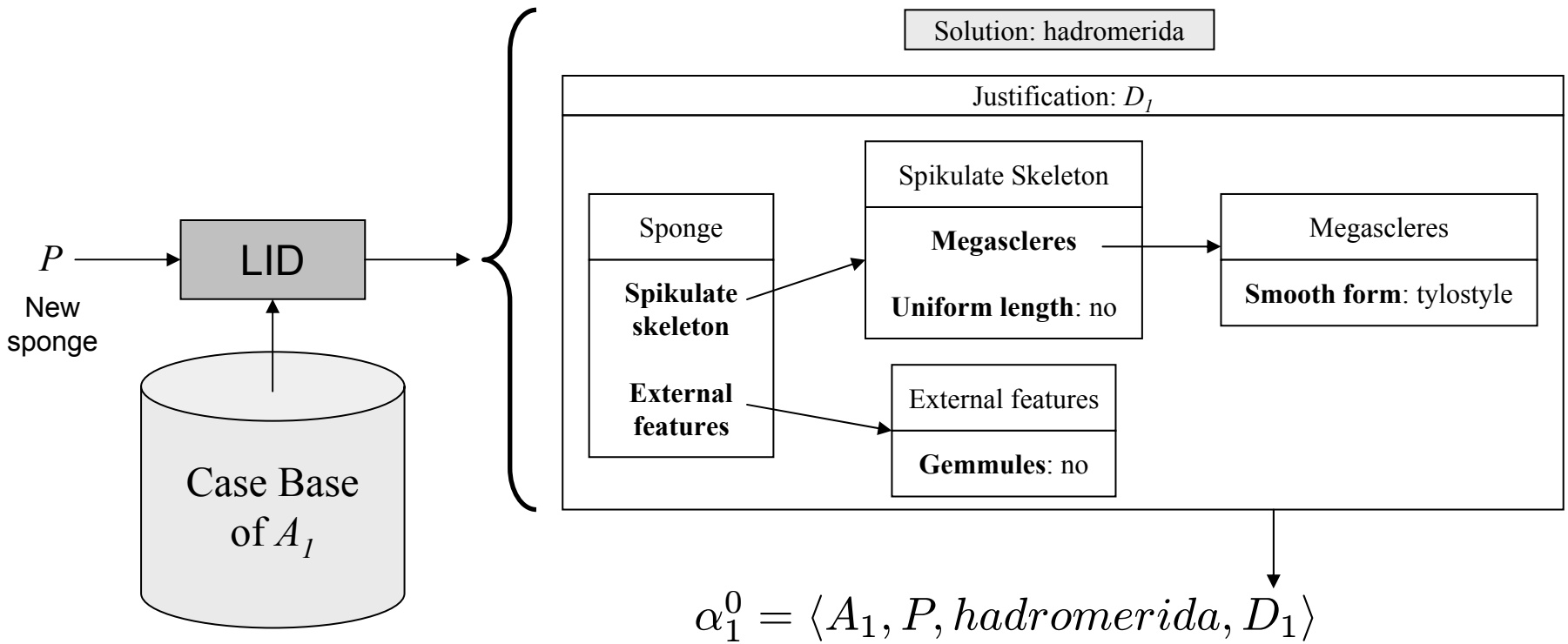


Justification example



$$\alpha_1^0 = \langle A_1, P, hadromerida, D_1 \rangle$$

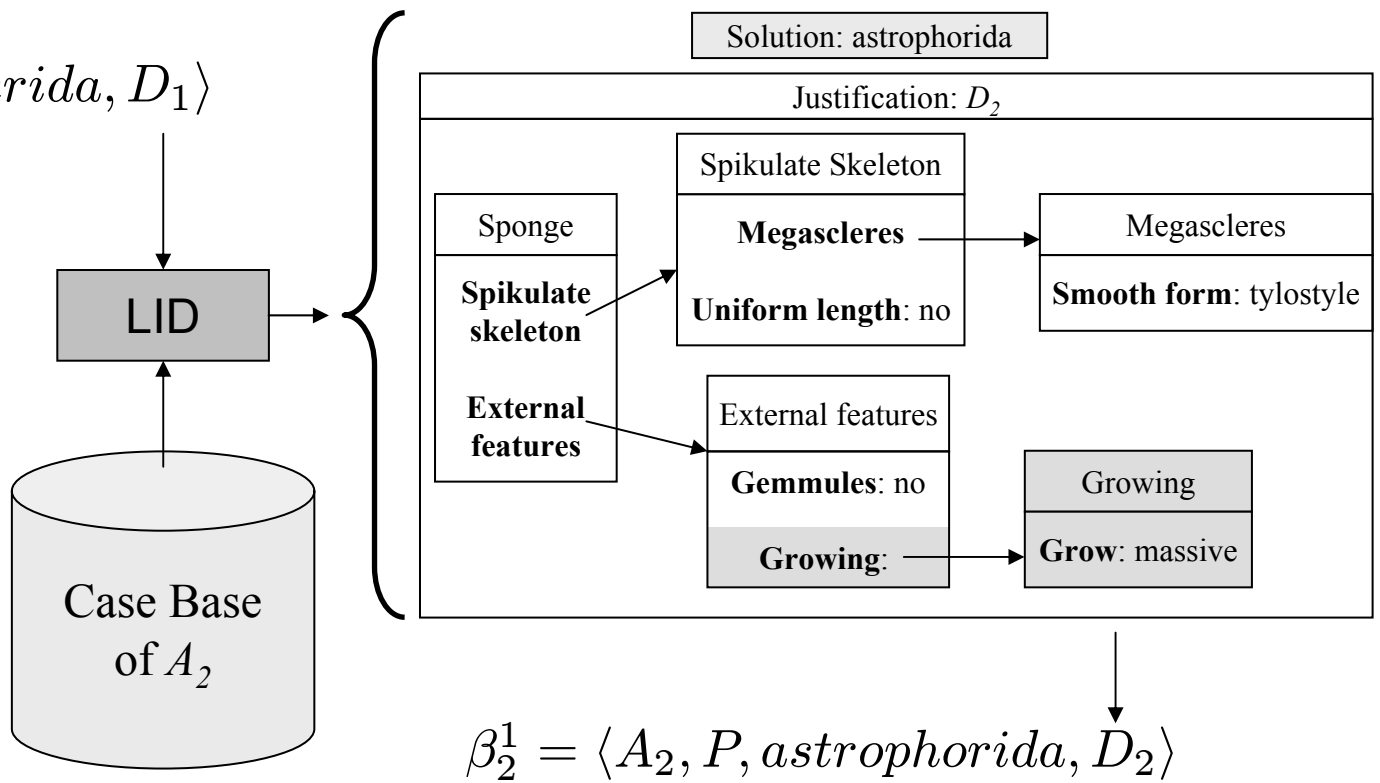
Justification example



The predicted solution is *hadromerida* because the *smooth form* of the *megascleres* of the *spiculate skeleton* of the *sponge* is of type *tylostyle*, the *spikulate skeleton* of the sponge has *not uniform length*, and there are *no gemmules* in the external features of the sponge.

