Argumentation-based Distributed Induction

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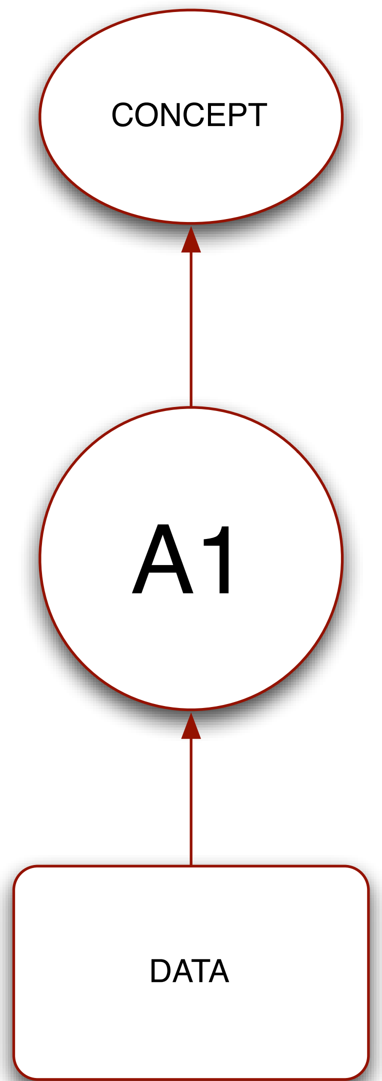
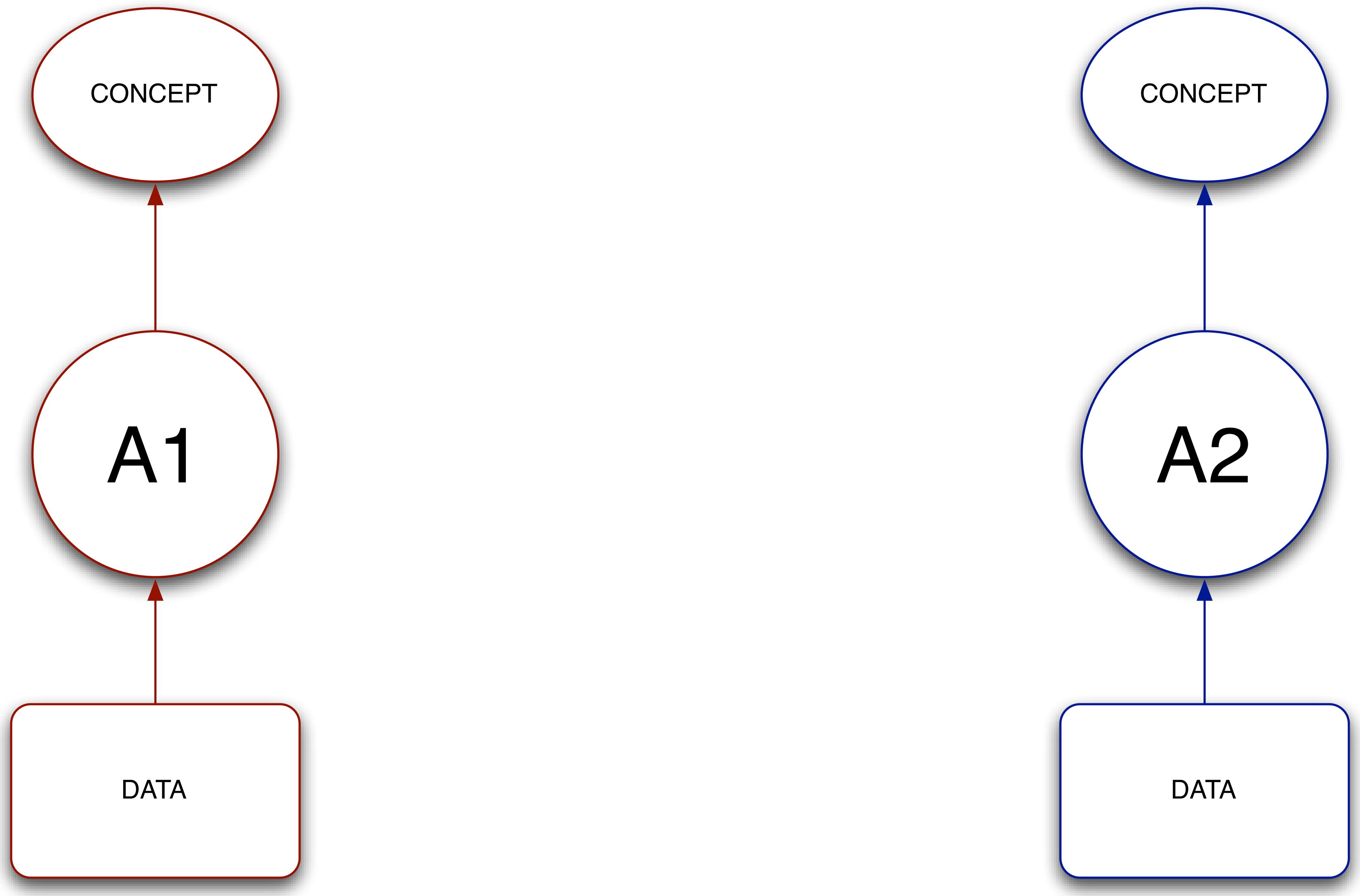
Outline

