



DEPARTAMENTO
DE COMPUTACIÓN

Facultad de Ciencias Exactas y Naturales - UBA

DeLP Servers and APL

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Departamento de Ciencias e Ingeniería de la Computación

UNIVERSIDAD NACIONAL DEL SUR
Bahía Blanca - ARGENTINA



Outline

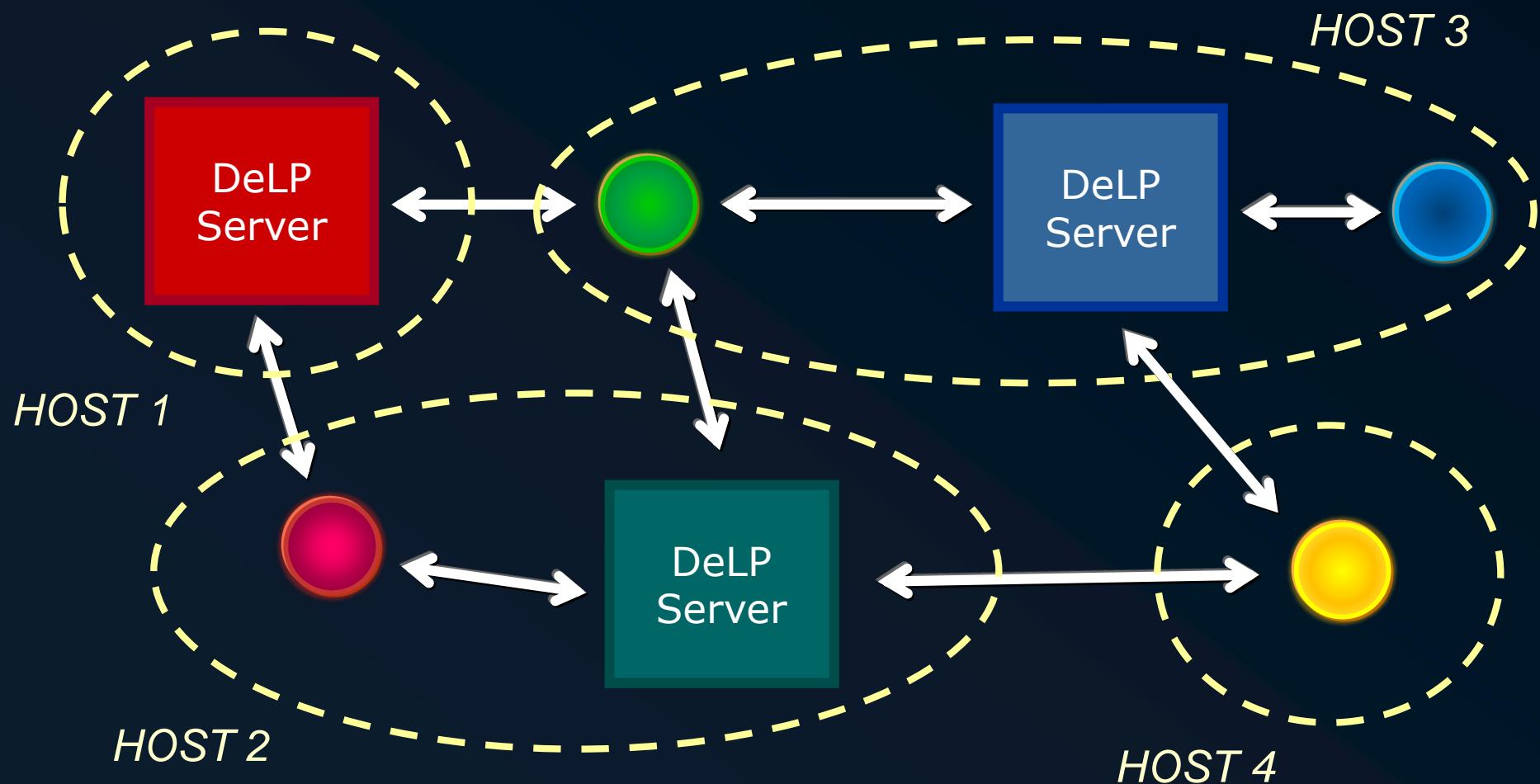
- *DeLP Servers*
- *APL-DeLP*
- *Conclusions*