Counterargument generation

$\alpha_1^0 = \langle A_1, P, hadromerida, D_1 \rangle$



$\beta_2^1 = \langle A_2, P, astrophorida, D_2 \rangle$

Argument types

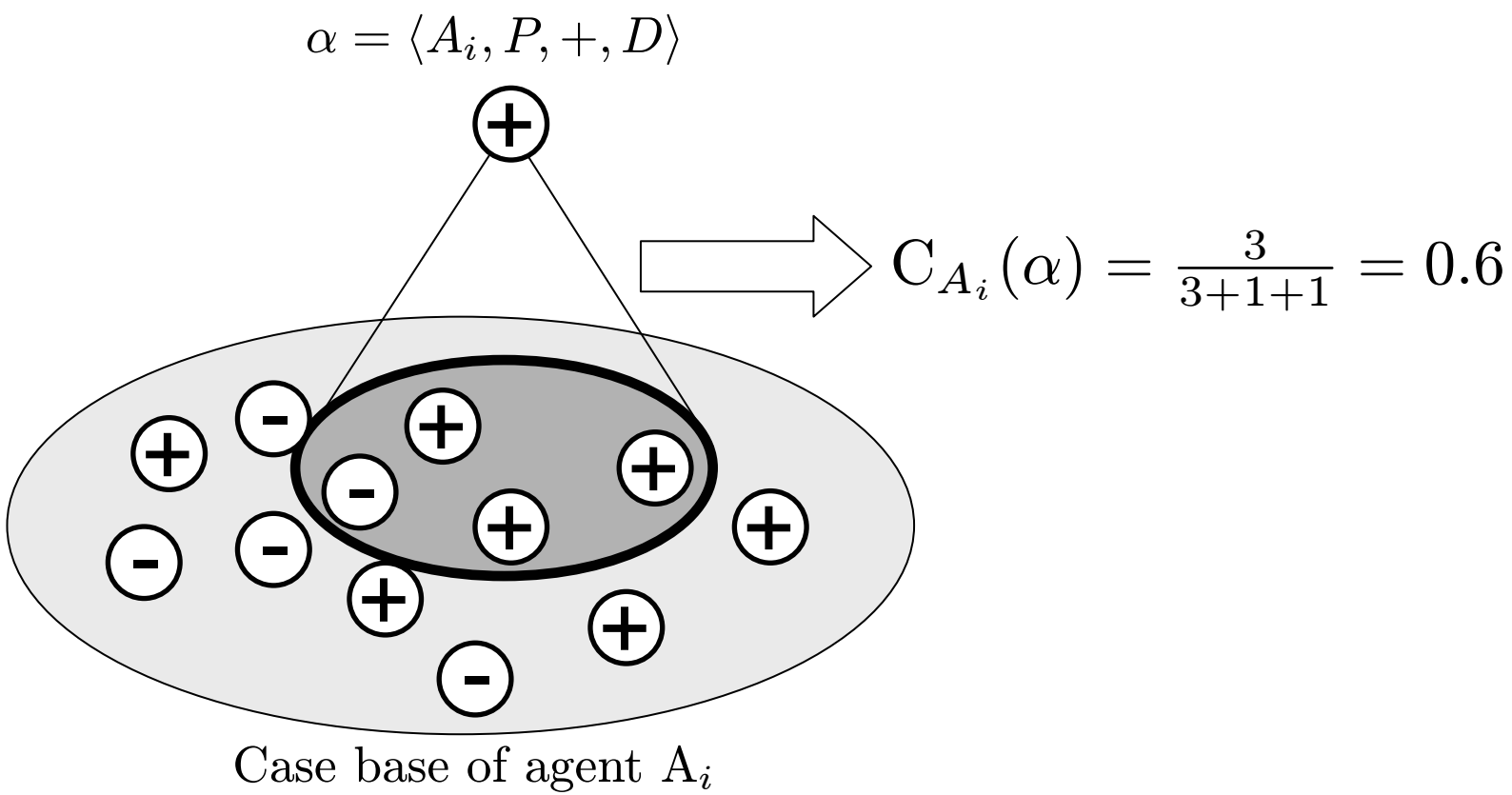
$\alpha = \langle A_i, P, +, D \rangle$

$\beta = \langle A_2, P, -, D_2 \rangle$

$c = \langle P_1, - \rangle$

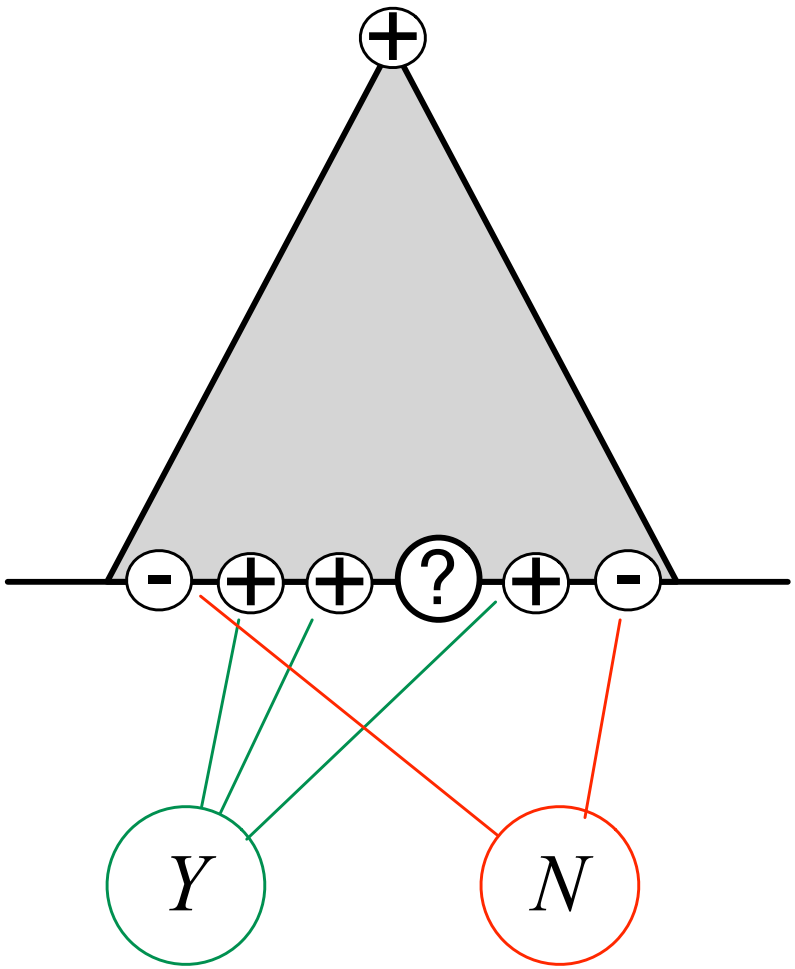
- *Justified Prediction*: An argument α endorsing a individual prediction
- *Counterargument*: An argument β offered in opposition to an argument α
- *Counterexample*: A case *c* contradicting an argument α

Case-based Confidence



Preference on Arguments

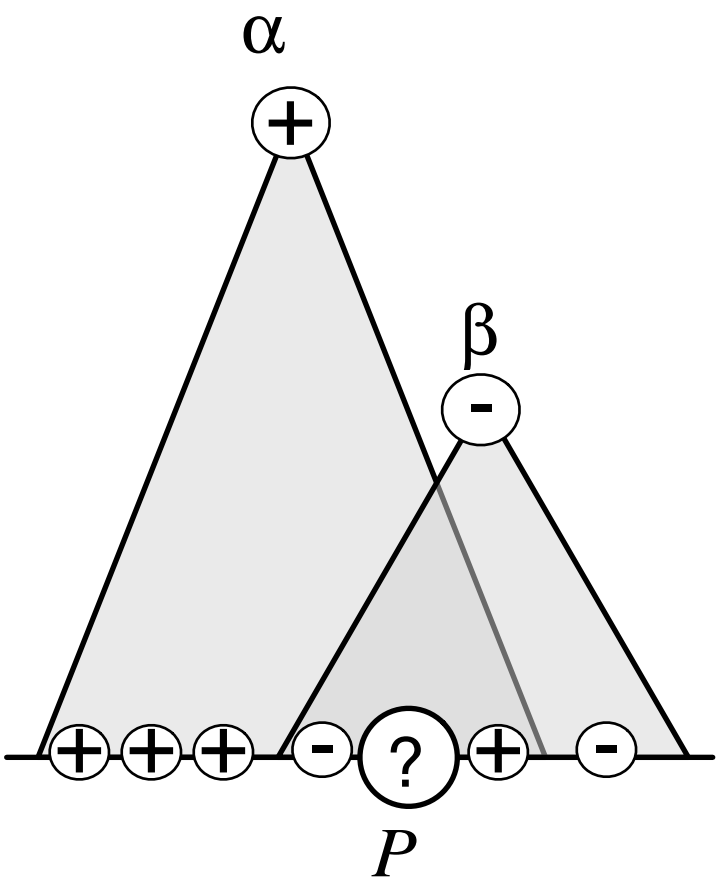
$$\alpha = \langle A_i, P, +, D \rangle$$



Confidence on an argument based on cases

$$C(\alpha) = \frac{Y}{Y + N}$$

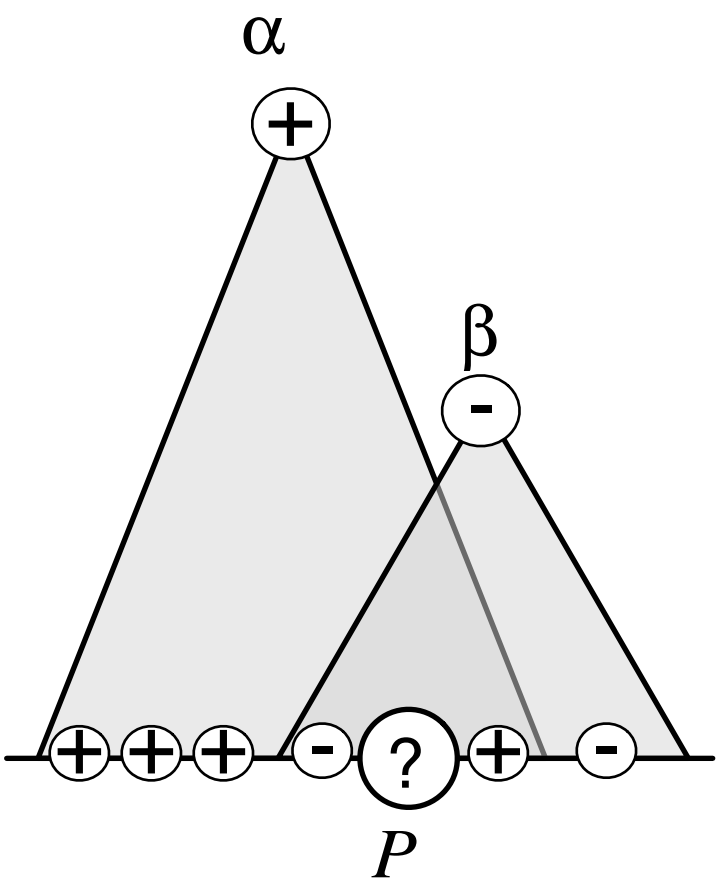
Preference on Arguments(2)



$$C(\alpha) = \frac{4}{5} = 0.8$$

$$C(\beta) = \frac{2}{3} = 0.66$$

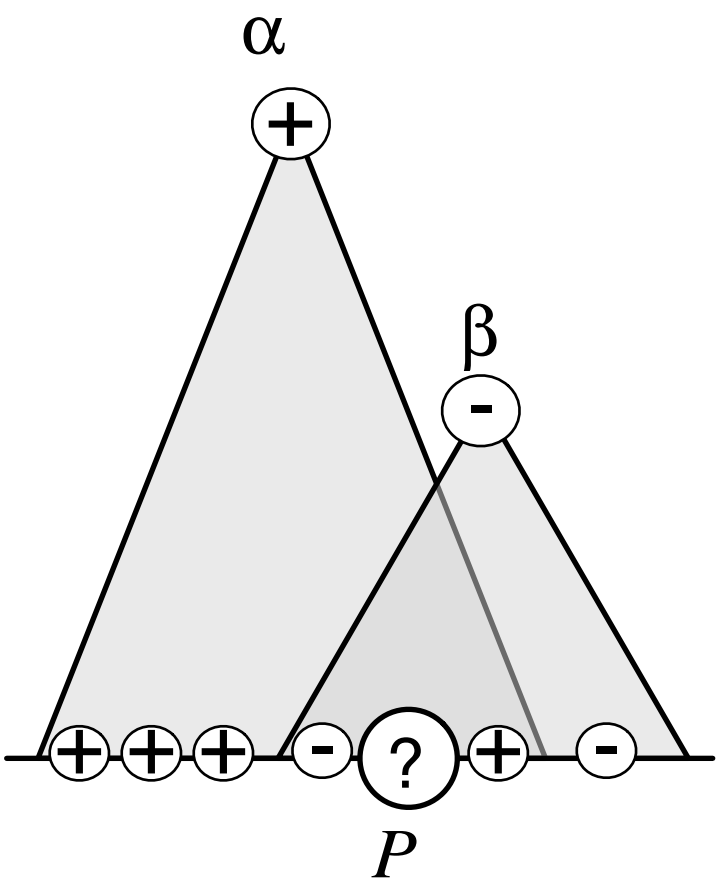
Preference on Arguments(2)