- Motivation
- Approach
- Evaluation
- Future

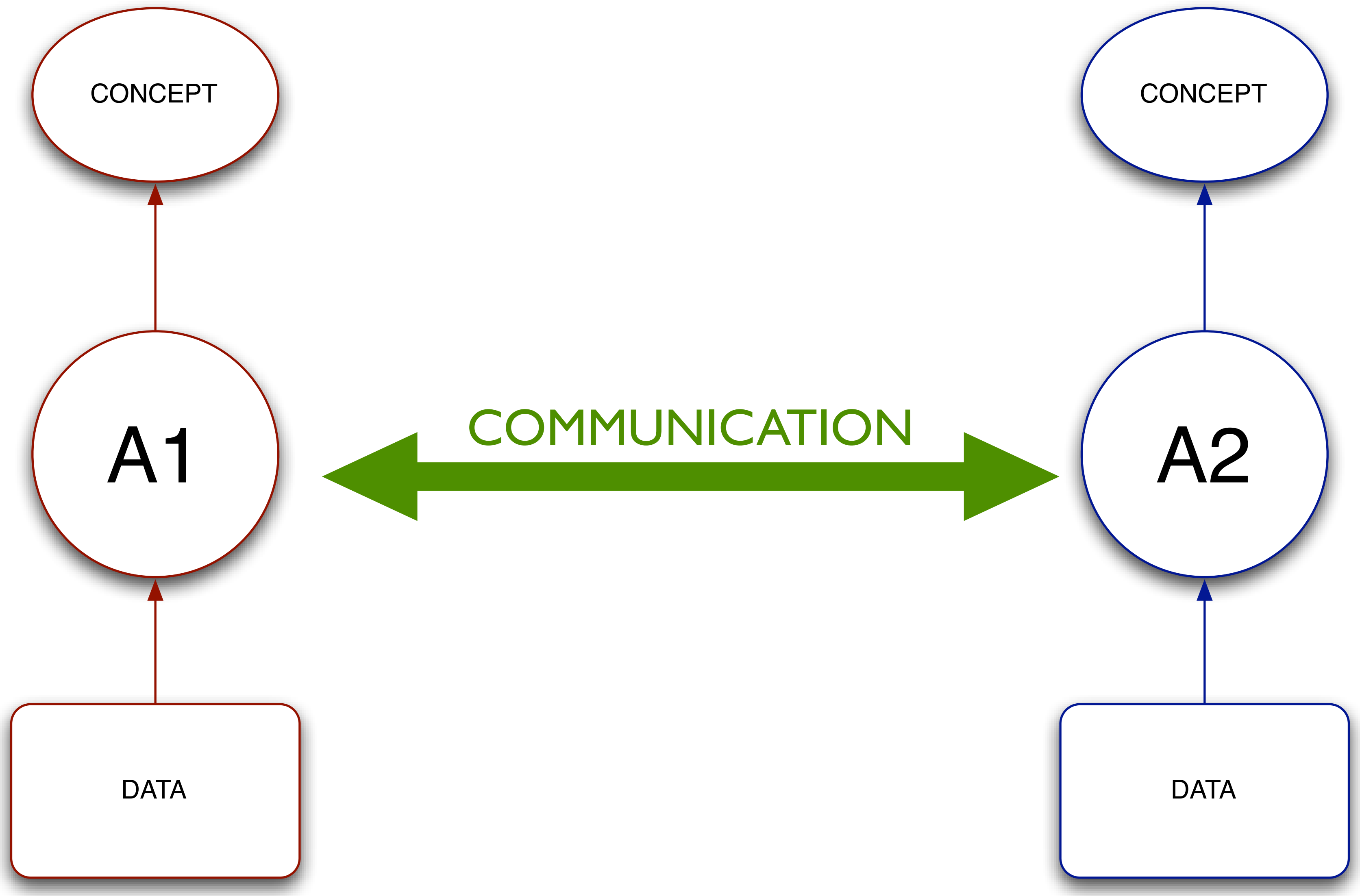
Motivation



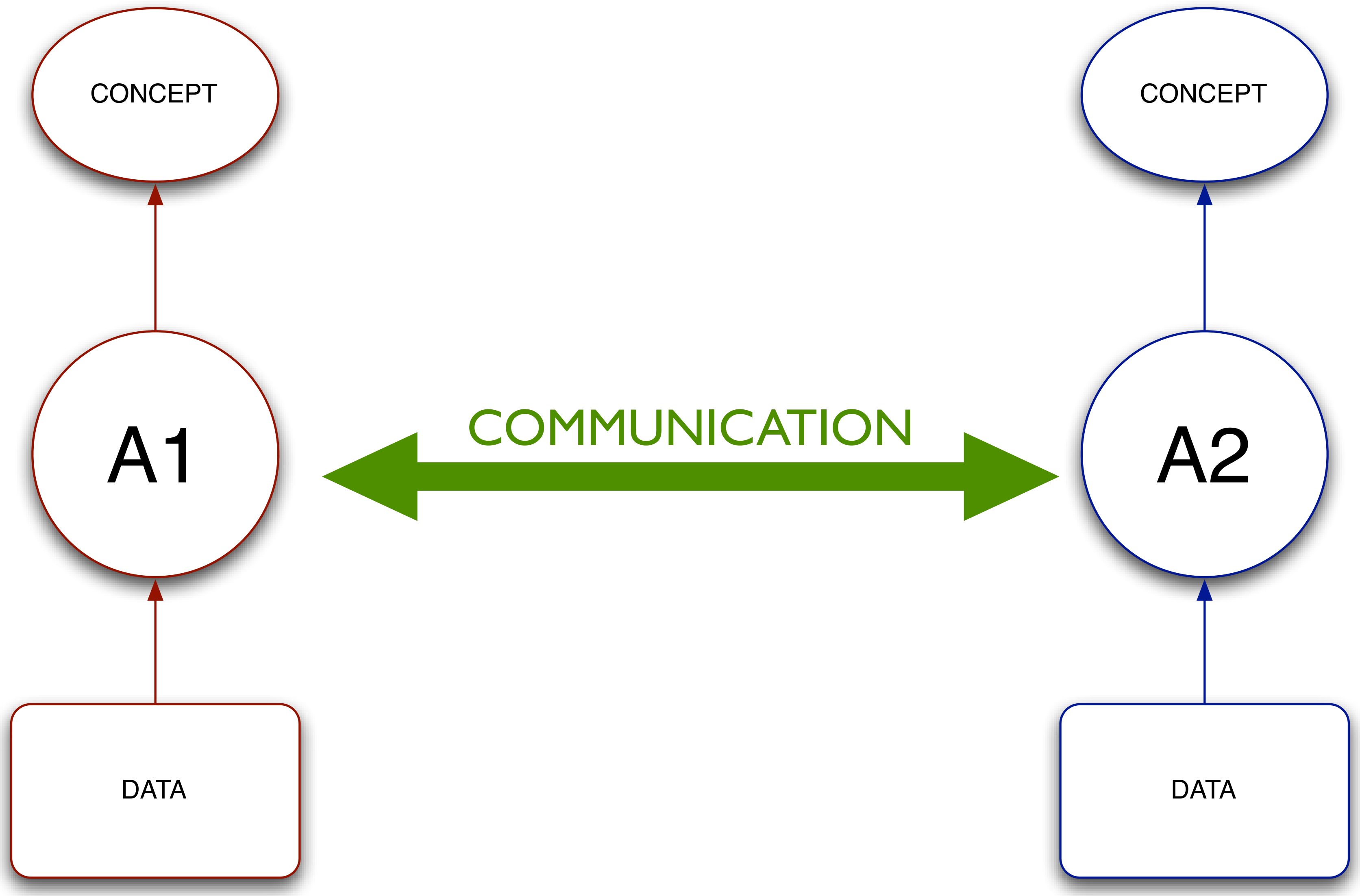
Motivation



Motivation



Motivation



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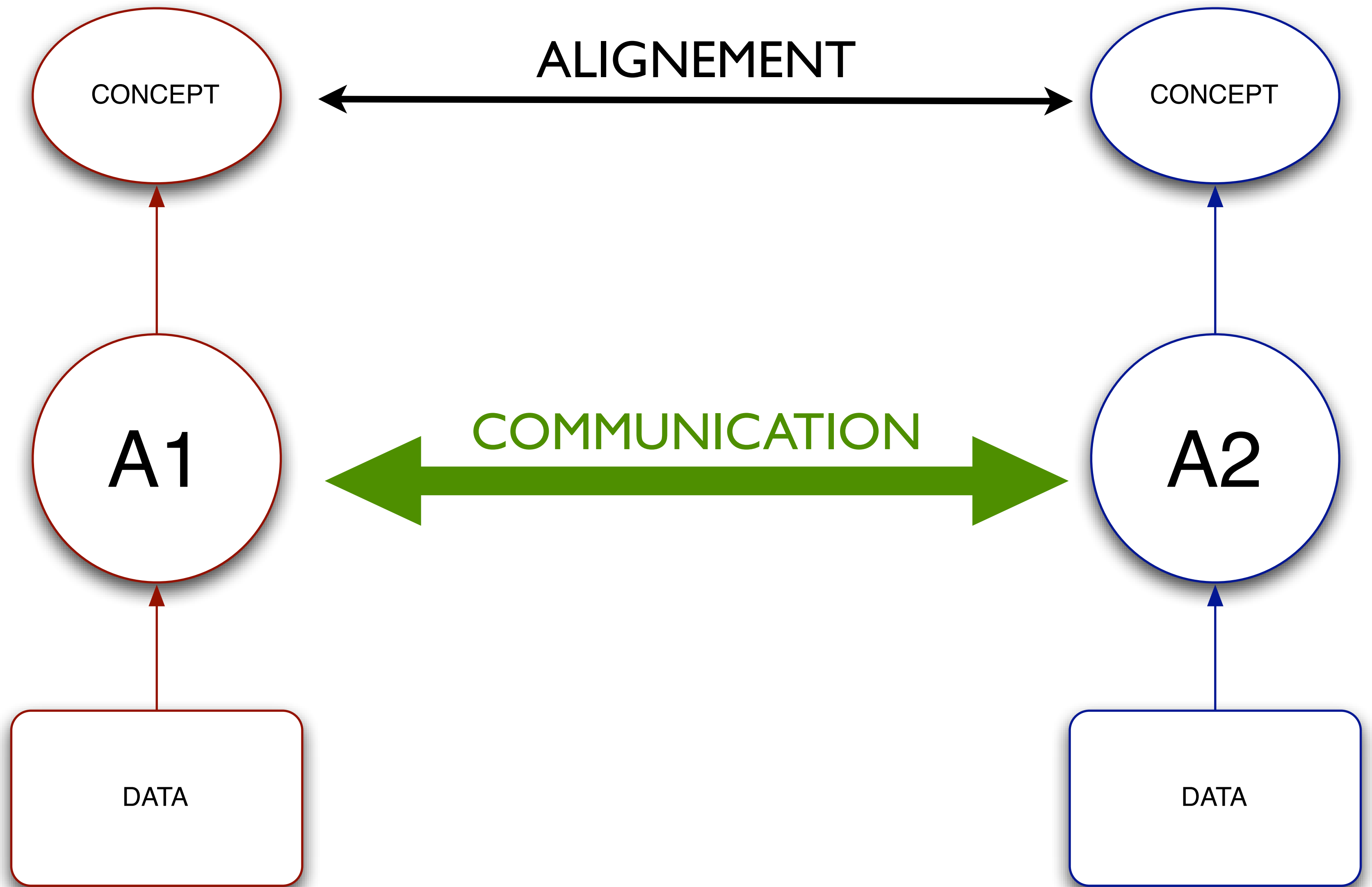
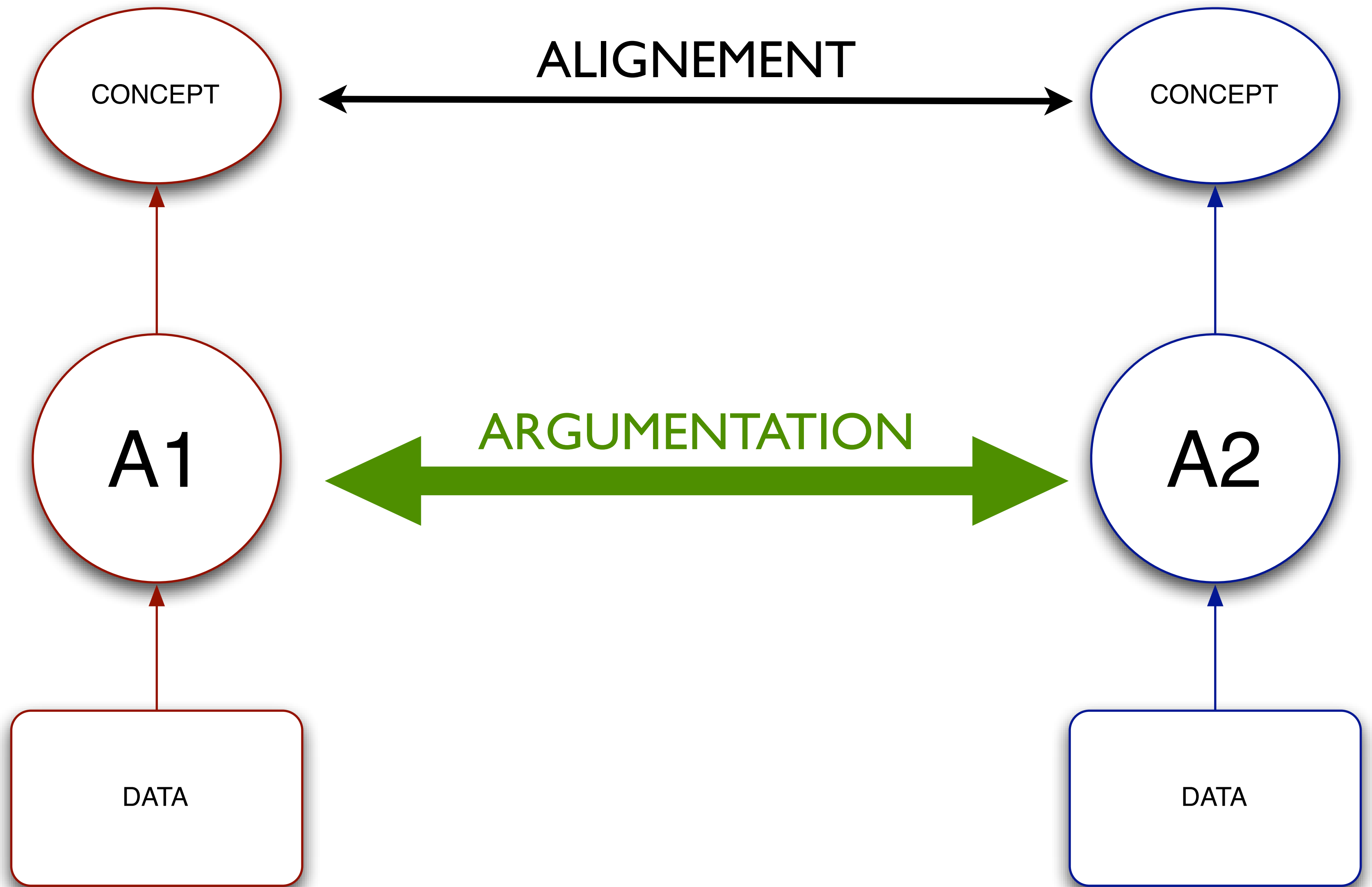


Motivation

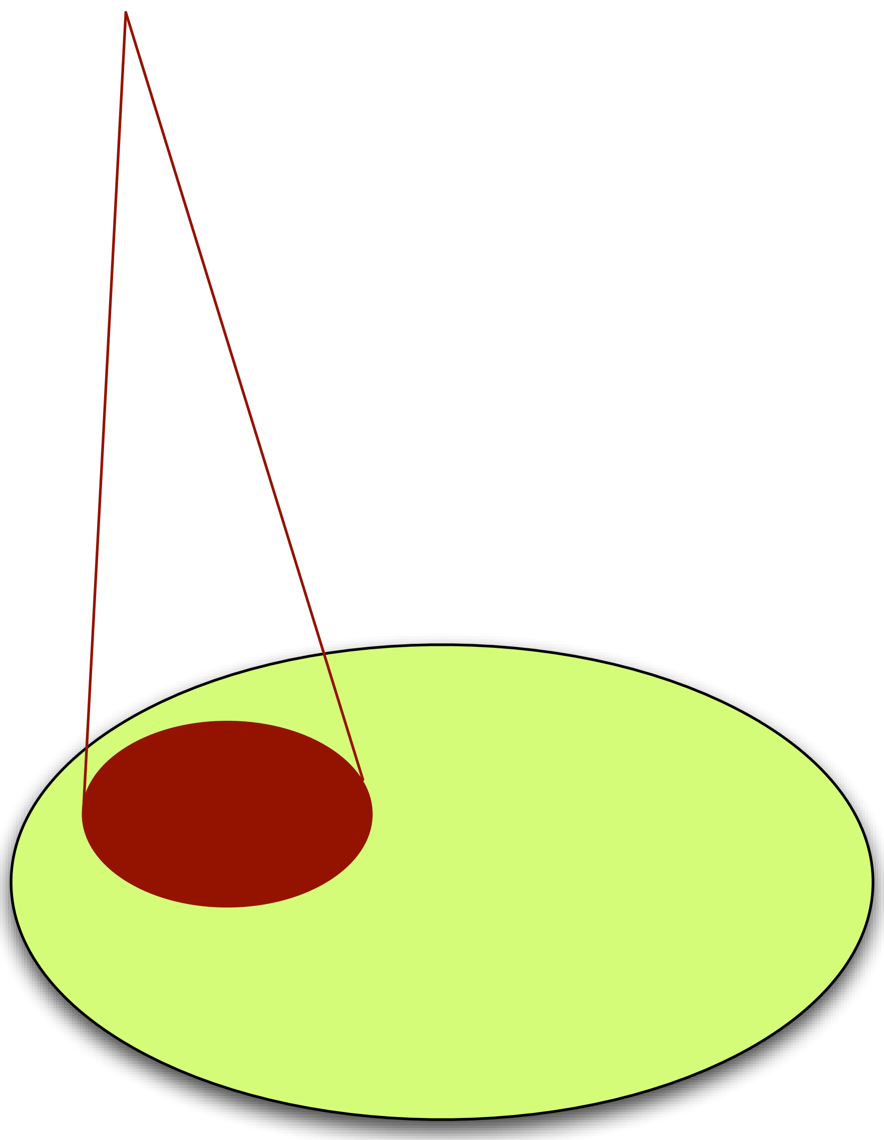


Goals

1. Distributed induction
2. argumentation-based communication process
3. on top of existing ML methods
   - ID3 (decision trees)
   - CN2 (rule induction)
   - INDIE (relational inductive learning)

Induction

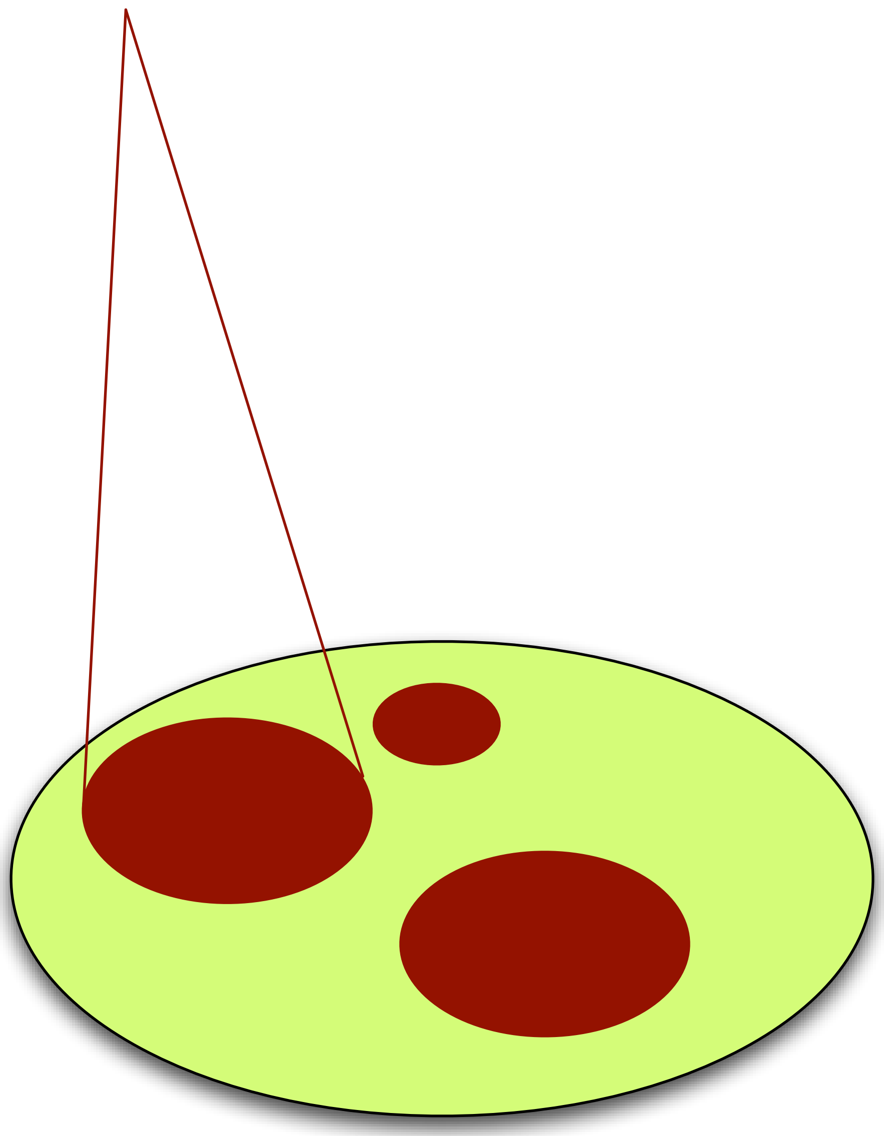
$p_1 \wedge p_2 \wedge p_3 \longrightarrow C$