DeLP
Servers

Introduction

- *DeLP Servers are generalized interpreters of DeLP.*
- *Here we present APL-DeLP, an Agent Programming Language (APL) based on Defeasible Argumentation Servers (DeLP-Servers).*
- *DeLP Servers are used as repositories of knowledge of the agent mental components.*
- *Contextual queries are used to model the interaction between these component.*

Local and Remote Reasoning Service



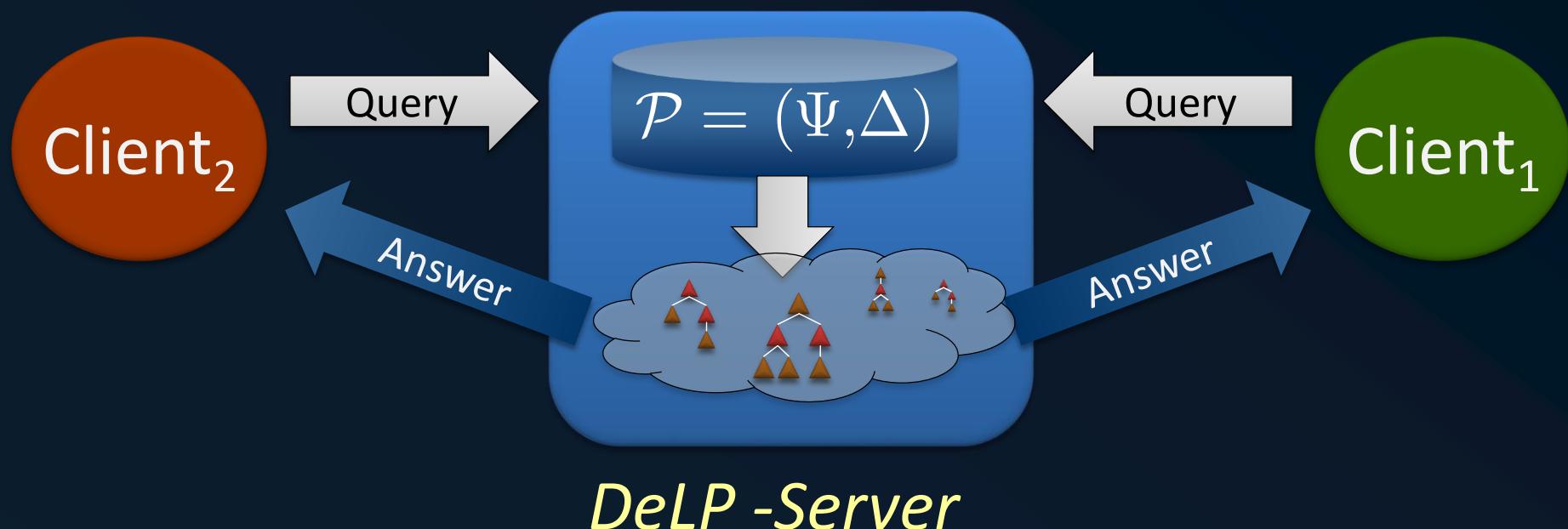
Agents could access and query different services with different knowledge bases.

Introduction

- *Agent deliberation is combined with the argumentative mechanism to support the dynamics of reasoning and execution.*
- *Therefore agents programmed using this language will be able to represent conflicting beliefs and goals, and reason effectively from them.*

DeLP - Server

- ▶ A *DeLP-Server* provides an argumentative reasoning service for multiple querying clients.
- ▶ The server will store a *DeLP* program, which is used to answer queries from different clients.

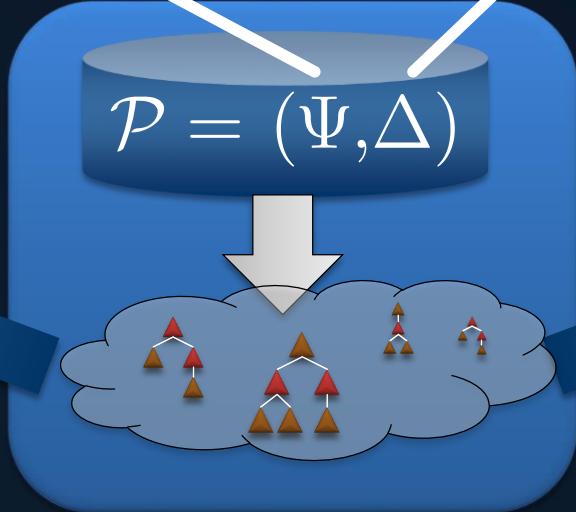


Ψ

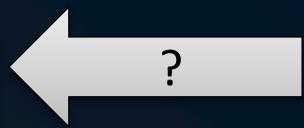
debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