$$C(\alpha) = \frac{4}{5} = 0.8$$ **Preferred**

$$C(\beta) = \frac{2}{3} = 0.66$$

Preference on Arguments(2)



$$C(\alpha) = \frac{4}{5} = 0.8$$ **Preferred**

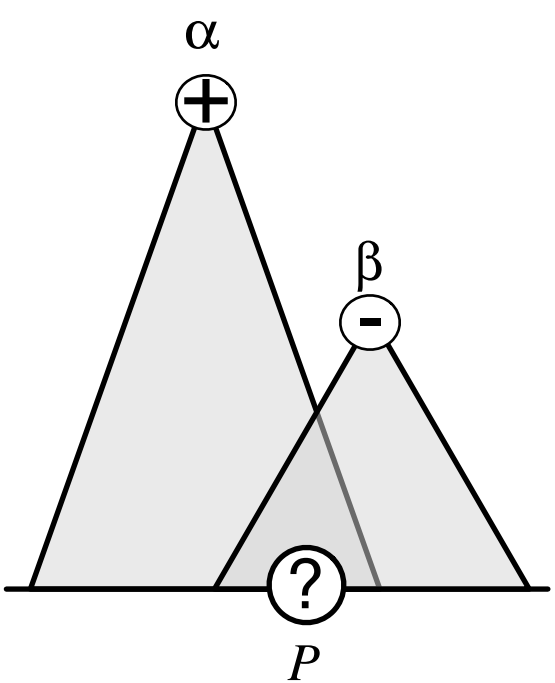
$$C(\beta) = \frac{2}{3} = 0.66$$

Joint Confidence

$$C(\alpha) = \frac{Y_\alpha^{A_1} + Y_\alpha^{A_2} + 1}{Y_\alpha^{A_1} + Y_\alpha^{A_2} + N_\alpha^{A_1} + N_\alpha^{A_2} + 2}$$

Relations between arguments

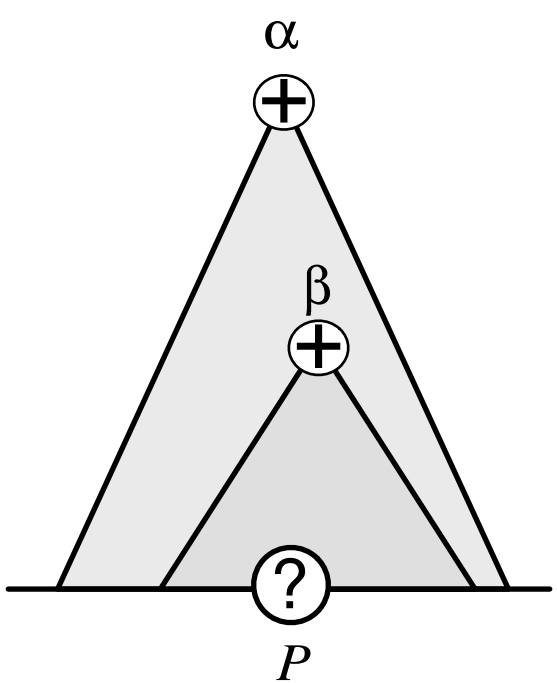
a)



$\alpha = \langle A_1, P, +, D_1 \rangle$

$\beta = \langle A_2, P, -, D_2 \rangle$

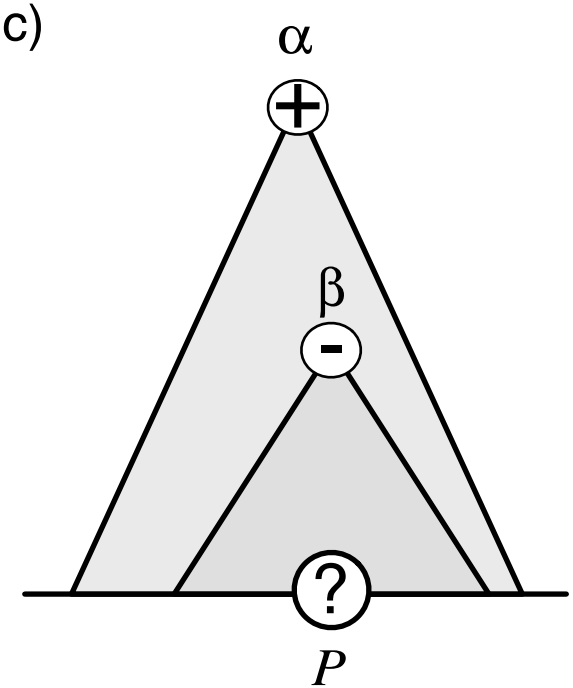
b)



$\alpha = \langle A_1, P, +, D_1 \rangle$

$\beta = \langle A_2, P, +, D_2 \rangle$

c)



$\alpha = \langle A_1, P, +, D_1 \rangle$

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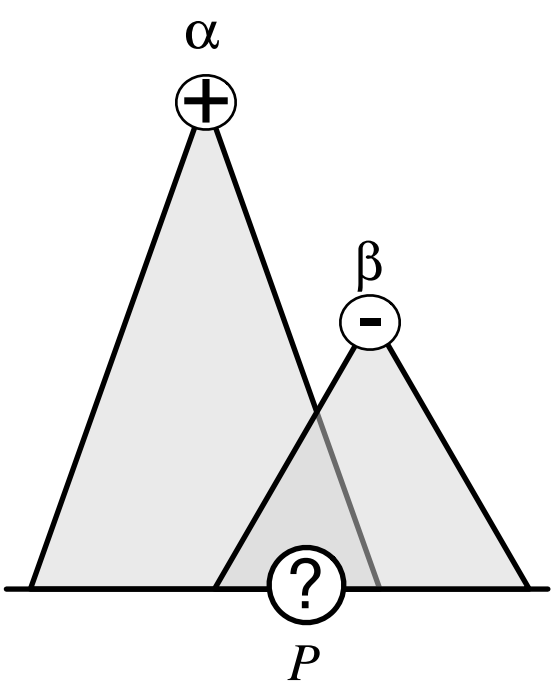
Relations between arguments

a)

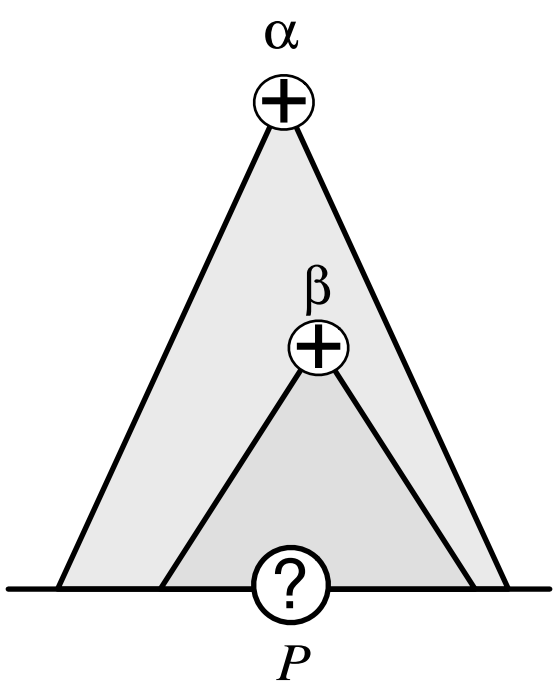


$\alpha = \langle A_1, P, +, D_1 \rangle$

$\beta = \langle A_2, P, -, D_2 \rangle$

Incomparable

b)

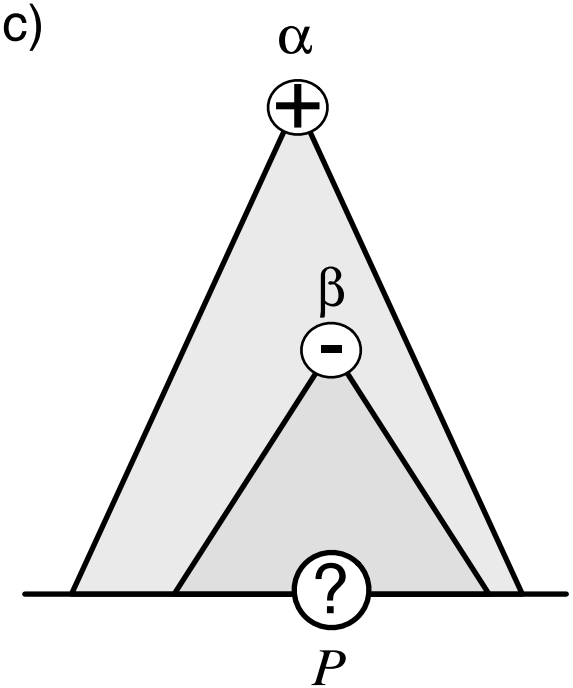


$\alpha = \langle A_1, P, +, D_1 \rangle$

$\beta = \langle A_2, P, +, D_2 \rangle$

Consistent

c)



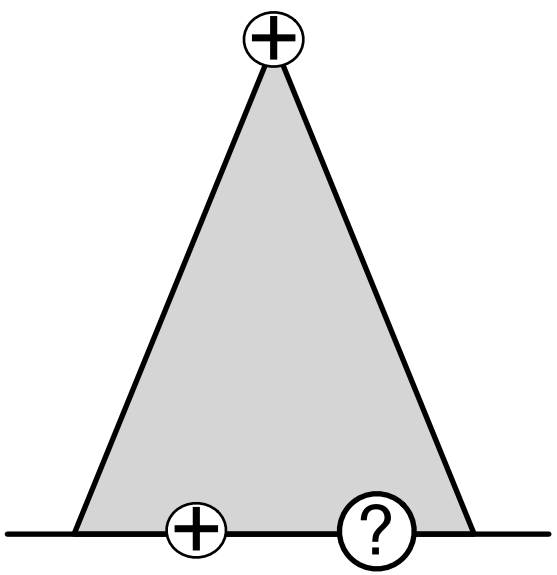
$\alpha = \langle A_1, P, +, D_1 \rangle$