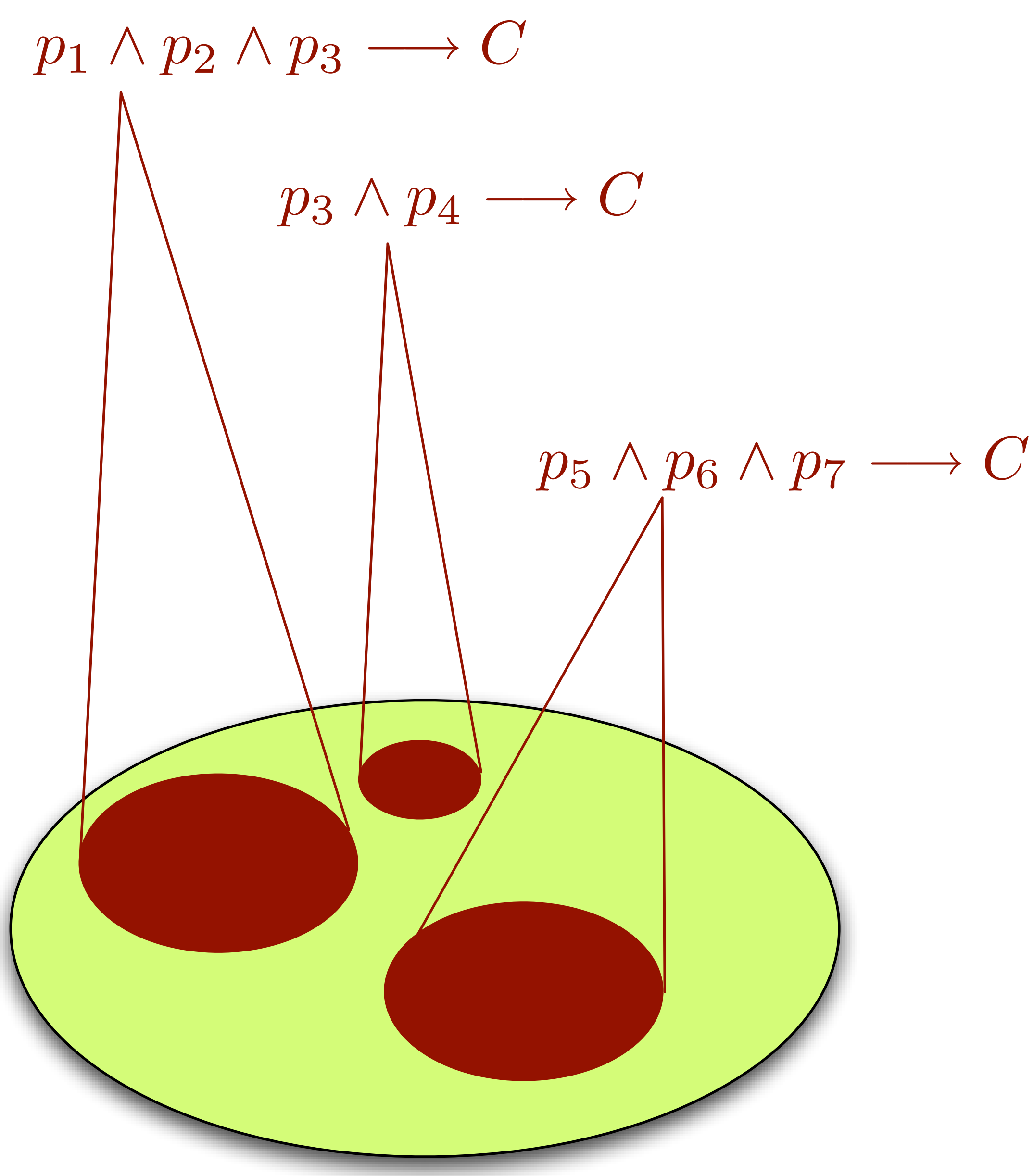
Hypothesis
(an example is a
concept C when
rule is satisfed)

Induction

$p_1 \wedge p_2 \wedge p_3 \longrightarrow C$

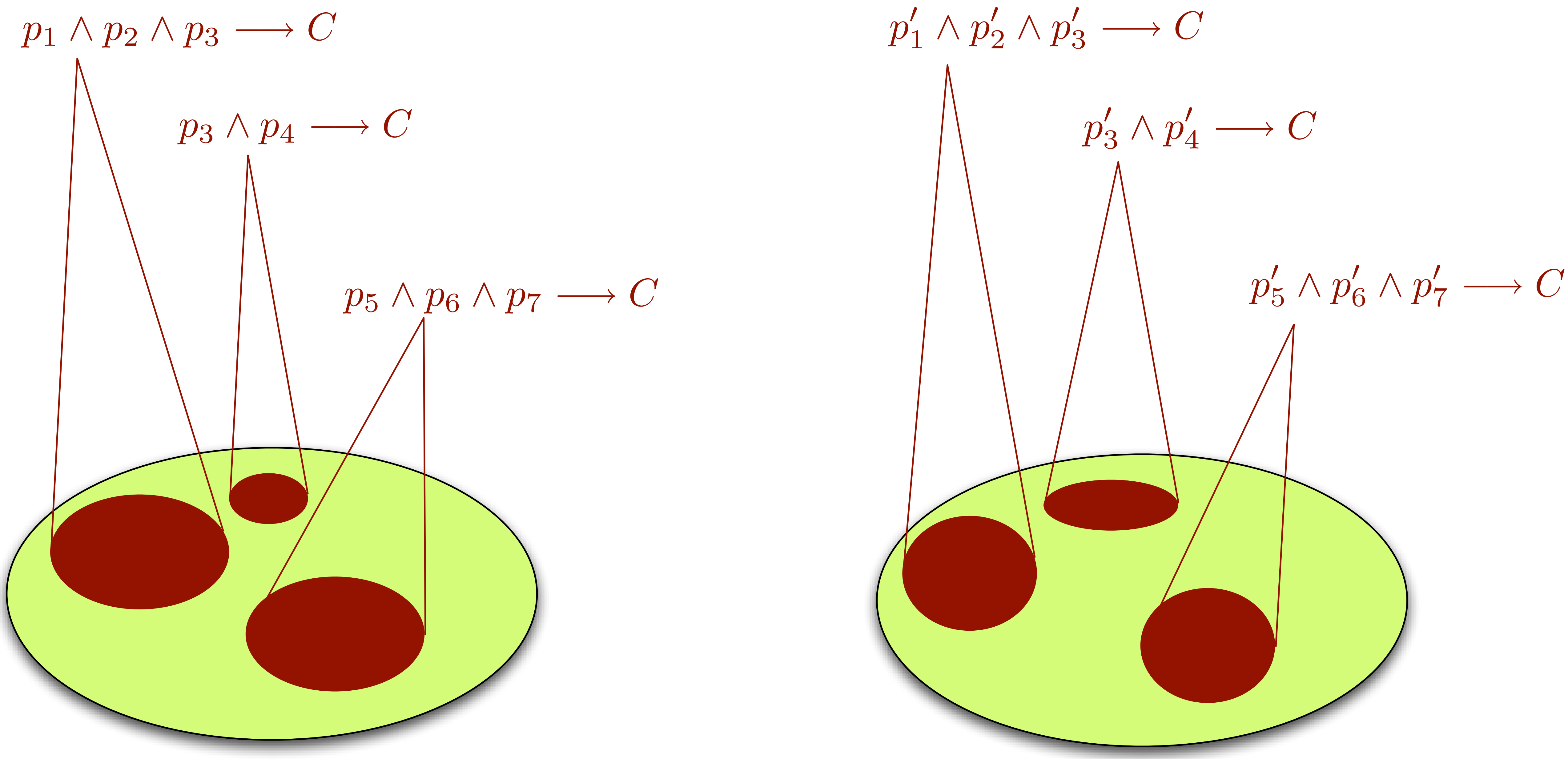


Induction



Hypothesis for C
=
disjunction of rules

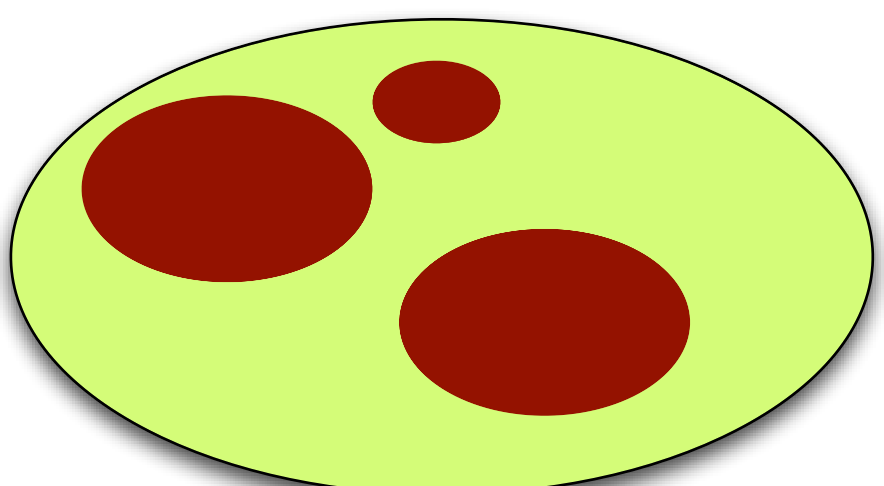
Induction with 2 agents

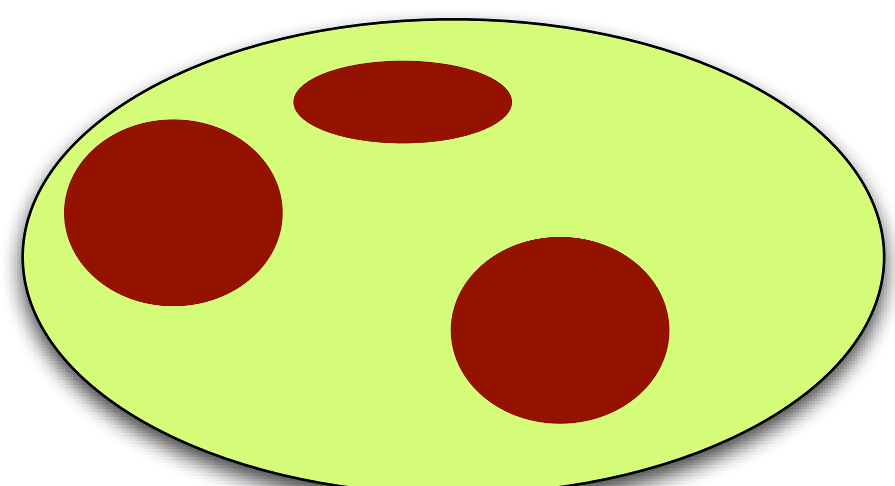


Agreement?

$$p_1 \wedge p_2 \wedge p_3 \longrightarrow C$$
$$p_3 \wedge p_4 \longrightarrow C$$
$$p_5 \wedge p_6 \wedge p_7 \longrightarrow C$$

$$p'_1 \wedge p'_2 \wedge p'_3 \longrightarrow C$$
$$p'_3 \wedge p'_4 \longrightarrow C$$
$$p'_5 \wedge p'_6 \wedge p'_7 \longrightarrow C$$





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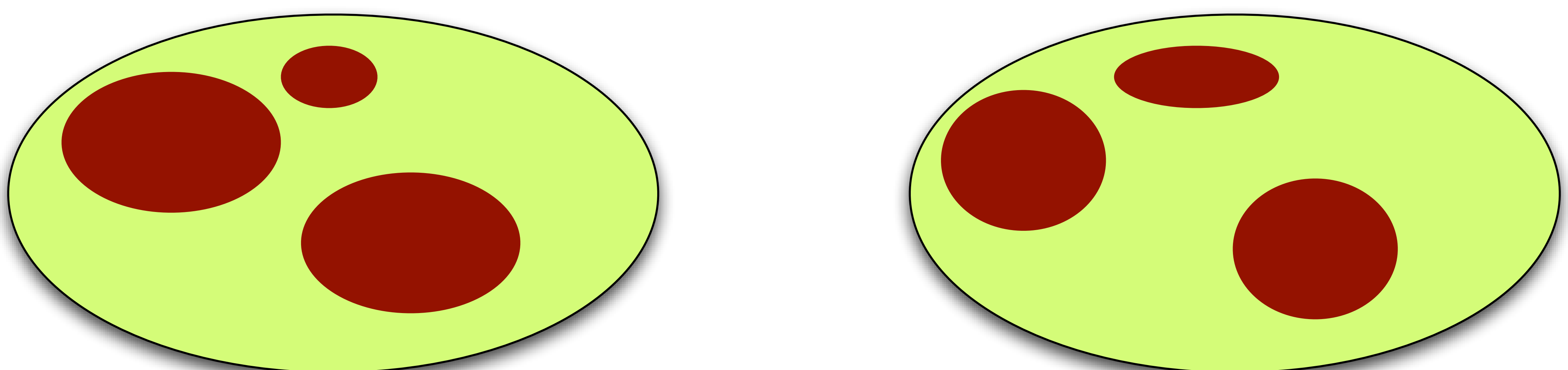

Agreement?