 Δ

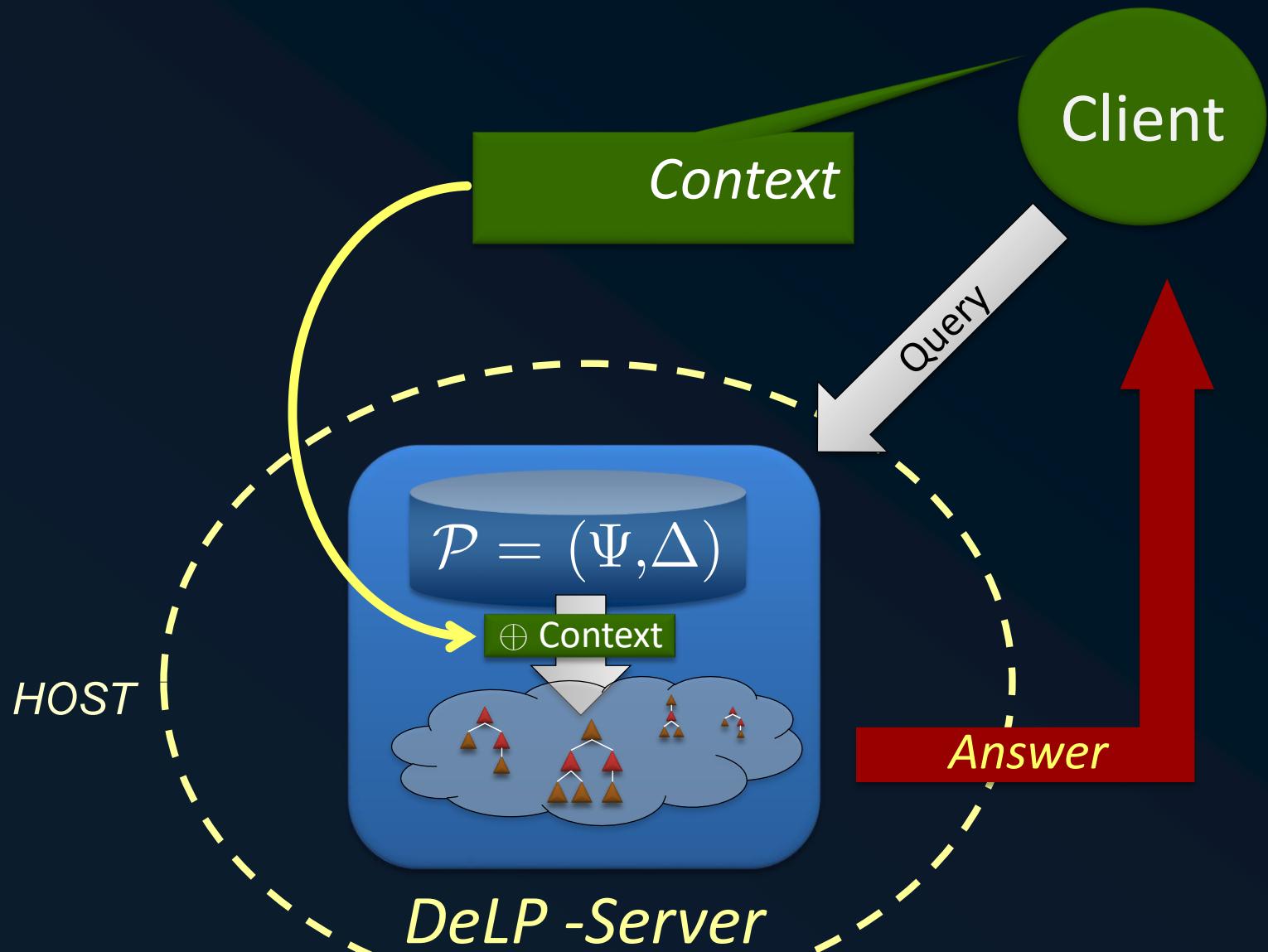
spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend



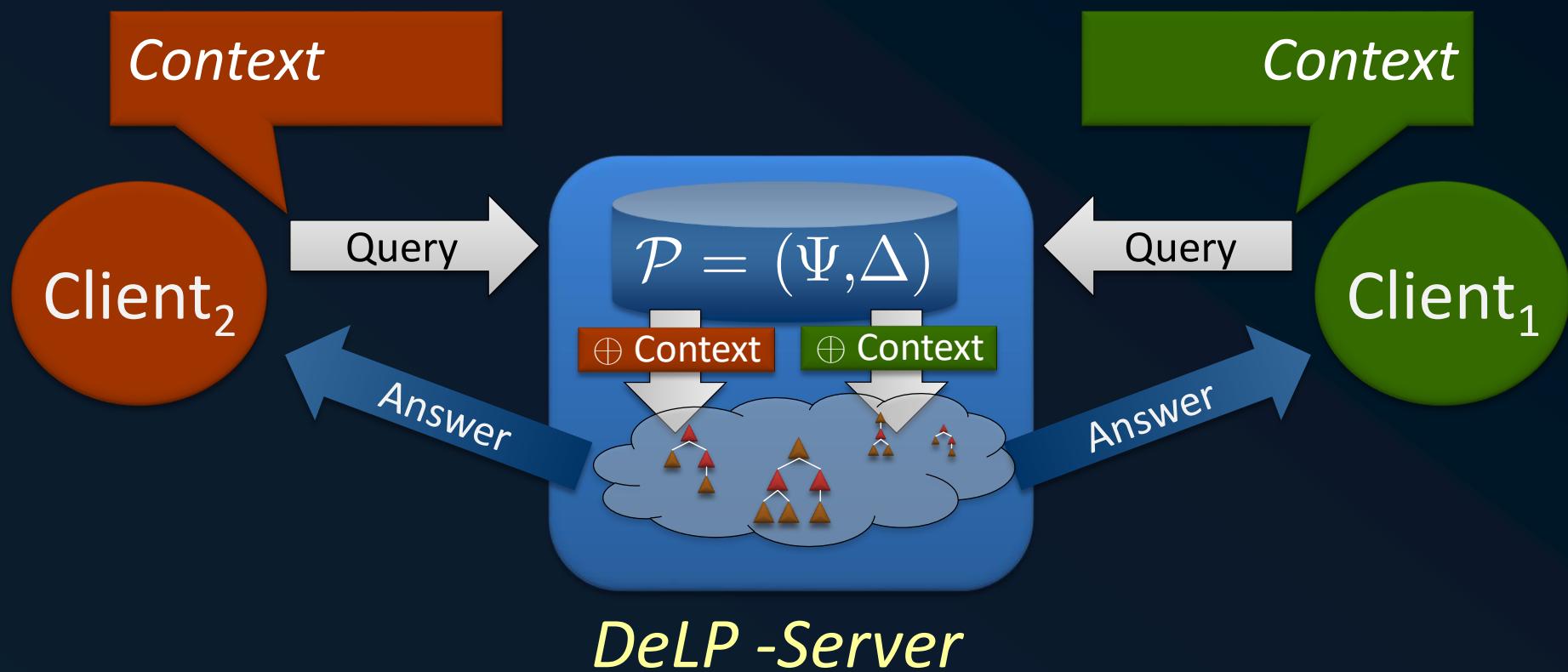
DeLP -Server



Local and Remote Reasoning Service



Information can be attached to a query, creating a contextual query and, together with the stored program, will create a temporary new program that will be used to answer the query.



Examples

Ψ

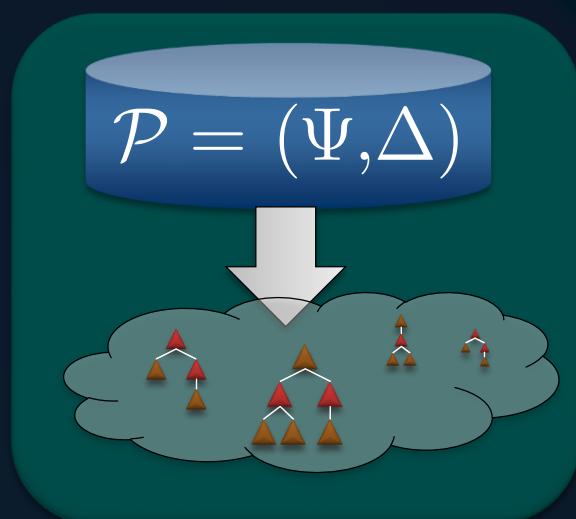
debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂

Client₁



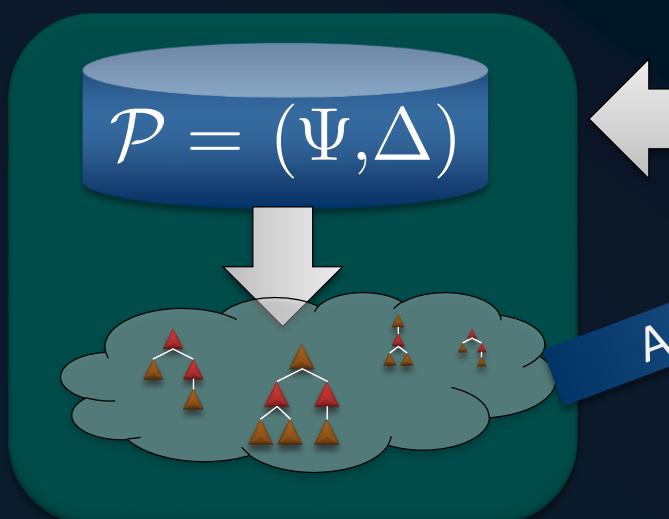
Ψ

debts
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Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂



travel?

Answer

Client₁

Undecided

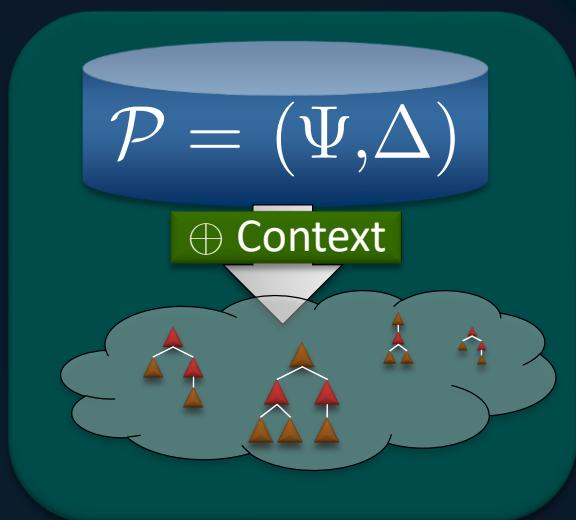
Ψ

debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
 $\text{travel} \prec \text{oneWeekVacation}, \text{spend}$
 \sim travel \prec \sim spend

Client₂



Context
oneWeekVacation

travel?

Client₁

Ψ

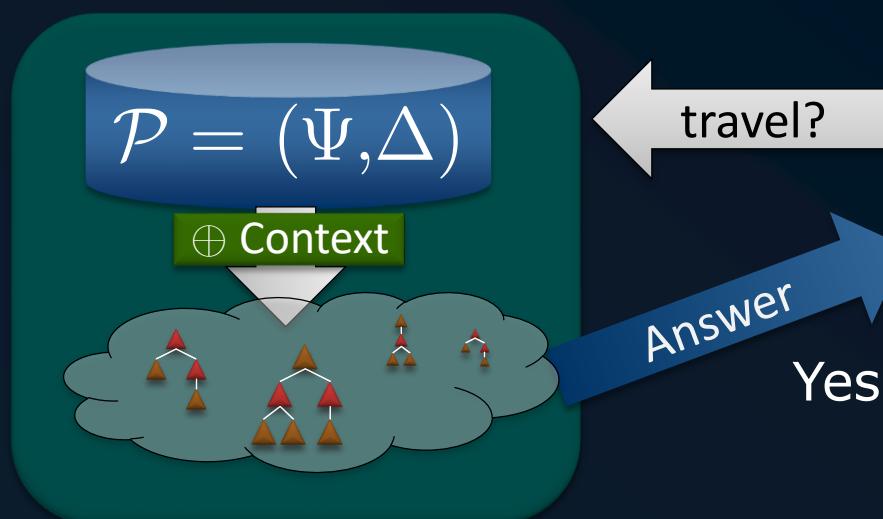
debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