$\beta = \langle A_2, P, -, D_2 \rangle$

Counterargument

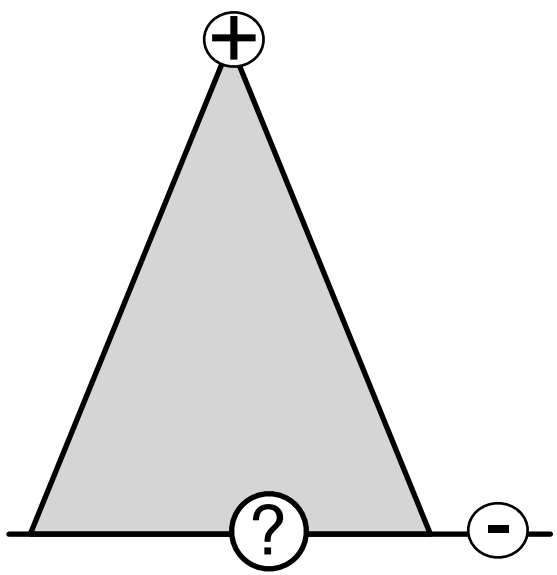
Relations between cases and justified predictions

a) $\alpha = \langle A_i, P, +, D \rangle$



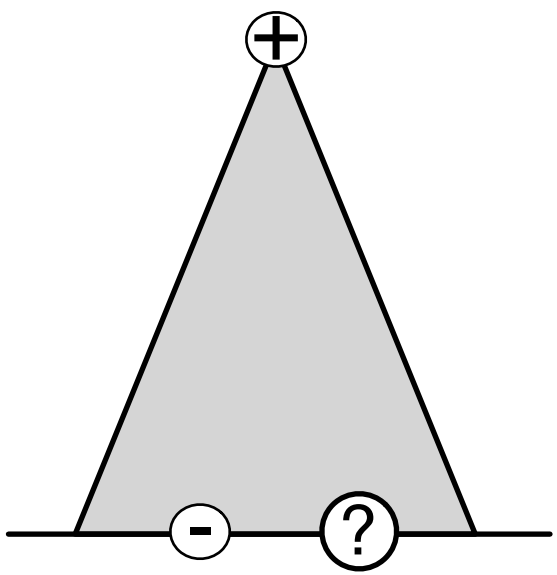
$c = \langle P_1, + \rangle$ P

b) $\alpha = \langle A_i, P, +, D \rangle$



P $c = \langle P_1, - \rangle$

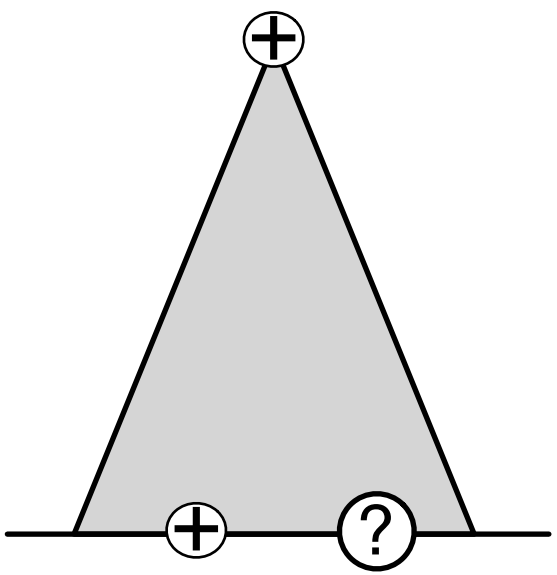
c) $\alpha = \langle A_i, P, +, D \rangle$



$c = \langle P_1, - \rangle$ P

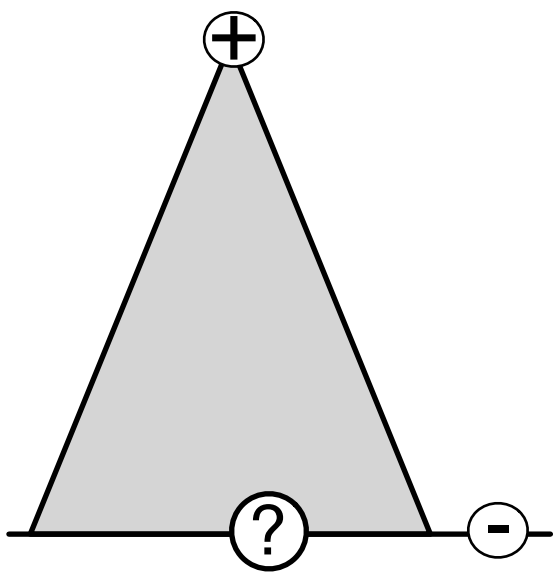
Relations between cases and justified predictions

a) $\alpha = \langle A_i, P, +, D \rangle$



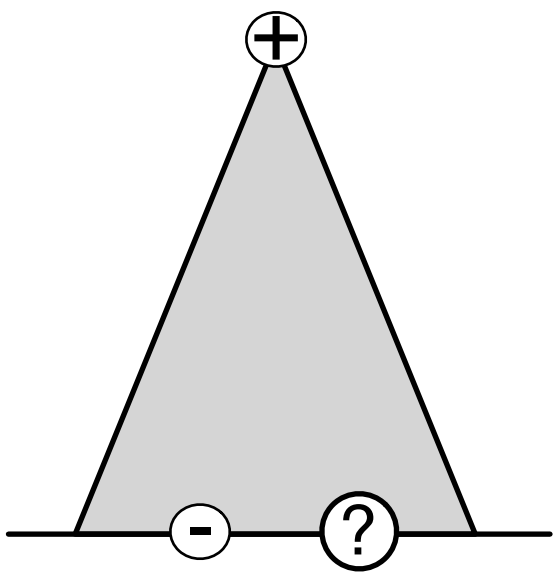
$c = \langle P_1, + \rangle$ P

b) $\alpha = \langle A_i, P, +, D \rangle$



P $c = \langle P_1, - \rangle$

c) $\alpha = \langle A_i, P, +, D \rangle$



$c = \langle P_1, - \rangle$ P

Endorsing case

Irrelevant case

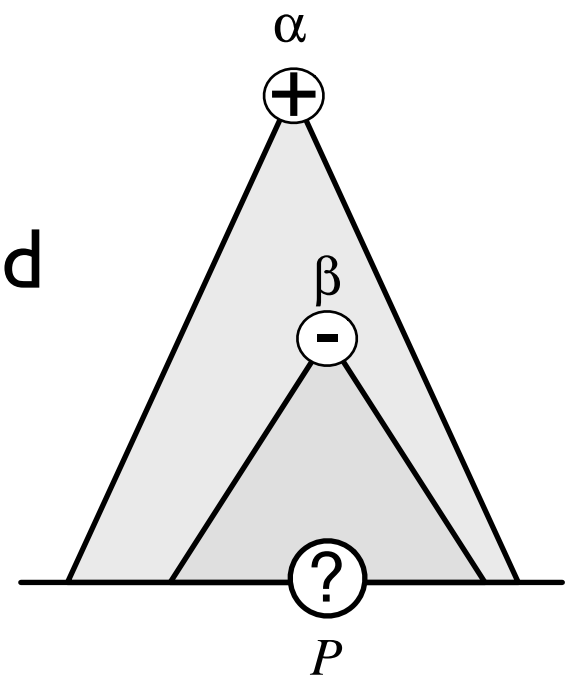
Counterexample

Argument Generation

- Generation of a Justified Prediction
  - LID generates a description $\alpha.\boldsymbol{D}$ subsuming $\boldsymbol{P}$
- Generation of a Counterargument
  - if no Counterargument can be generated then:
- Selection of a Counterexample

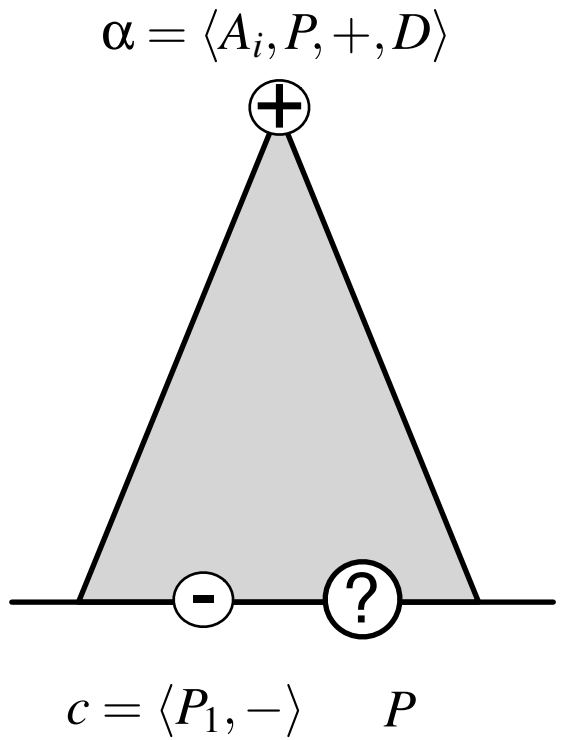
Counterargument Generation

- Counterarguments are generated based on the *specificity criterion*
- LID generates a description β.***D*** subsuming ***P*** and subsumed by α.***D***



Selection of a Counterexample

- Select a case ***c*** subsumed by α.***D*** and endorsing a different solution class.