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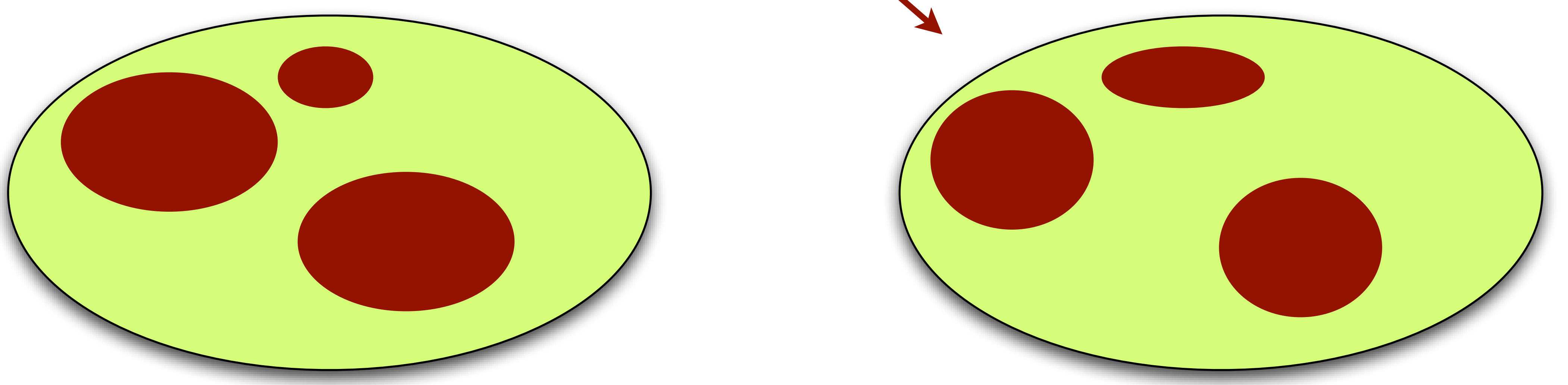

Agreement?

$$p_1 \wedge p_2 \wedge p_3 \longrightarrow C$$
$$p_3 \wedge p_4 \longrightarrow C$$
$$p_5 \wedge p_6 \wedge p_7 \longrightarrow C$$

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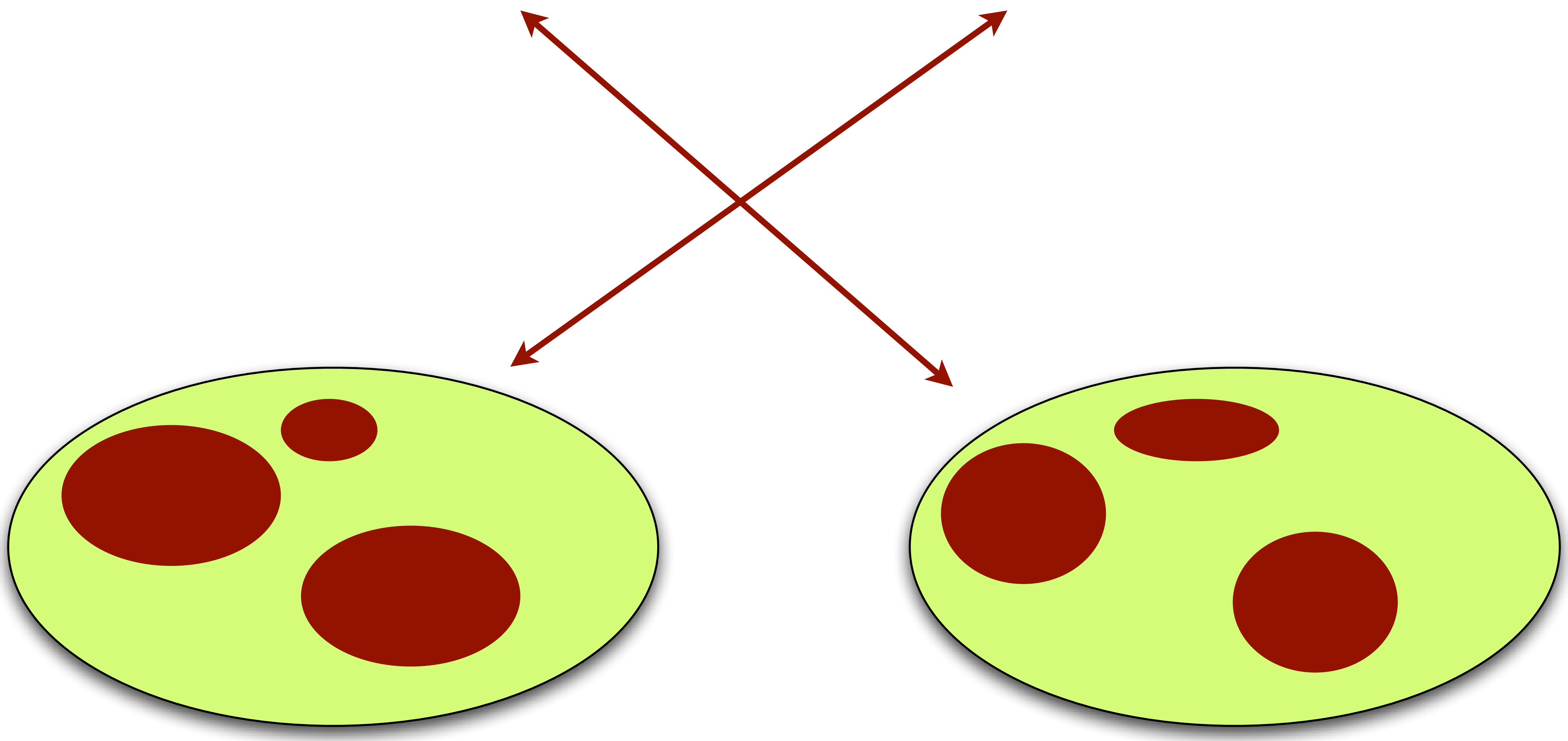

Approach

Argumentation

- Argumentation as a process :
  - to reach an agreed concept between 2 agents
  - regulated interchange for contrasting, attacking, and revising beliefs
- Working upon existing ML induction methods
  - ID3
  - CN2
  - INDIE

Argumentation

Examples $e = \langle P, S \rangle \ where \ (S \in \mathcal{S})$

Hypotheses $\mathbb{H} = \{r_1, ..., r_m\}$

Rules $r = \langle H, S \rangle$

Argumentation

Examples $e = \langle P, S \rangle \ where \ (S \in \mathcal{S})$

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Argumentation

Examples $e = \langle P, S \rangle \ where \ (S \in \mathcal{S})$

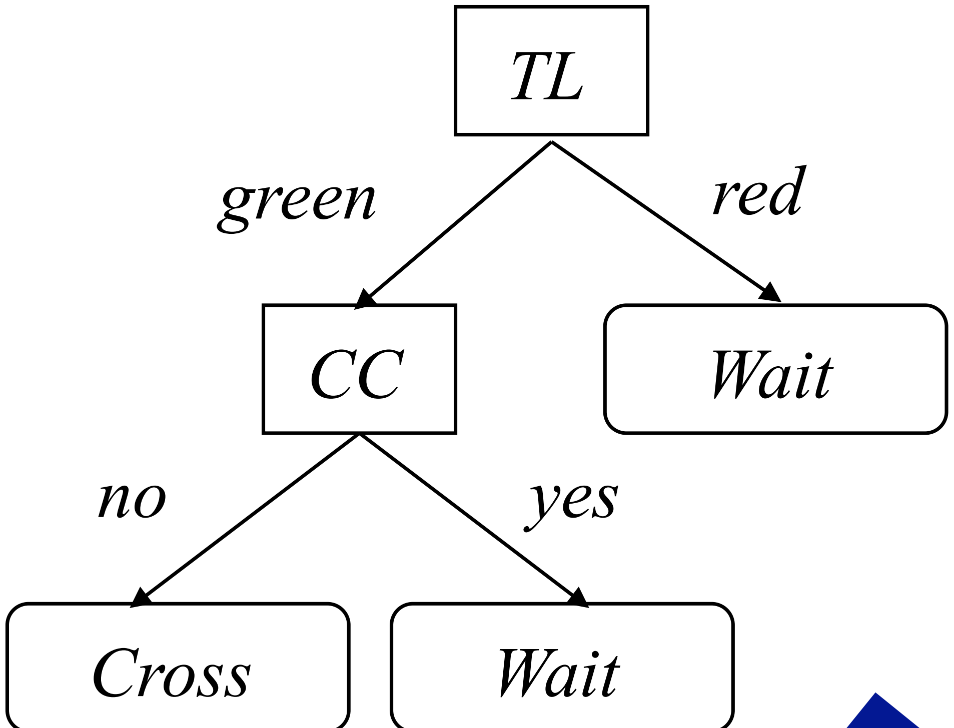
Hypotheses $\mathbb{H} = \{r_1, ..., r_m\}$

Rules $r = \langle H, S \rangle$

Argument $\alpha = \langle A, r \rangle$

Counter-example $\beta = \langle A, e, \alpha \rangle$

ID3 rule conversion



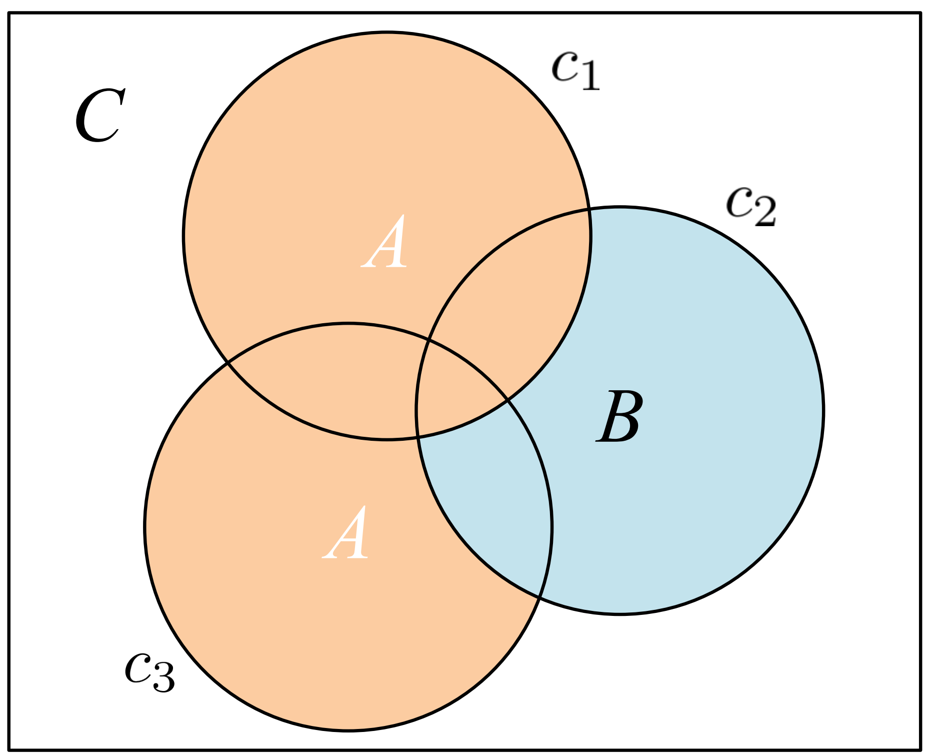
$$\begin{cases} r_1 := \langle TL = green \wedge CC = no, Cross \rangle \\ r_2 := \langle TL = green \wedge CC = yes, Wait \rangle \\ r_3 := \langle TL = red, Wait \rangle \end{cases}$$

CN2 post-process

Post-processing removes order dependencies among rules used in CN2

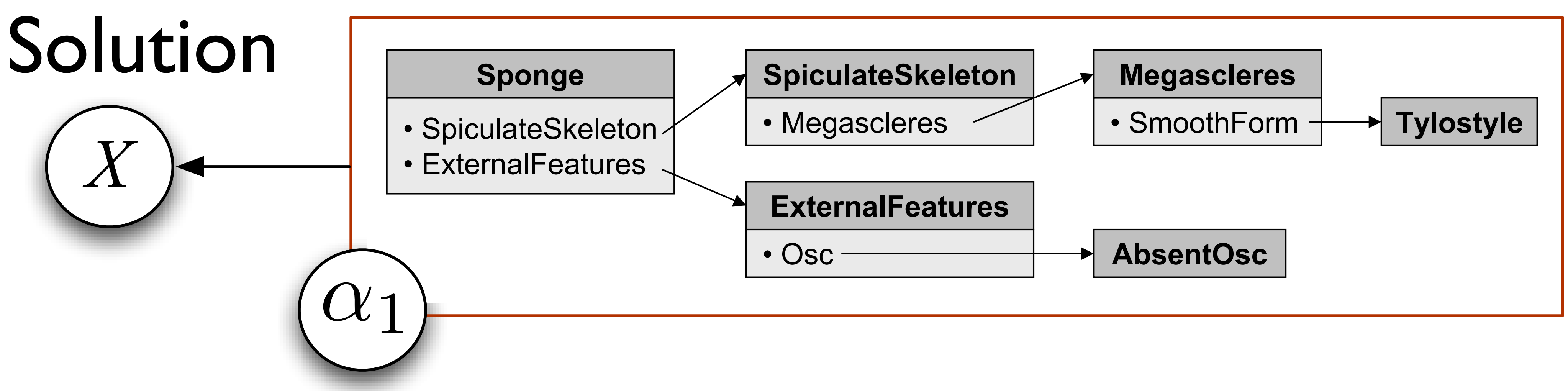
CN2 output:

$$\left.\begin{array}{l} r_1 = \langle c_1, A\rangle \\ r_2 = \langle c_2, B\rangle \\ r_3 = \langle c_3, A\rangle \\ \textit{default: } C \end{array}\right\} \Rightarrow$$