oneWeekVacation

 Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂



Client₁

Ψ

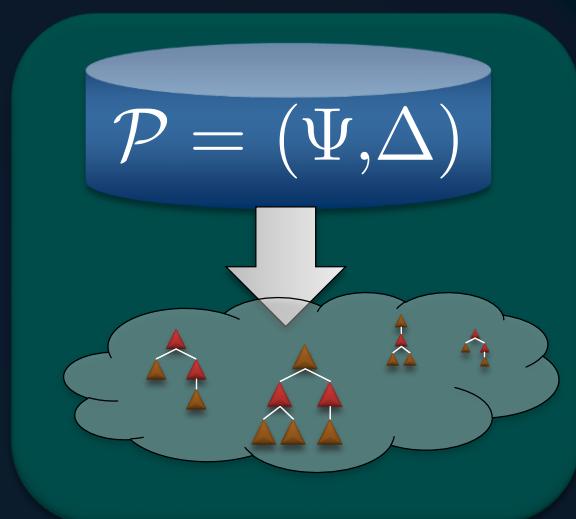
debts
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Δ

spend \prec savings
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spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂

Client₁



Ψ

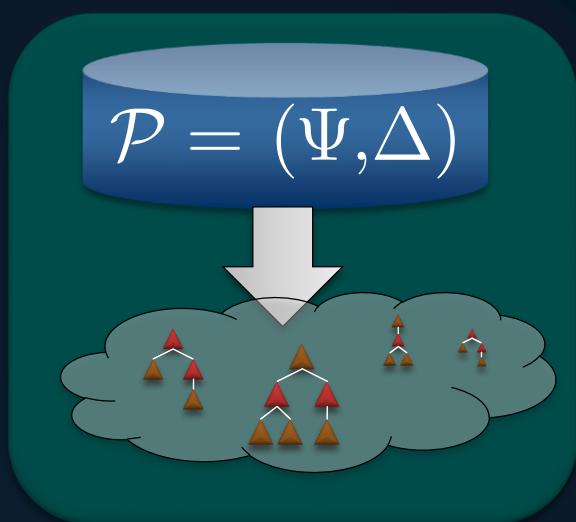
debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂

spend?



Client₁

Ψ

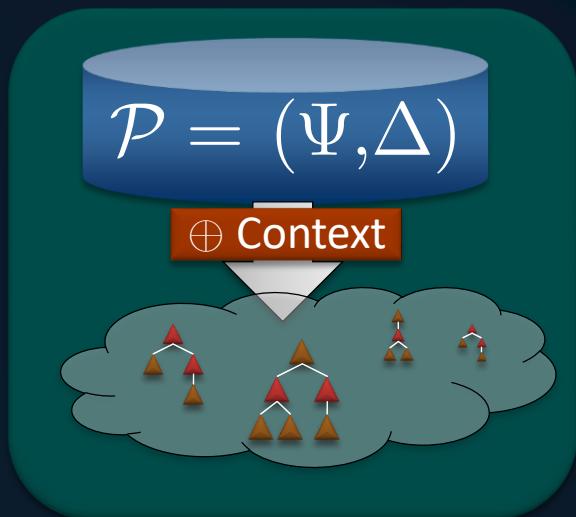
debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

 Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Context \sim savingsClient₁

spend?

Client₂

Ψ

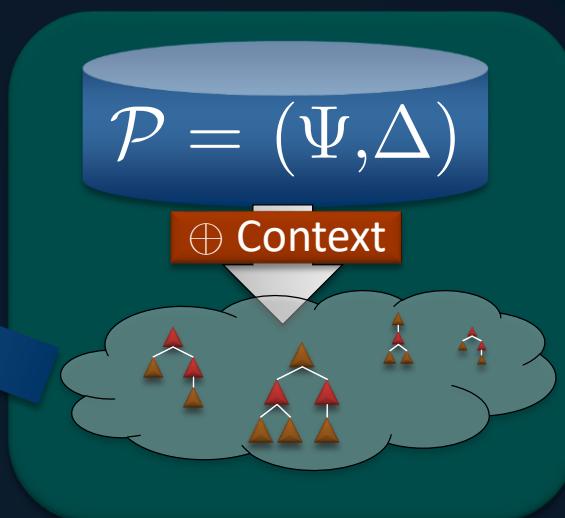
debts
~~savings~~
girlfriend
goodSalary
 \sim afraidToFlight

 Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Context \sim savingsClient₁

spend?