AMAL protocol

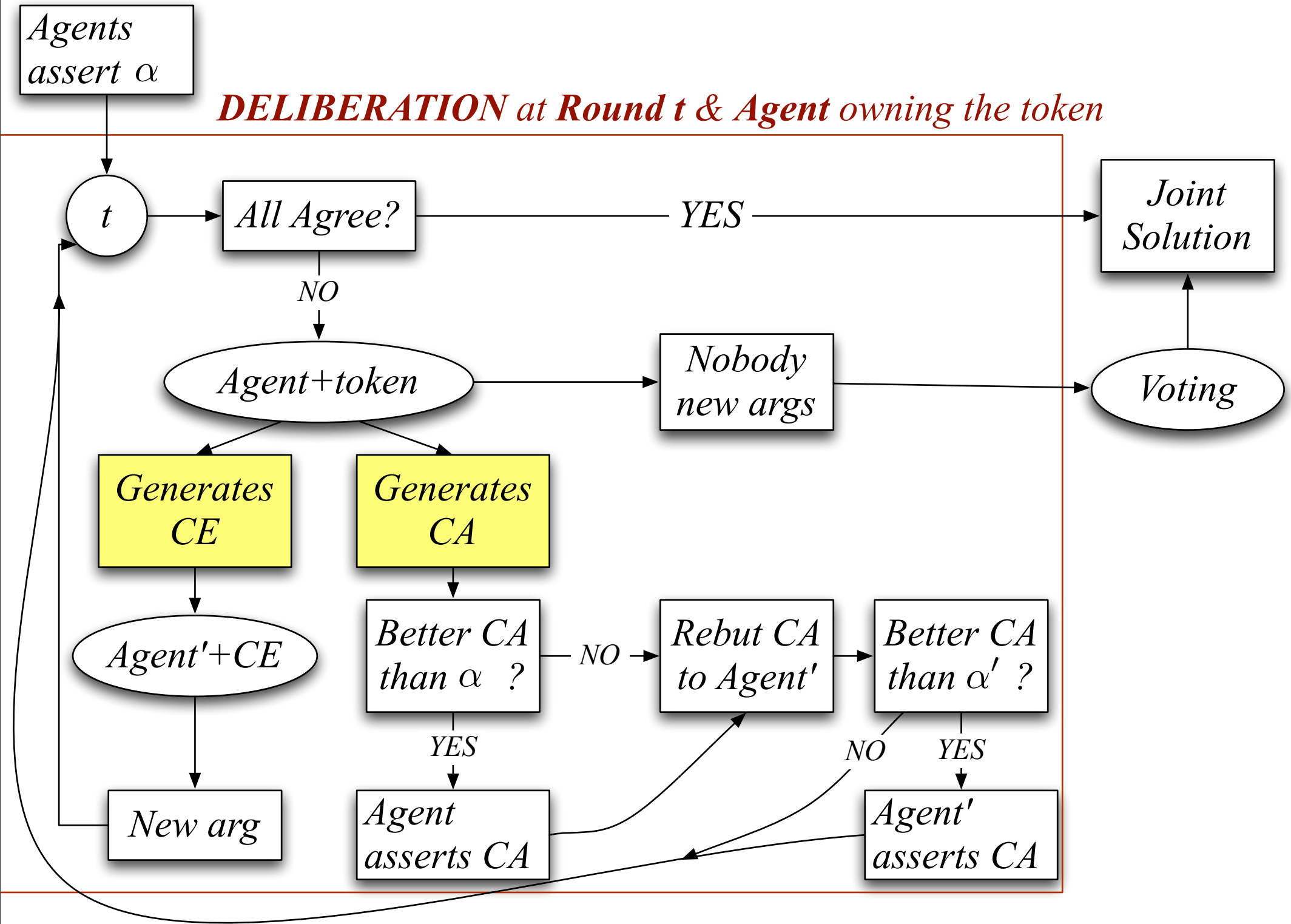
$H_t = \langle \alpha_1^t, ..., \alpha_n^t \rangle$ Assertions of *n* agents at round *t*

$assert(\alpha)$ Justified prediction asserted in the next round

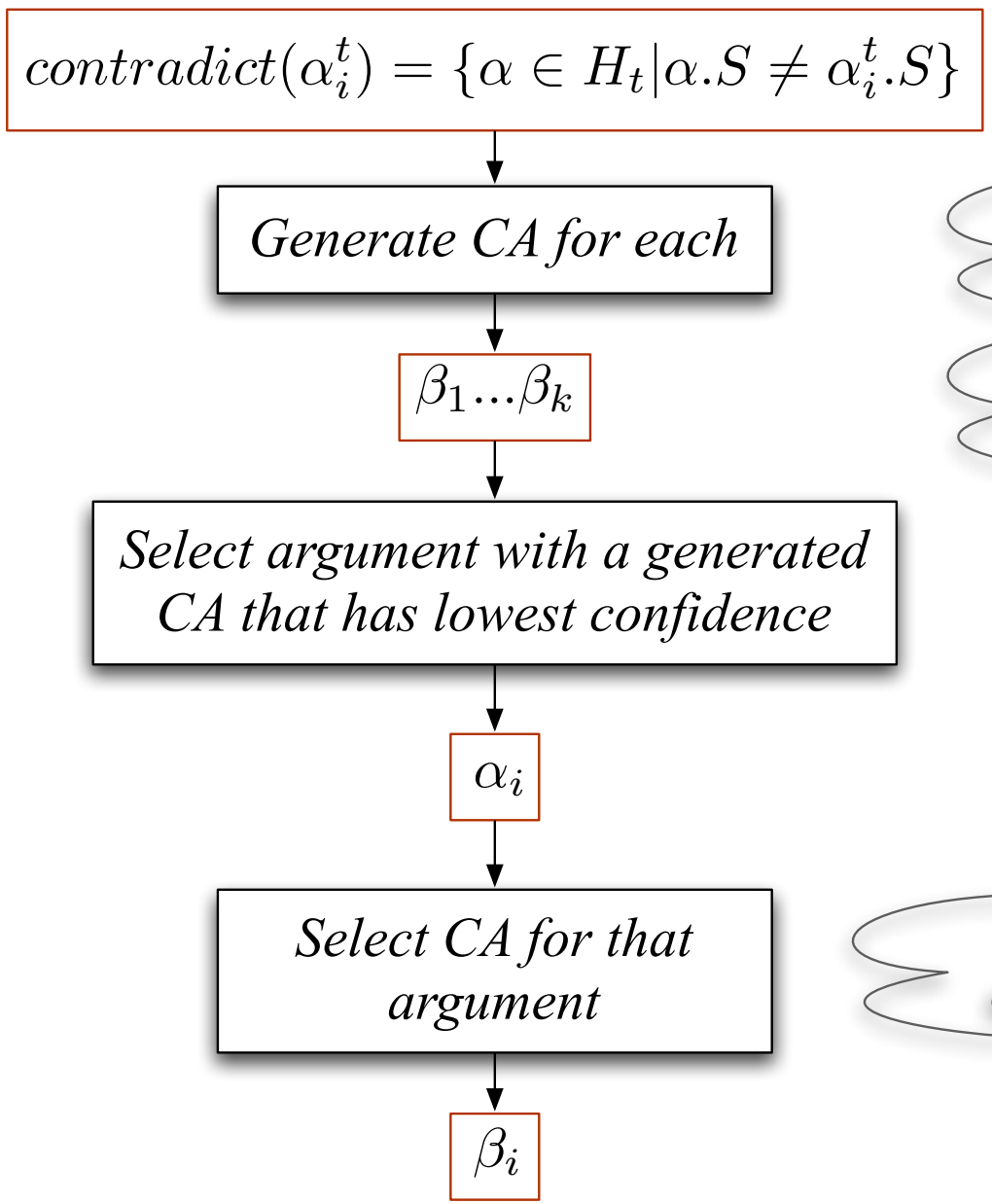
$rebut(\beta, \alpha)$ Agent states a counterargument ß

$contradict(\alpha_i^t) = \{\alpha \in H_t | \alpha.S \neq \alpha_i^t.S\}$

Set of contradicting arguments for agent A_i at round t (those predicting a different solution)


Agents assert α
DELIBERATION at Round t & Agent owning the token
t
All Agree?
YES
Joint Solution
NO
Agent+token
Nobody new args
Voting
Generates CE
Generates CA
Agent'+CE
Better CA than α ?
NO
Rebut CA to Agent'
Better CA than α' ?
YES
NO
YES
New arg
Agent asserts CA
Agent' asserts CA