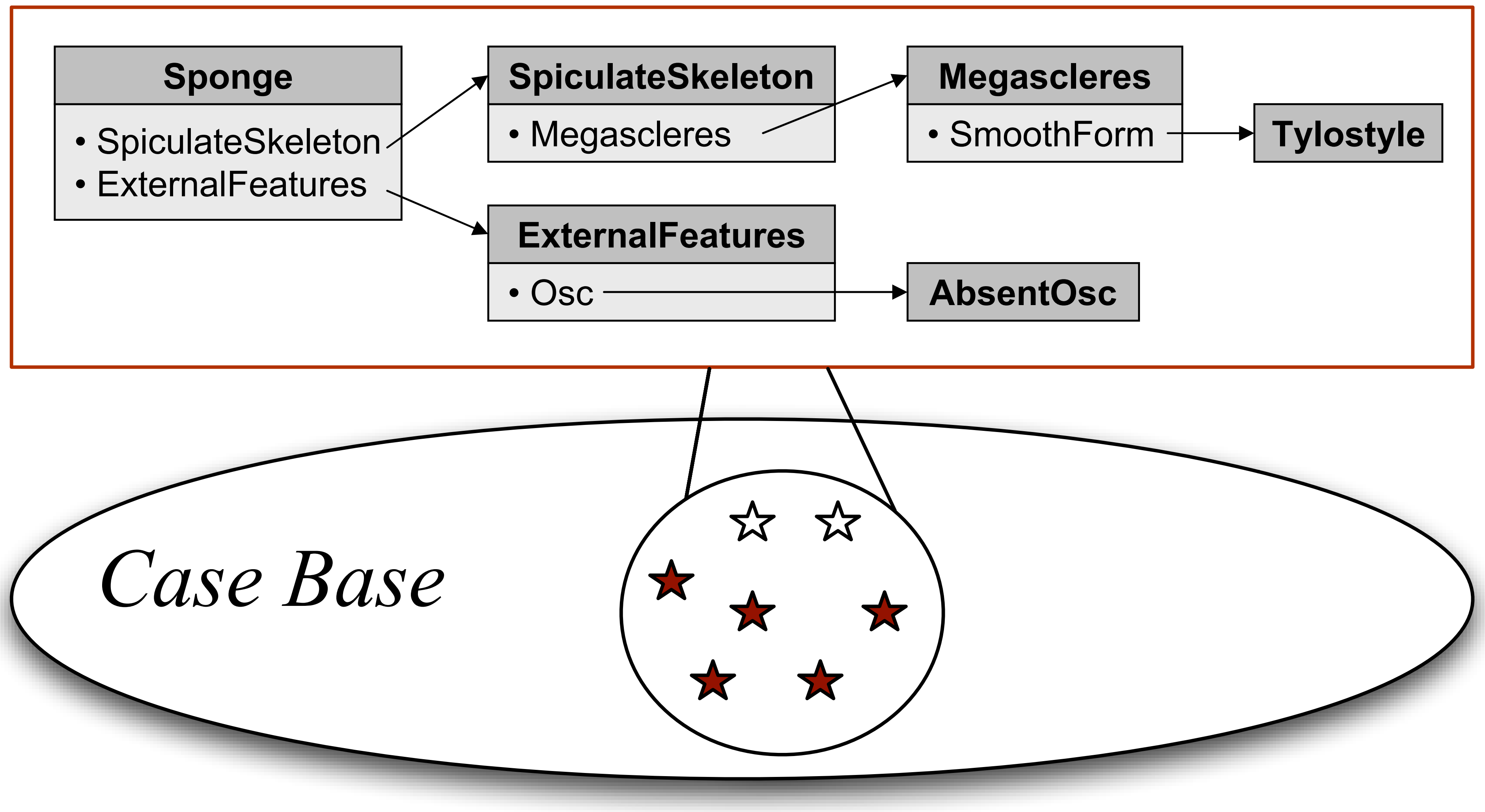
$$\Rightarrow \left\{\begin{array}{l} r'_1 = \langle c_1, A\rangle \\ r'_2 = \langle c_2 \wedge \neg c_1, B\rangle \\ r'_3 = \langle c_3 \wedge \neg c_1 \wedge \neg c_2, A\rangle \\ r'_4 = \langle \neg c_1 \wedge \neg c_2 \wedge \neg c_3, C\rangle \end{array}\right.$$

Argument


Solution
X
α1
Sponge
• SpiculateSkeleton
• ExternalFeatures
SpiculateSkeleton
• Megascleres
Megascleres
• SmoothForm
Tylostyle
ExternalFeatures
• Osc
AbsentOsc

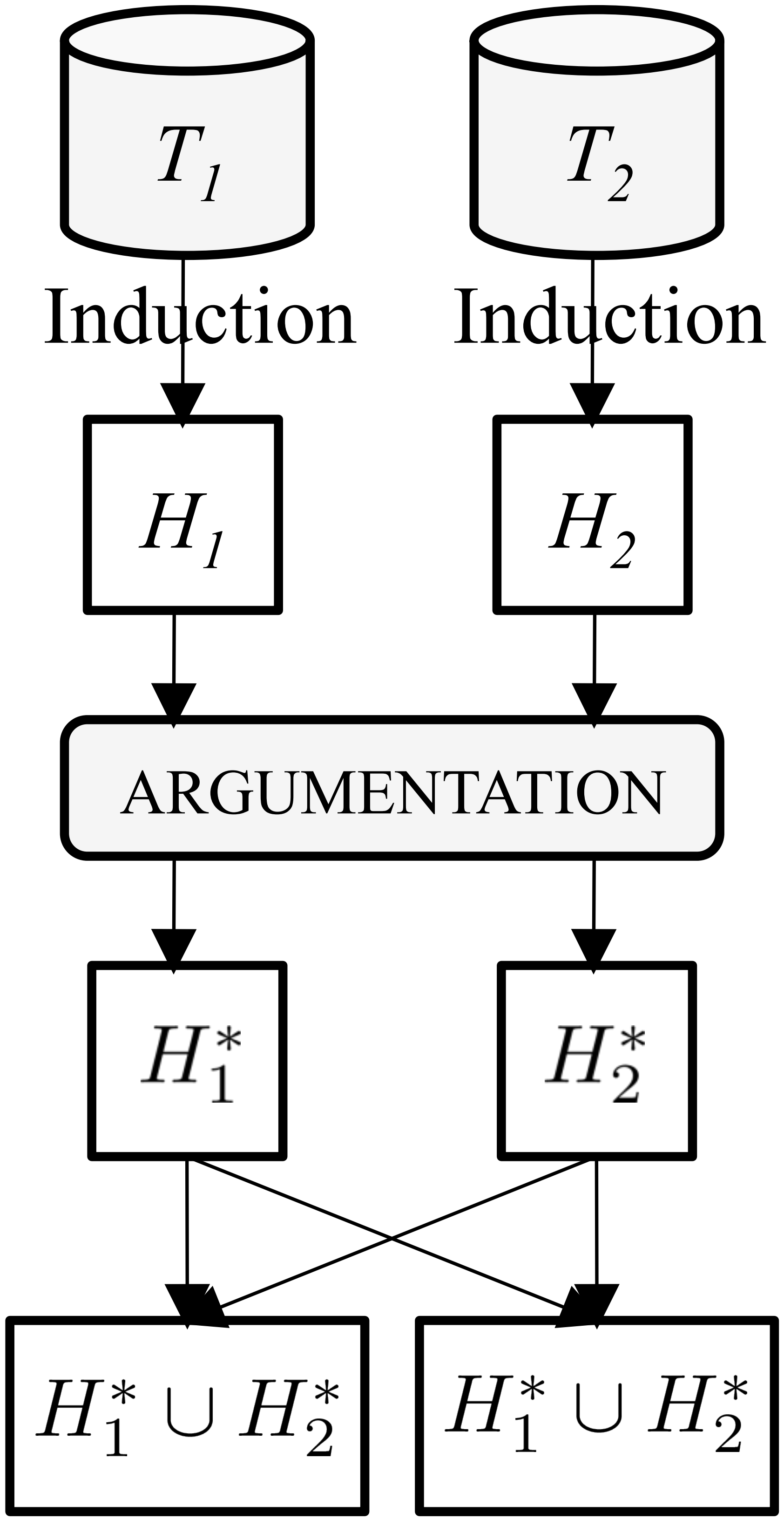
Argument evaluation

The other's arguments
are contrasted with one's examples



Finding Couter-examples of an argument

ADI Argumentation-based Distributed Induction



Induction by individual agent using a specific ML method (ID3, CN2, INDIE)

Argumentation about each rule held by an agent (first one agent then the other)

Hypotheses union eliminating redundancies

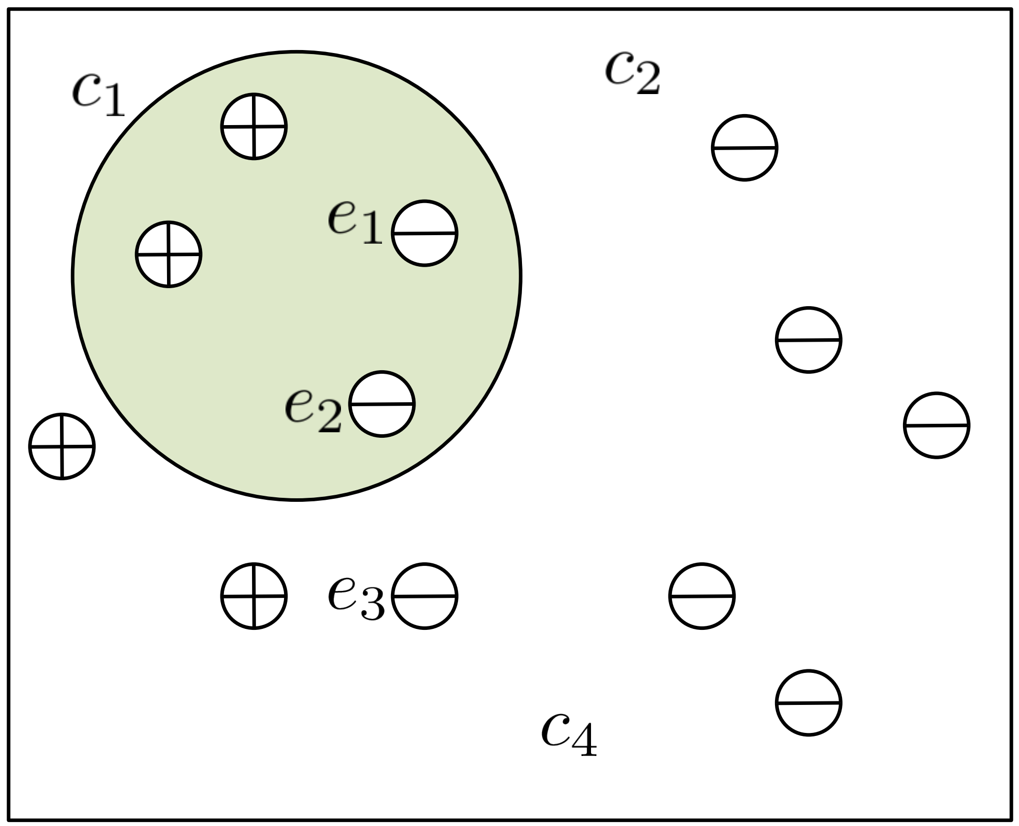
ADI argumentation

H_1^0

$$r_1 = \langle c_1, + \rangle$$
$$r_2 = \langle c_2, - \rangle$$
$$r_3 = \langle c_3, + \rangle$$
$$r_4 = \langle c_4, - \rangle$$