Argument Generation



May not found a CA for each

If empty generates CE

Most likely to "convince" the other agent to change assertion

Confidence-weighted Voting

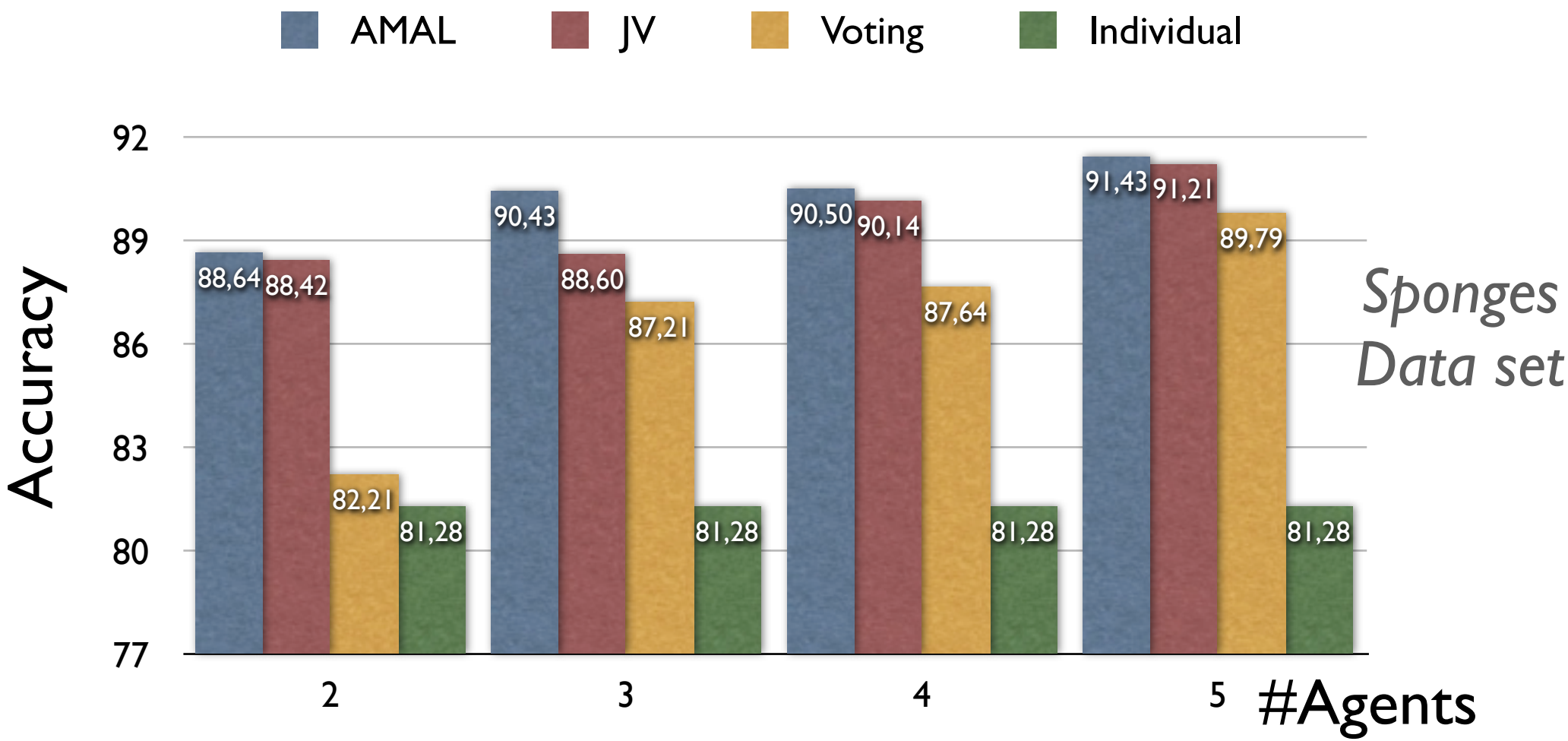
- Each argument in H_t is a vote for an alternative
- Each vote is weighted by the *joint confidence* measure of that argument
- Weighted voting: alternative with higher aggregated confidence wins

$$S = \arg\max_{S_k \in \mathcal{S}} \sum_{\alpha_i \in H_t | \alpha_i . S = S_k} C(\alpha_i)$$

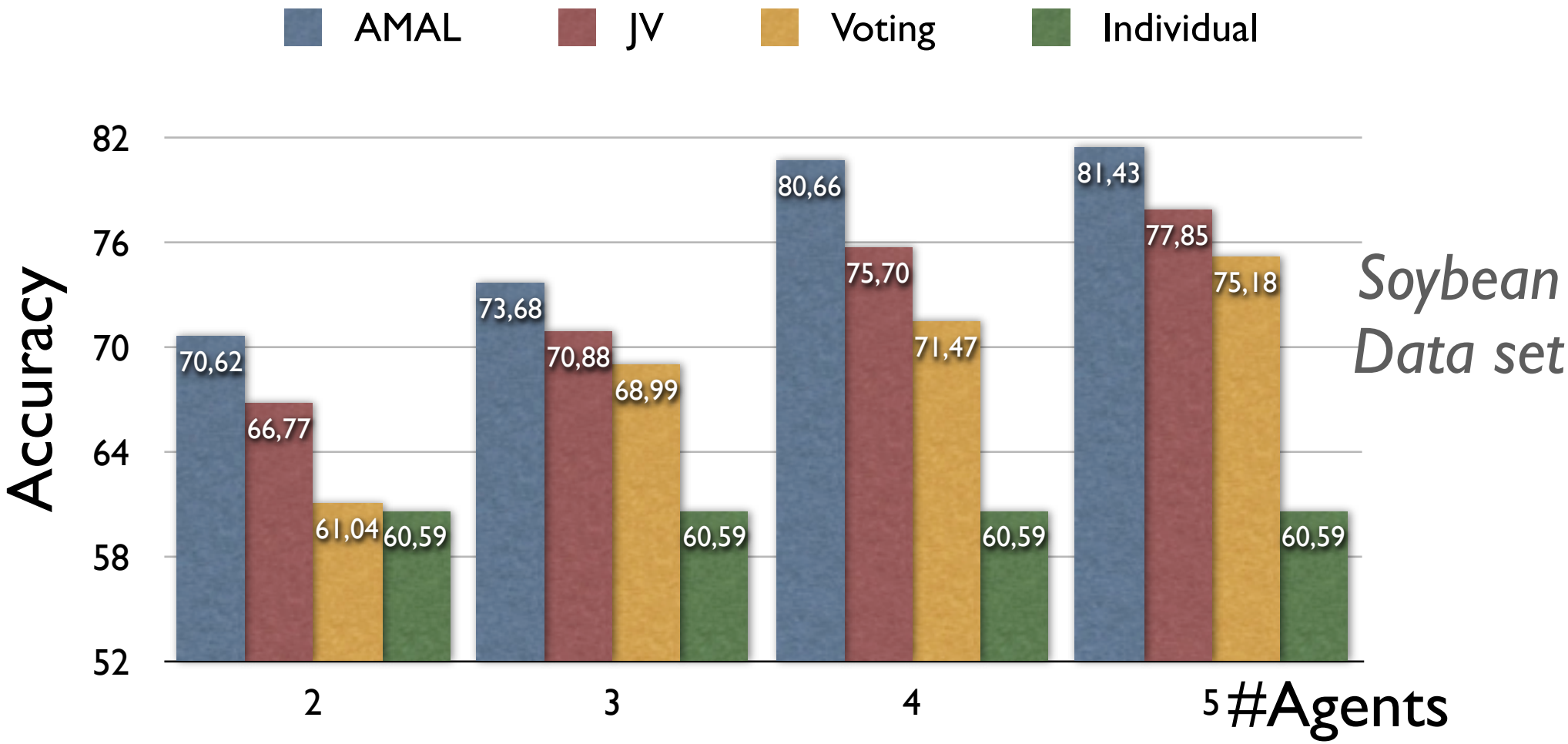
Experiments

- Designed to validate 2 hypotheses
  - average of 5 10-fold cross validation runs
- (H1) that argumentation is a useful framework for ***joint deliberation*** and can improve over other typical methods such as voting; and
- (H2) that learning from communication improves the ***individual performance*** of a learning agent participating in an argumentation process.