$$\alpha_1 = \langle A_1, r_1 \rangle$$

T_2



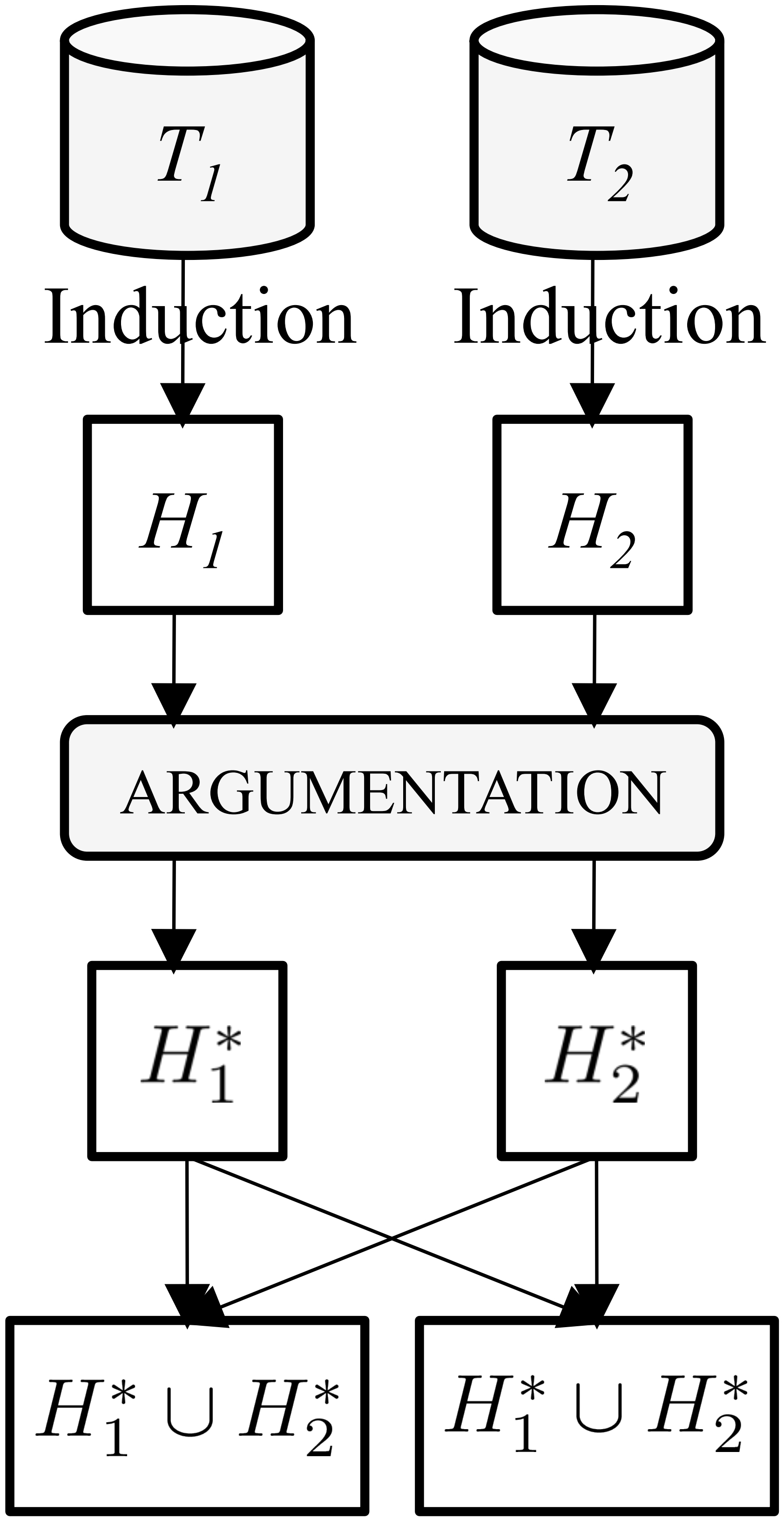
$$C(\alpha_1) = \{e_1, e_2\}$$

$$\beta = \langle A_2, e_1, \alpha_1 \rangle$$

Belief revision: Agent A_1 incorporates counter-exmple e_1 and updates induction hypotheses

RADI

Reduced Argumentation-based Distributed Induction



Induction by individual agent using a specific ML method (ID3, CN2, INDIE)

Argumentation about hypothesis of one agent (then the other agent)

Hypotheses union eliminating redundancies

Argumentation in RADI

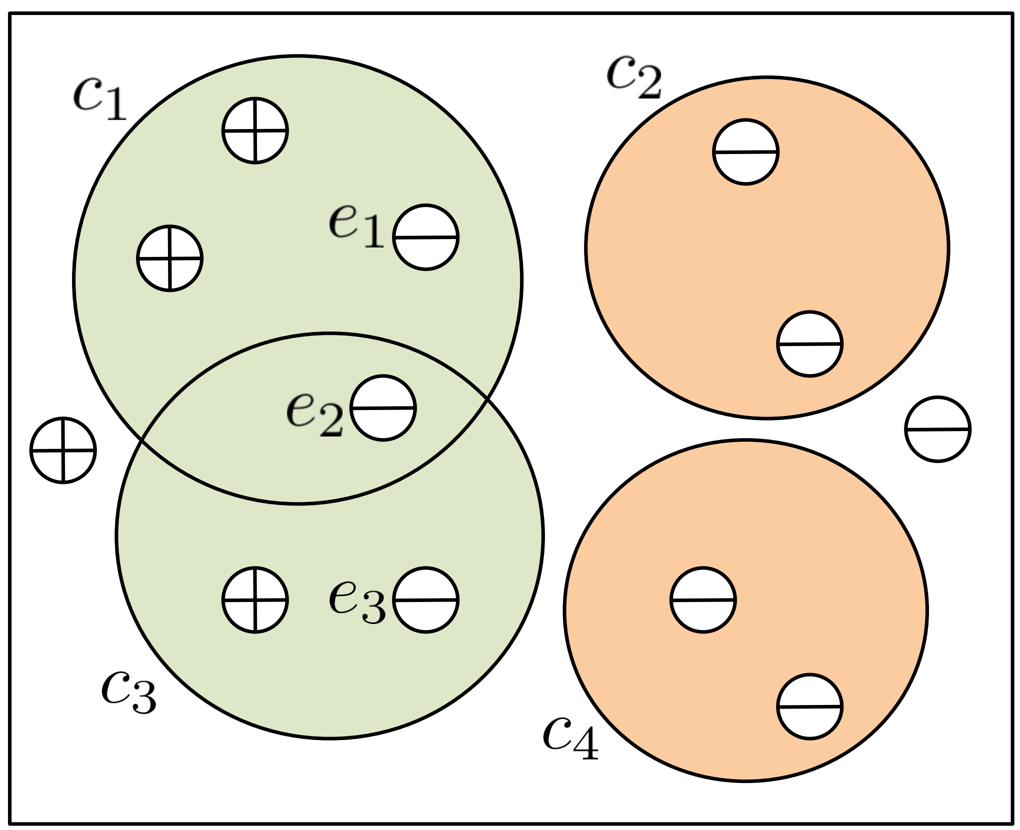
H_1^0

$$r_1 = \langle c_1, + \rangle$$
$$r_2 = \langle c_2, - \rangle$$
$$r_3 = \langle c_3, + \rangle$$
$$r_4 = \langle c_4, - \rangle$$

$\mathcal{R}^0$

$$\alpha_1 = \langle A_1, r_1 \rangle$$
$$\alpha_2 = \langle A_1, r_2 \rangle$$
$$\alpha_3 = \langle A_1, r_3 \rangle$$
$$\alpha_4 = \langle A_1, r_4 \rangle$$

T_2

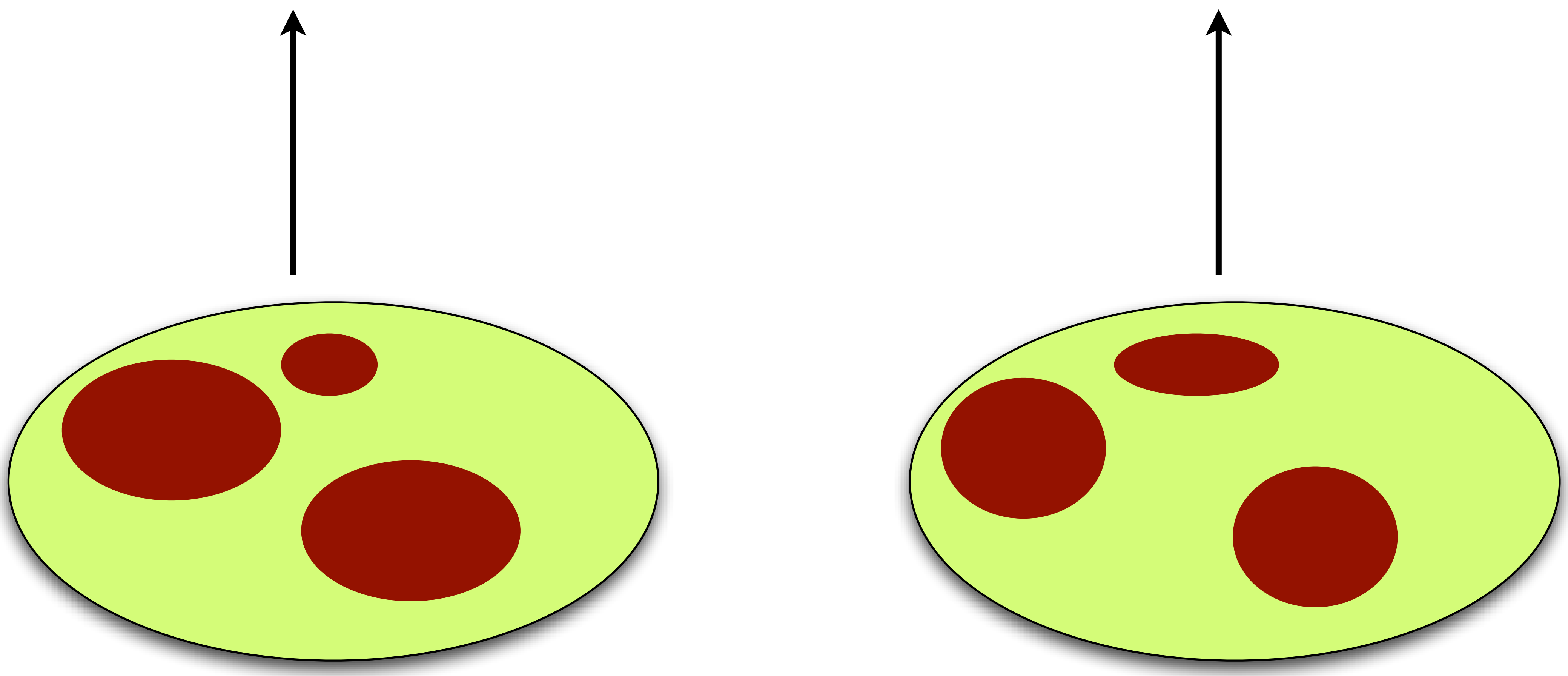


$$C(\alpha_1) = \{e_1, e_2\}$$
$$C(\alpha_2) = \emptyset$$
$$C(\alpha_3) = \{e_2, e_3\}$$
$$C(\alpha_4) = \emptyset$$