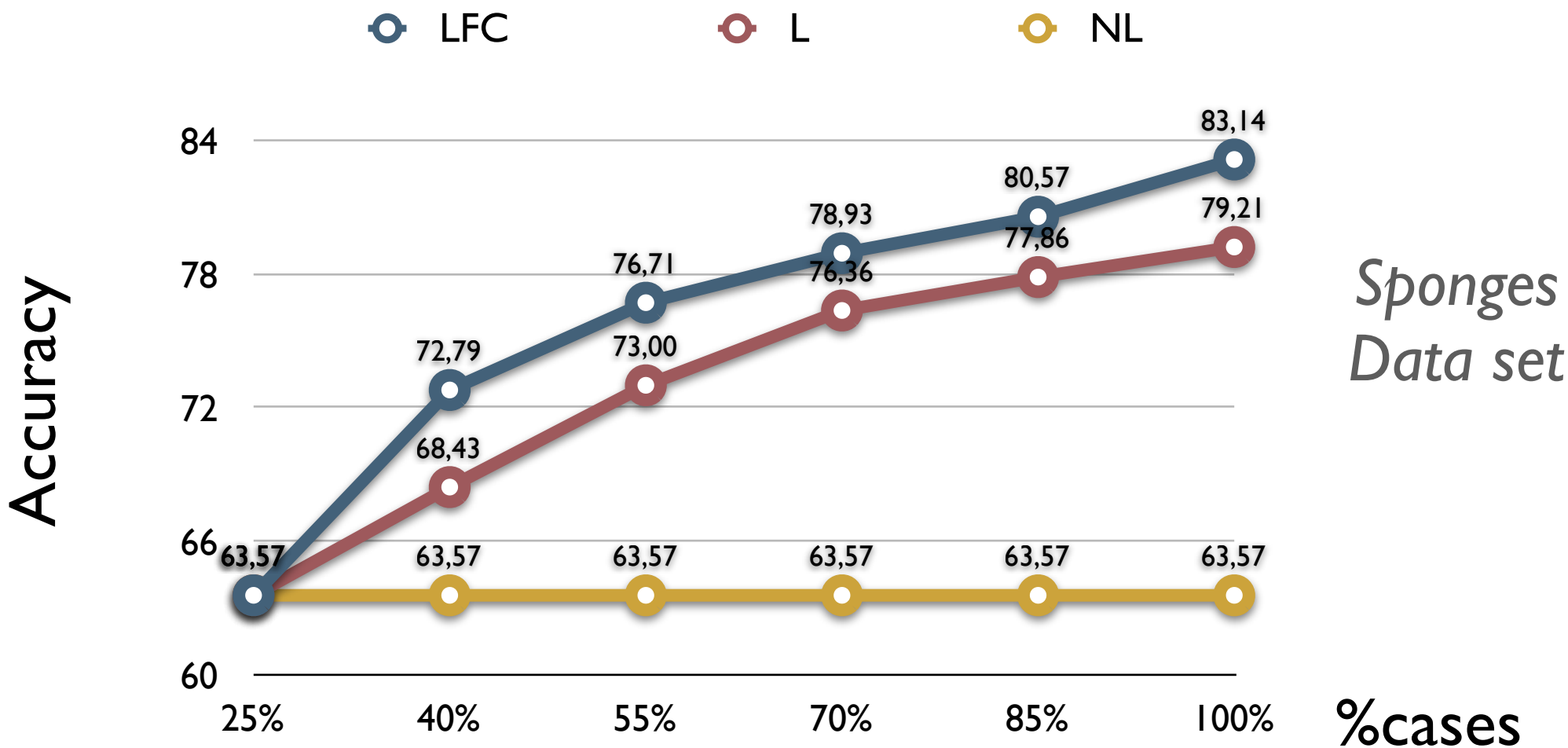
Accuracy after Deliberation



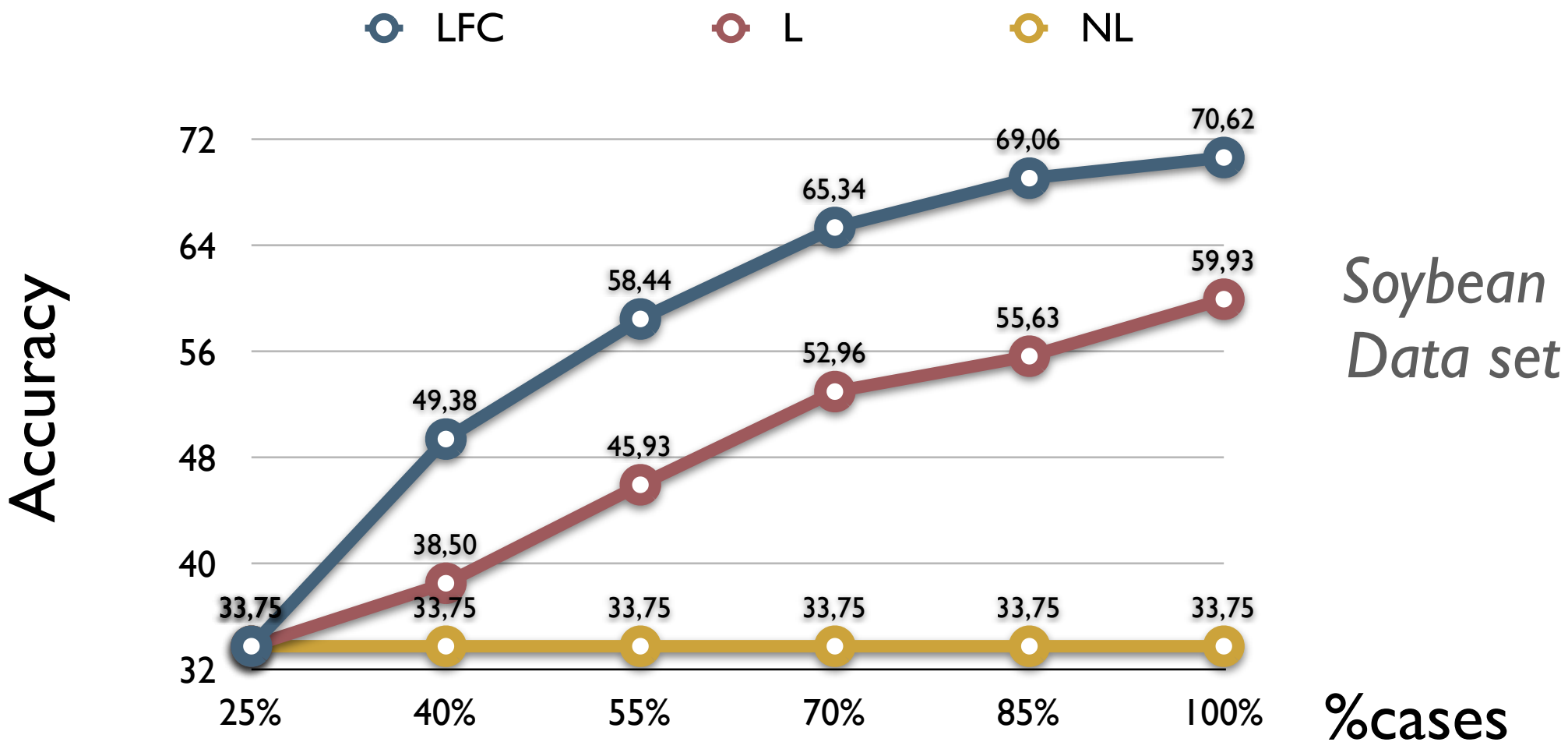
Accuracy after Deliberation



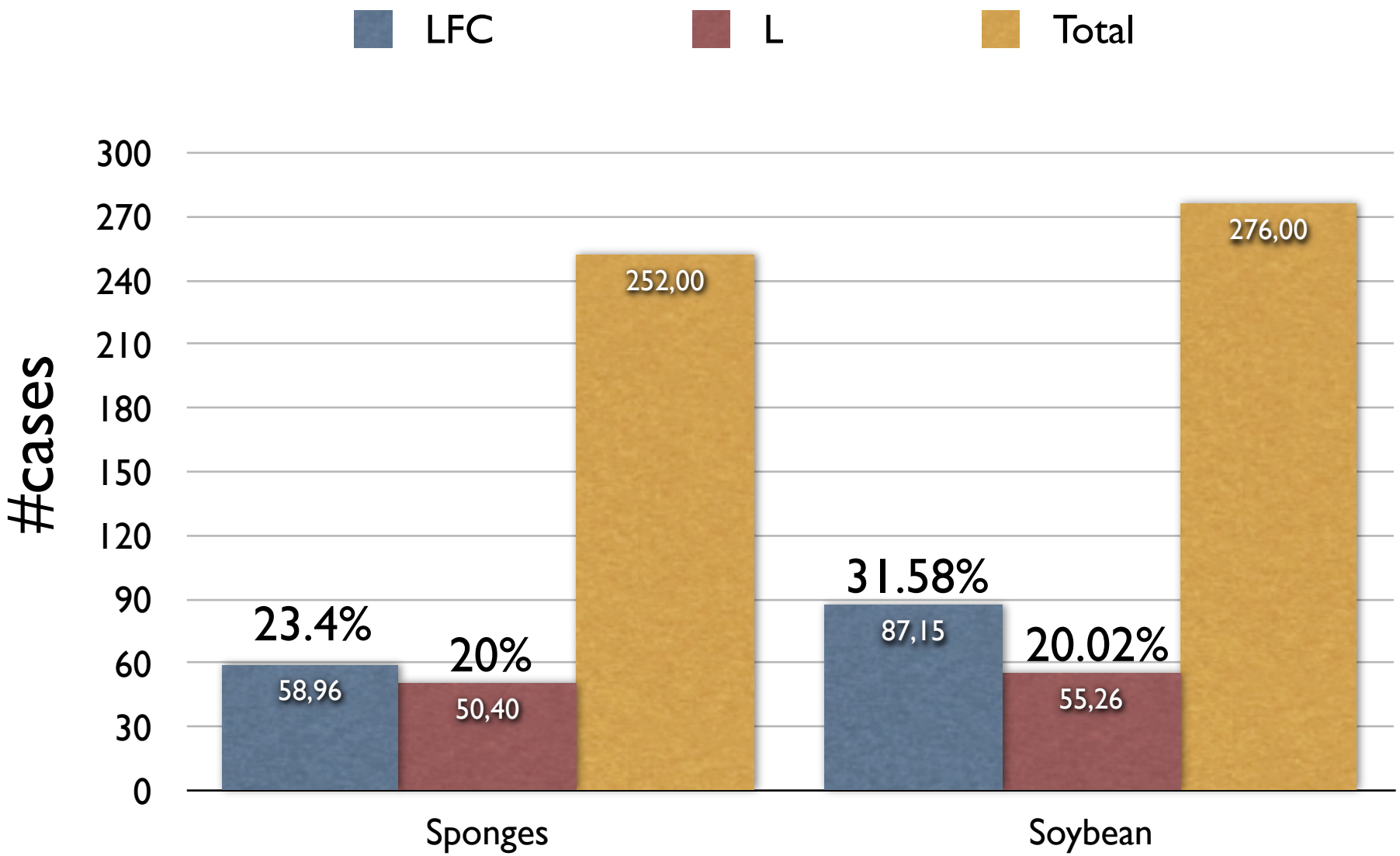
Individual Learning from Communication

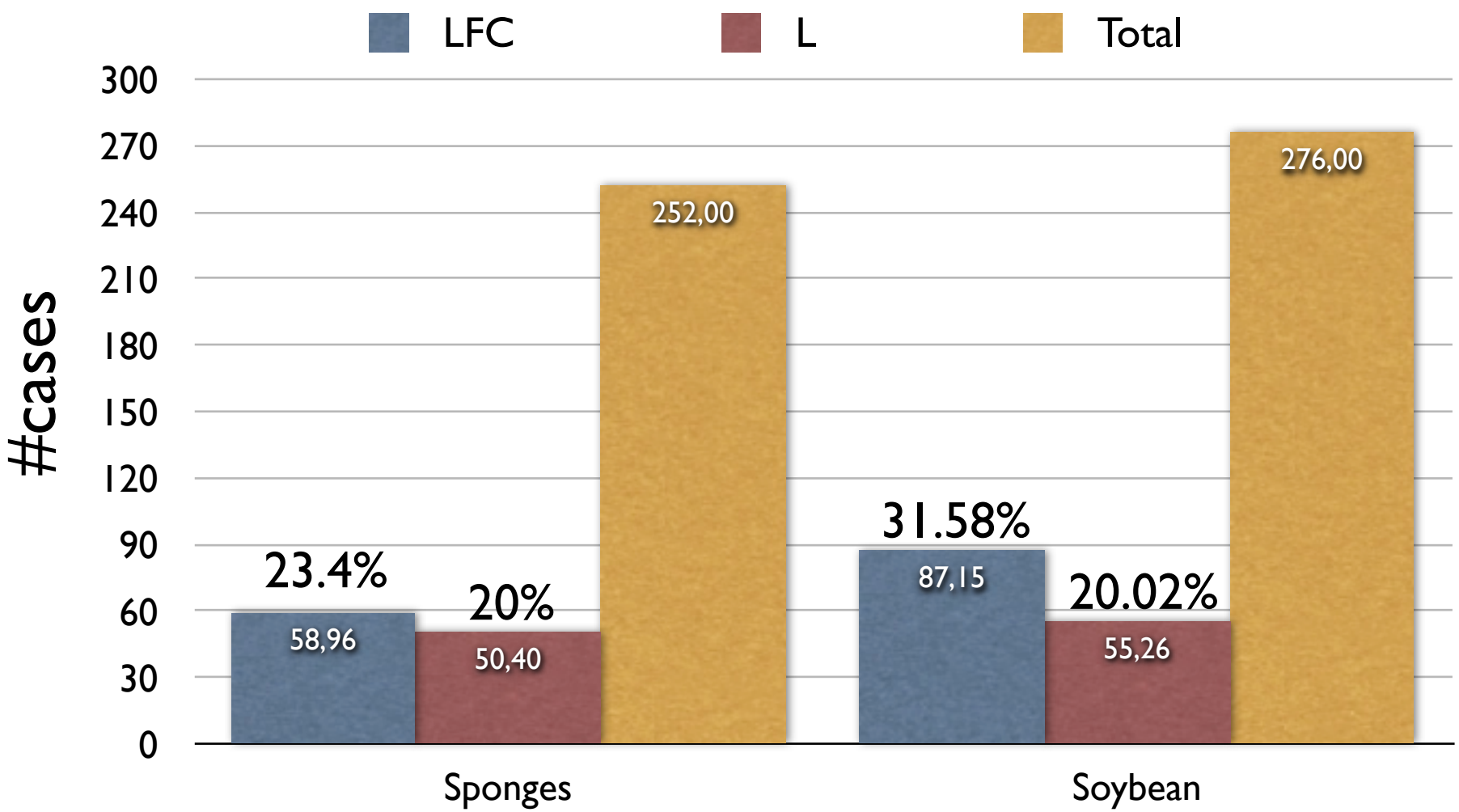


Individual Learning from Communication

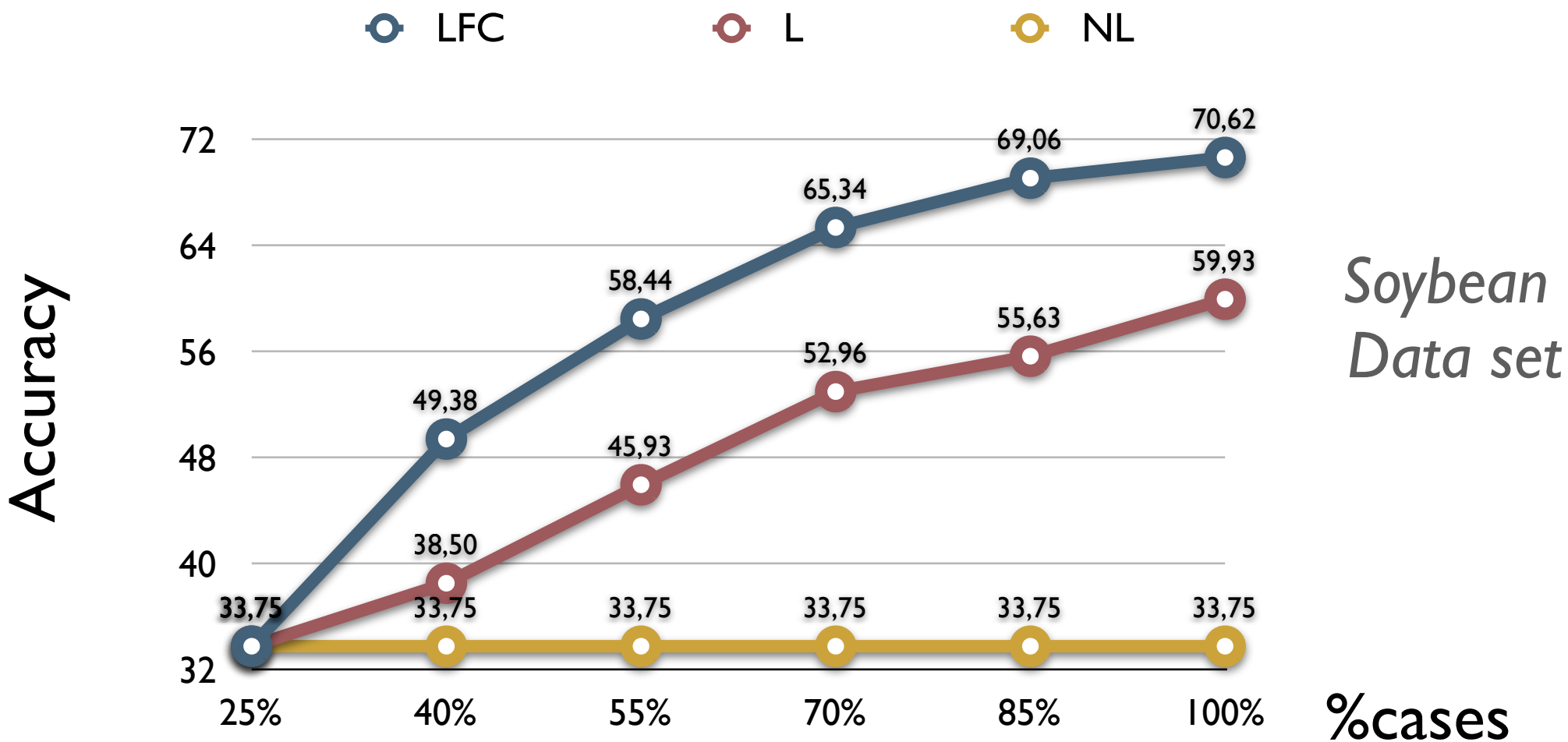


Case Base Size

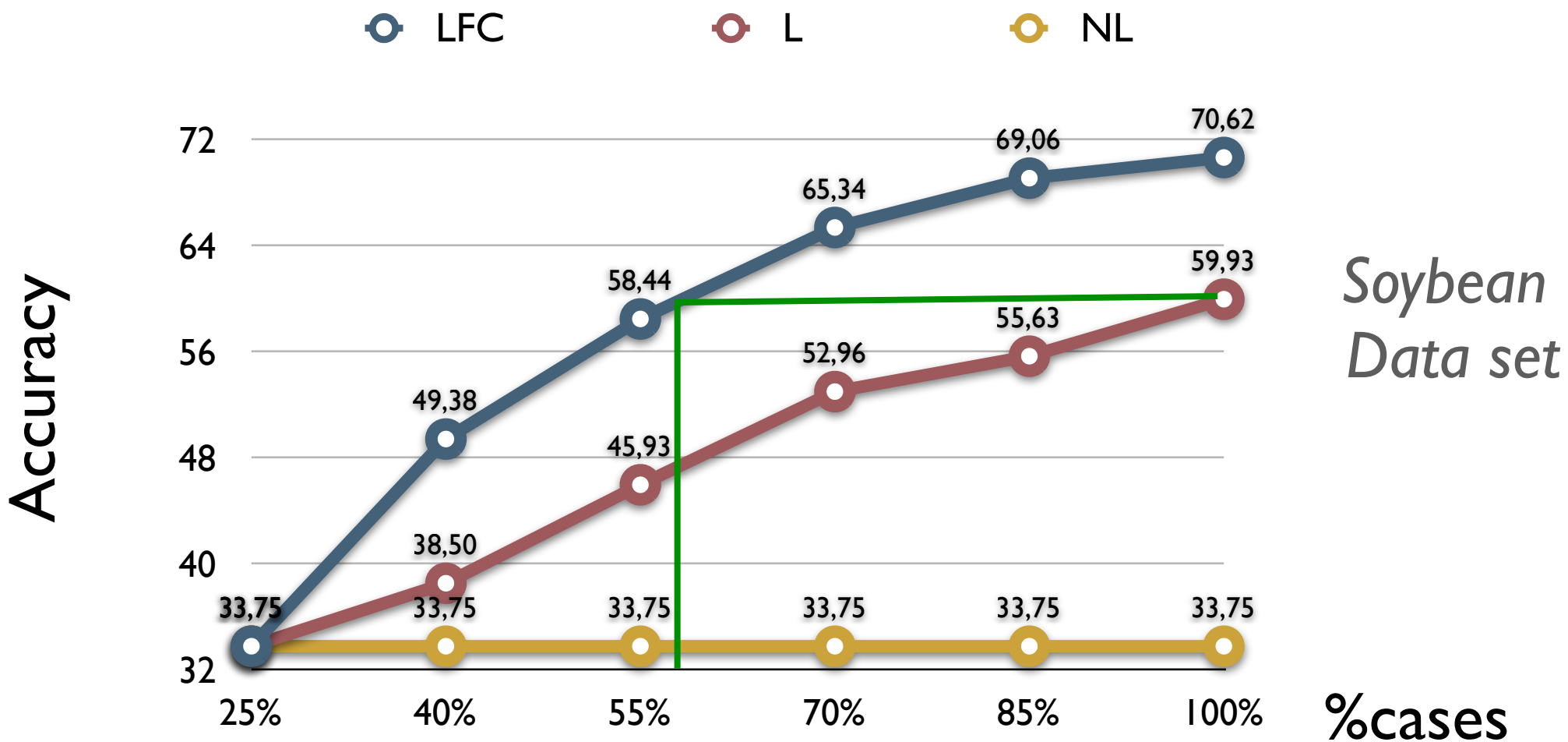



LFC
L
Total
#cases
300
270
240
210
180
150
120
90
60
30
0
23.4%
58,96
20%
50,40
252,00
31.58%
87,15
20.02%
55,26
276,00
Sponges
Soybean

Learning from a few good cases while arguing



Learning from a few good cases while arguing



Conclusions

- An argumentation framework for learning agents
- a case-based preference relation over arguments,
  - by computing a confidence estimation of arguments
- a case-based policy to generate counter-arguments and select counterexamples
- an argumentation-based approach for learning from communication

Future Work

- Framework for agents using induction
  - better policies for generating CA
  - collaborative search in generalization space
- Deliberative Agreement
  - for social choice and collective judgment models
  - aggregation procedures of sets of interconnected judgments
  - deliberation over sets of interconnected judgments

AMAL vs Centralized