$$I^0 = \{\alpha_1, \alpha_3\}$$
$$B^0 = \{e_2\}$$

Agreement

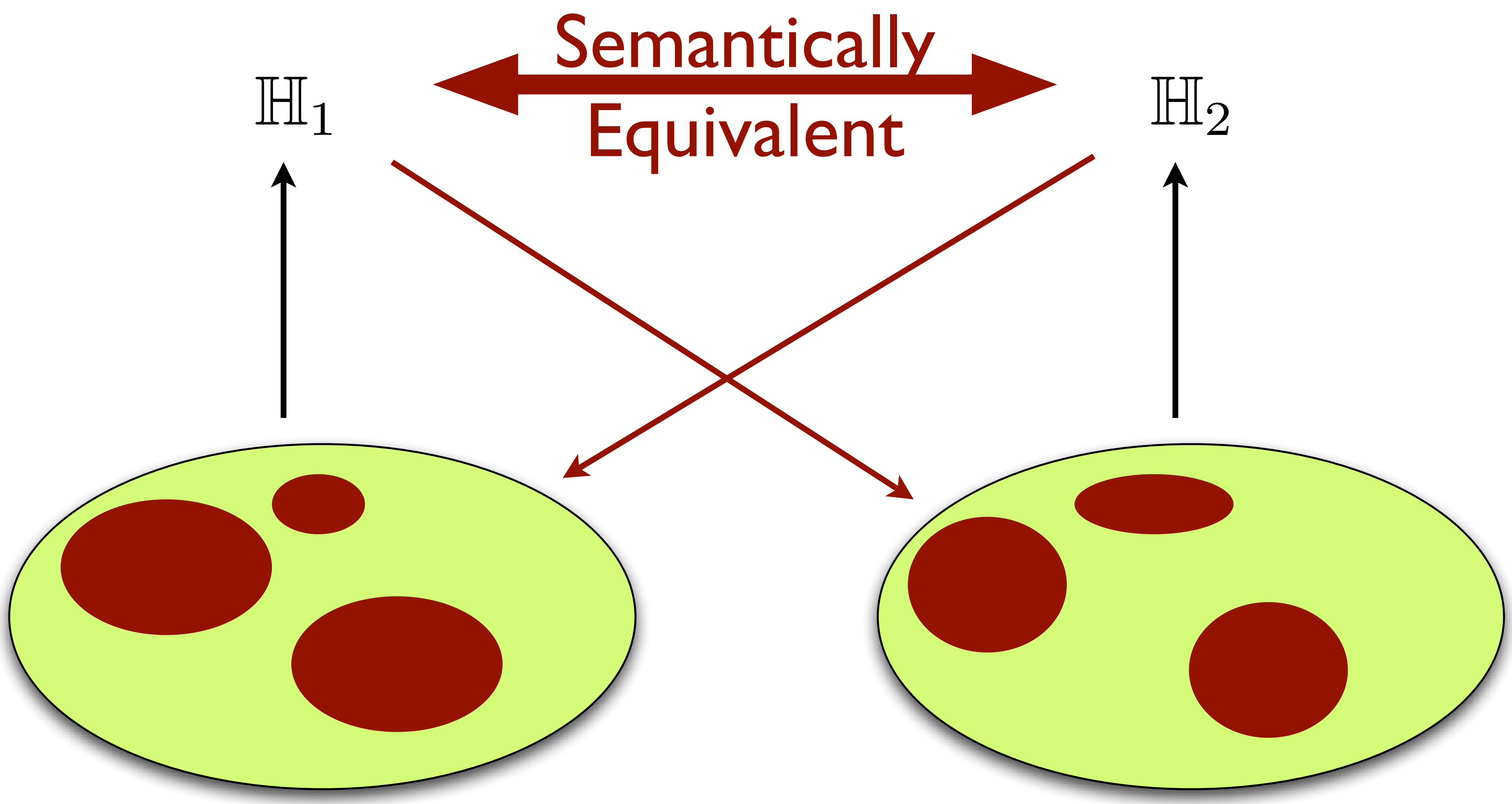
$\mathbb{H}_1$ $\mathbb{H}_2$



E_1^+ E_2^+

$\mathbb{H}_1 \sqsubseteq E_1^+$ $\mathbb{H}_2 \sqsubseteq E_2^+$

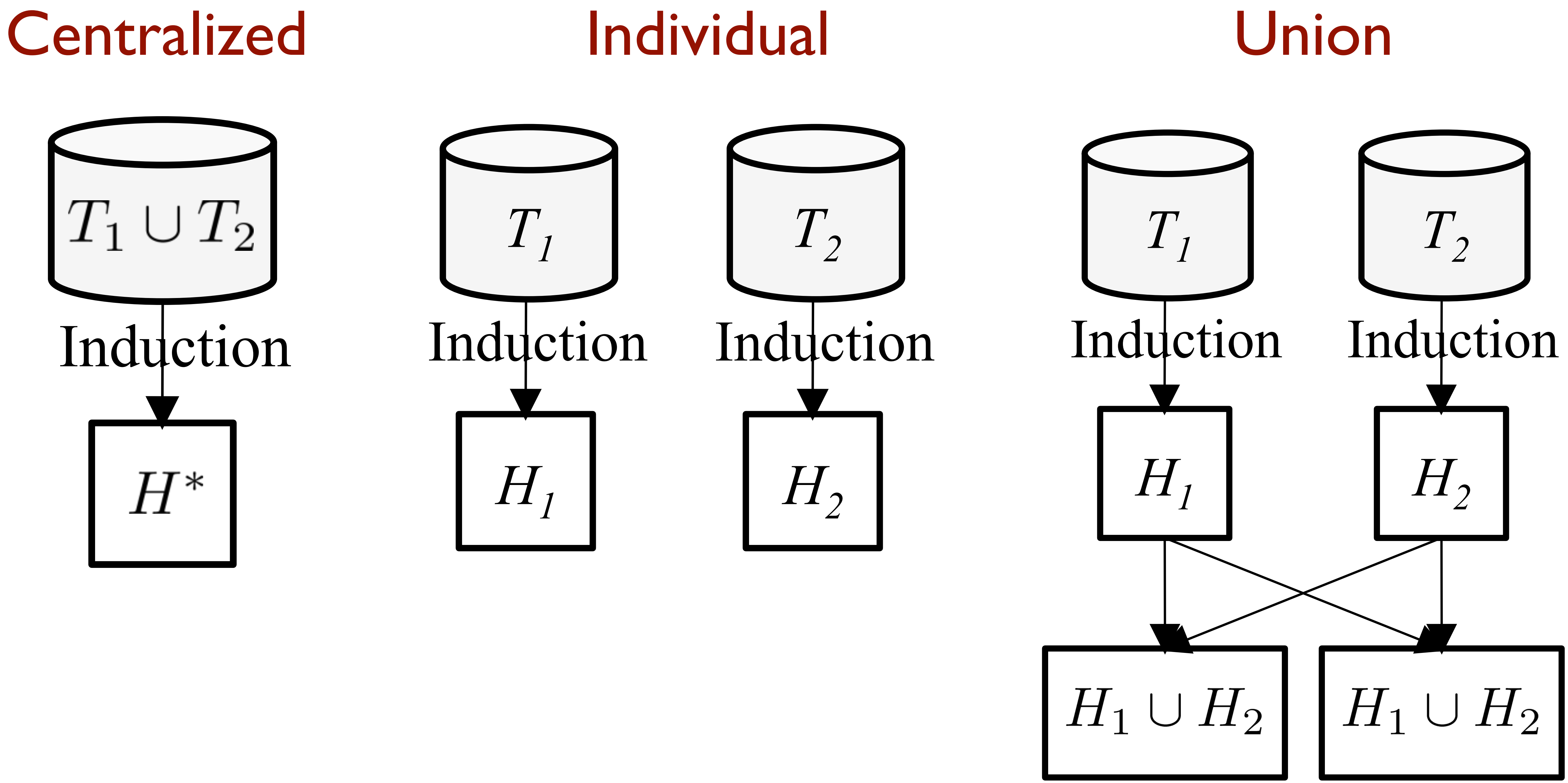
Agreement

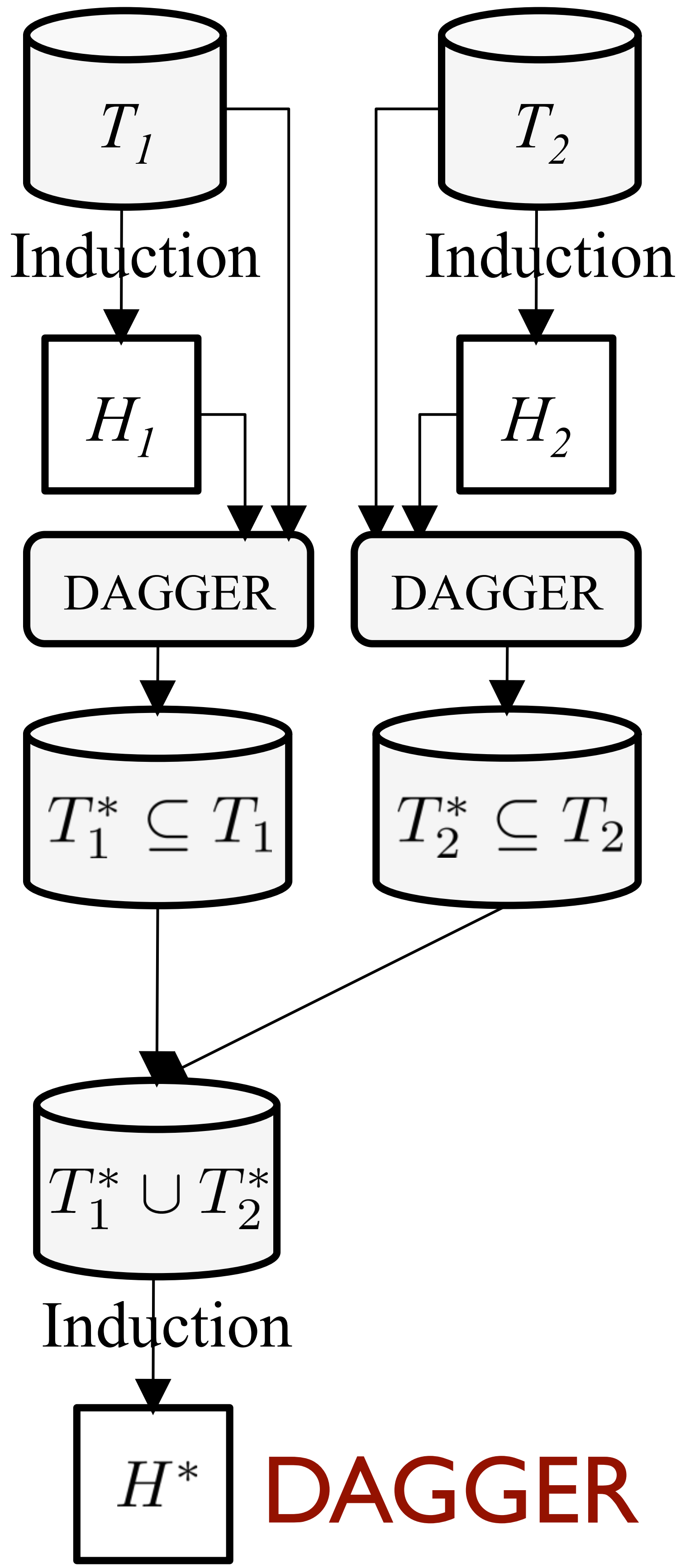


E_1^+ | E_2^+
$\mathbb{H}_1 \sqsubseteq E_1^+$ | $\mathbb{H}_2 \sqsubseteq E_2^+$
$\mathbb{H}_1 \sqsubseteq E_2^+$ | $\mathbb{H}_2 \sqsubseteq E_1^+$

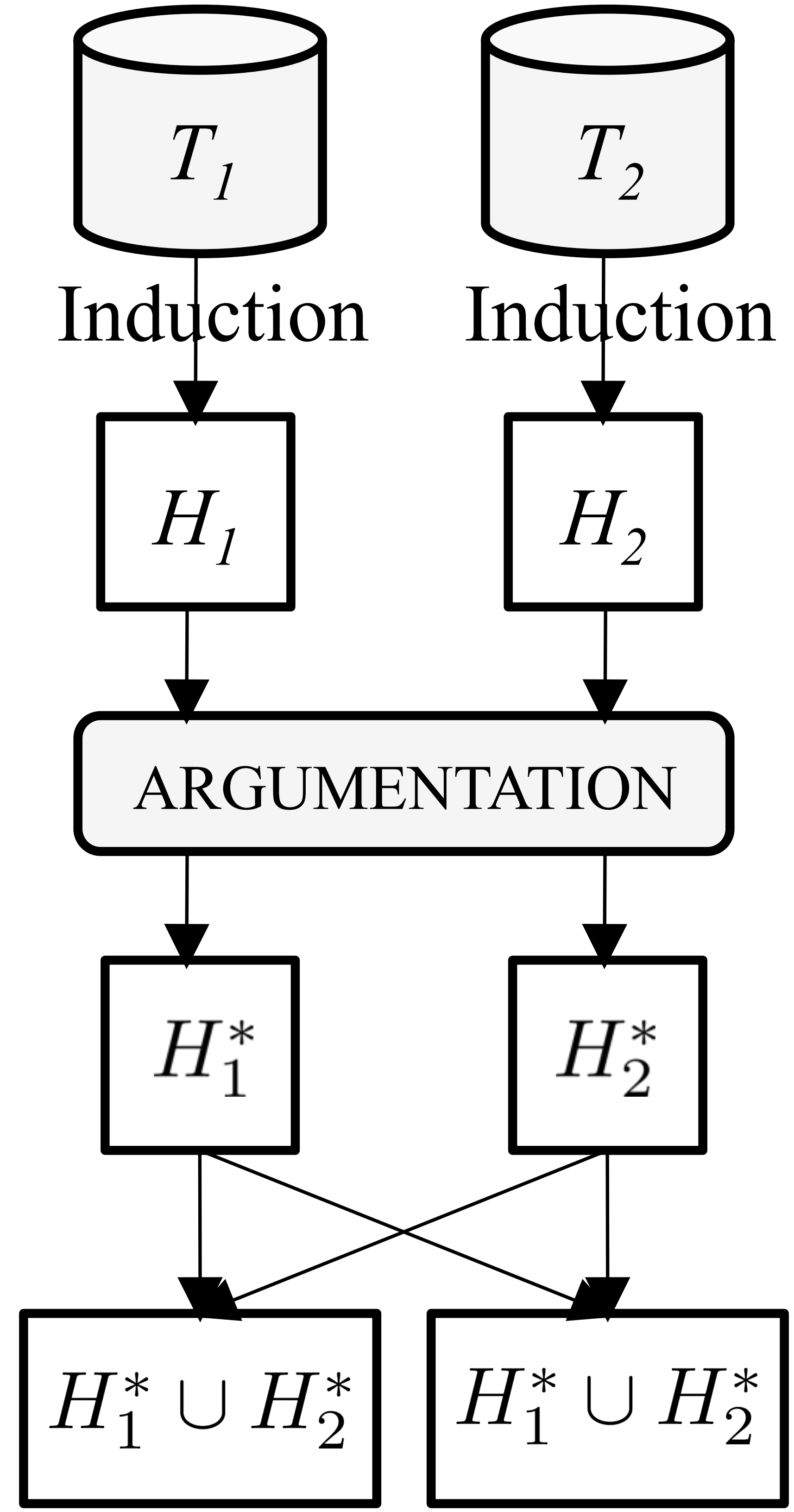
Evaluation
of ADI & RADI

Distribution





DAGGER



ADI/RADI

Evaluation

Accuracy								
	Training				Test			
	Soybean	Zoology	Cars	Sponges	Soybean	Zoology	Cars	Sponges
ID3-centralized	100,00	100,00	100,00	99,44	85,00	99,00	88,95	58,57
ID3-Individual	85,67	93,85	93,84	80,20	76,50	90,00	86,83	55,54
ID3-union	90,25	94,73	97,73	94,05	81,00	94,00	**90,99**	60,36
ID3-DAGGER	99,57	100,00	76,36	99,76	80,67	92,50	68,95	**62,50**
ID3-ADI	100,00	100,00	100,00	99,70	**88,50**	**99,00**	88,95	58,21
ID3-RADI	100,00	100,00	100,00	99,74	87,67	**99,00**	89,24	58,21

Data set: 90% training; 10% test

2 Agents: 50% training set

Best results in bold (when not statistically significant more than one results are in bold)

Evaluation

Accuracy								
	Training				Test			
	Soybean	Zoology	Cars	Sponges	Soybean	Zoology	Cars	Sponges
ID3-centralized	100,00	100,00	100,00	99,44	85,00	99,00	88,95	58,57
ID3-Individual	85,67	93,85	93,84	80,20	76,50	90,00	86,83	55,54
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ID3-DAGGER	99,57	100,00	76,36	99,76	80,67	92,50	68,95	**62,50**
ID3-ADI	100,00	100,00	100,00	99,70	**88,50**	**99,00**	88,95	58,21
ID3-RADI	100,00	100,00	100,00	99,74	87,67	**99,00**	89,24	58,21

Training:

ADI & RADI indistinguishable results from Centralized

DAGGER good accuracy but not as Centralized

Evaluation

Accuracy								
	Training				Test			
	Soybean	Zoology	Cars	Sponges	Soybean	Zoology	Cars	Sponges
ID3-centralized	100,00	100,00	100,00	99,44	85,00	99,00	88,95	58,57
ID3-Individual	85,67	93,85	93,84	80,20	76,50	90,00	86,83	55,54
ID3-union	90,25	94,73	97,73	94,05	81,00	94,00	**90,99**	60,36
ID3-DAGGER	99,57	100,00	76,36	99,76	80,67	92,50	68,95	**62,50**
ID3-ADI	100,00	100,00	100,00	99,70	**88,50**	**99,00**	88,95	58,21
ID3-RADI	100,00	100,00	100,00	99,74	87,67	**99,00**	89,24	58,21

Test:

ADI & RADI accuracy equal or better than Centralized

DAGGER sometimes is better

Union works very well only for Cars data set

ADI & RADI are less prone to overfitting

Evaluation

Accuracy								
	Training				Test			
	Soybean	Zoology	Cars	Sponges	Soybean	Zoology	Cars	Sponges
CN2-centralized	100,00	100,00	100,00	100,00	**84,66**	94,00	**80,64**	**78,57**
CN2-Individual	87,82	94,62	89,90	88,29	77,83	87,50	**80,84**	74,46
CN2-union	54,91	91,65	80,41	70,71	53,66	86,00	80,00	68,20
CN2-DAGGER	99,49	99,65	95,86	99,88	79,33	92,50	75,34	**78,93**
CN2-ADI	100,00	100,00	100,00	100,00	**84,90**	**93,50**	**80,61**	**79,11**
CN2-RADI	100,00	100,00	100,00	100,00	**84,66**	93,50	80,17	**78,93**

Evaluation

Accuracy								
	Training				Test			
	Soybean	Zoology	Cars	Sponges	Soybean	Zoology	Cars	Sponges
INDIE-centralized	99,64	100,00	100,00	100,00	83,00	**94,00**	91,80	95,00
INDIE-Individual	89,21	94,07	93,93	96,45	77,50	85,50	87,76	94,11
INDIE-union	91,44	96,48	97,42	97,90	78,00	90,00	**91,80**	94,29
INDIE-DAGGER								
INDIE-ADI	99,64	100,00	100,00	100,00	**84,33**	93,00	**91,25**	**95,89**
INDIE-RADI	99,64	100,00	100,00	100,00	**84,50**	**94,00**	**91,37**	94,11

DAGGER assumes propositional data sets, and is incompatible with INDIE that works only in relational data sets

Performance

	Time	Examples shared	Rules sent	Induction calls
Centralized	2,80	100,00%	0,00	1,00
Individual	1,50	0,00%	0,00	1,00
Union	1,50	0,00%	67,63	1,00
DAGGER	3,50	68,56%	64,75	1,00
ADI	155,40	19,04%	3.748,70	58,90
RADI	18,20	21,52%	679,34	5,77

Results averaged over all data sets

Performance

	Time	Examples shared	Rules sent	Induction calls
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RADI	18,20	21,52%	679,34	5,77

Results averaged over all data sets

DAGGER requires exchanging more examples (68%) but few rules (only the final result, like Union)

ADI & RADI requires exchanging more rules but fewer examples

RADI better than ADI: faster, less rules, less calls, (only requires to exchange slightly more examples)

Performance

	Time	Examples shared	Rules sent	Induction calls
Centralized	2,80	100,00%	0,00	1,00
Individual	1,50	0,00%	0,00	1,00
Union	1,50	0,00%	67,63	1,00
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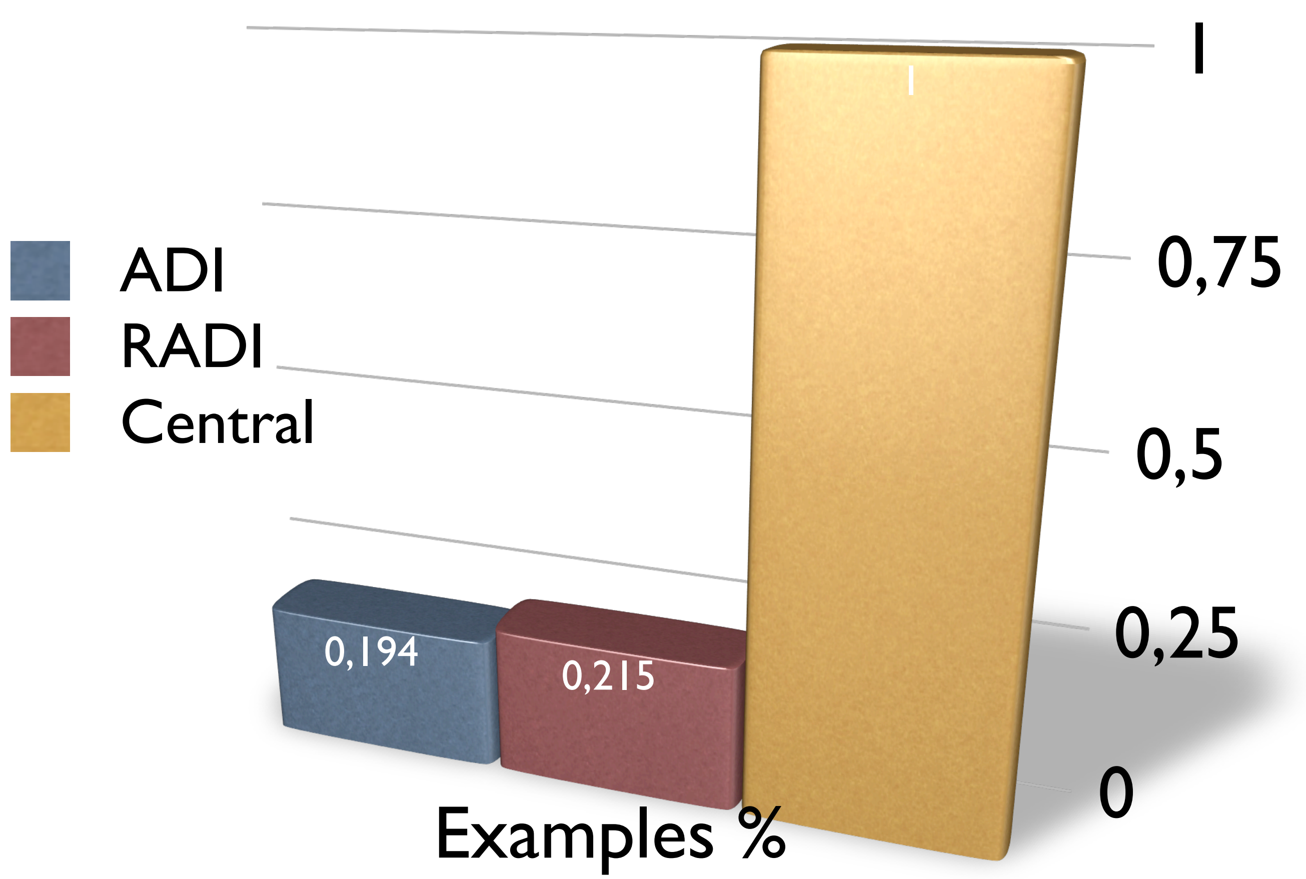
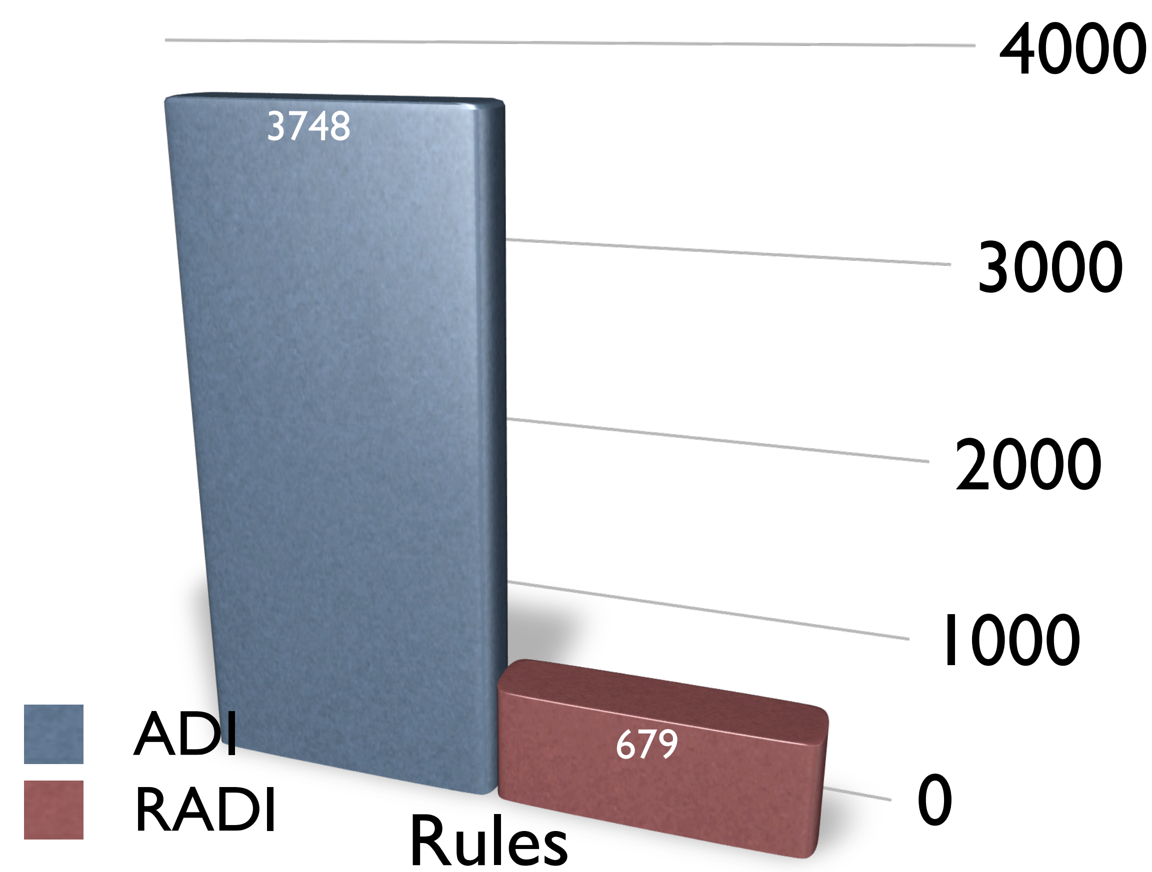


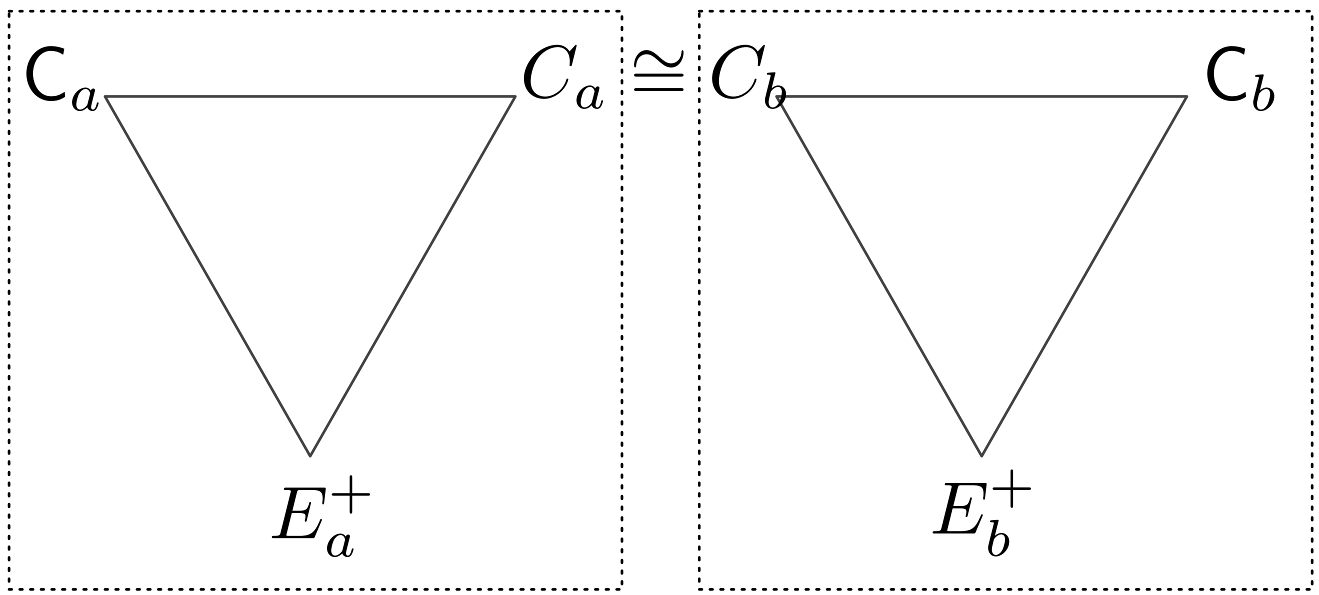


Conclusions

- General approach (w.r.t. induction methods)
  - counter-examples only (counter-arguments not used)
- Argumentation process allows a regulated interchange of information among learning agents about hypotheses, examples and their consistency
- ADI and RADI support distributed induction over existing ML inductive methods
  - less prone to overfitting

Future Work

- Concept Convergence
  - Counter-arguments require new inductive methods



- Argumentation among N agents (using induction)
  - What about convergence?
  - Majority rule problem?