Answer
NoClient₂

Formalism

Contextual Queries

A particular kind of contextual query is used to manage the issues of mental component interaction $[(\Phi^+, \Theta^-), Q]$, where:

Φ^+ *is a set of prioritized literals to add to Ψ .*

Θ^- *a set of literals to:*

- remove from Ψ , and*
- heads of the rules to be removed from Δ*

Q *the literal object of the query.*

Ψ

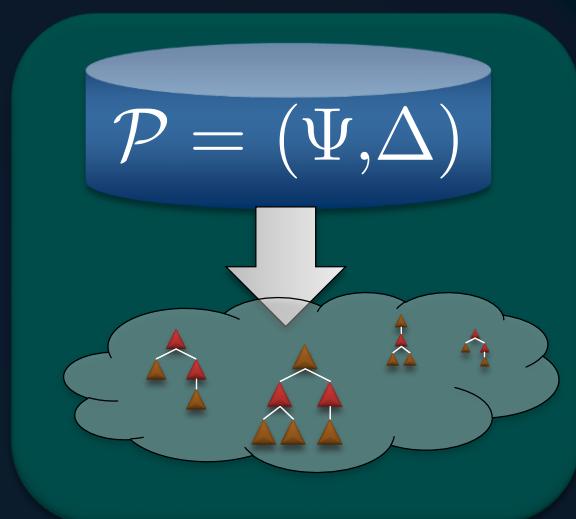
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Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂

Client₁



DeLP -Server

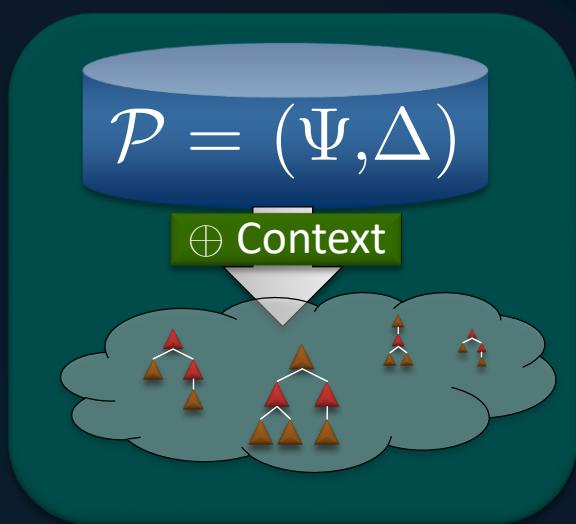
Ψ

debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

 Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂



(add) oneWeekVacation
(eliminate rules) \sim spend

travel?

Client₁

$$[(\Phi^+, \Theta^-), Q] = [(\{\text{oneWeekVacation}\}, \{\sim \text{spend}\}), \text{travel}]$$

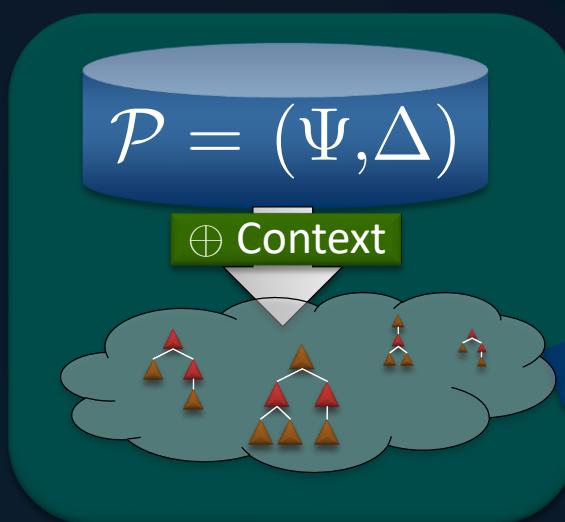
Ψ

debts
savings
girlfriend
goodSalary
 \sim afraidToFlight
oneWeekVacation

 Δ

spend \leftarrow savings
 \sim spend \leftarrow debts
spend \leftarrow savings, goodSalary, debts
travel \leftarrow oneWeekVacation, spend
 \sim travel \leftarrow \sim spend

Client₂



Client₁

$$[(\Phi^+, \Theta^-), Q] = [(\{\text{oneWeekVacation}\}, \{\sim \text{spend}\}), \text{travel}]$$

Ψ

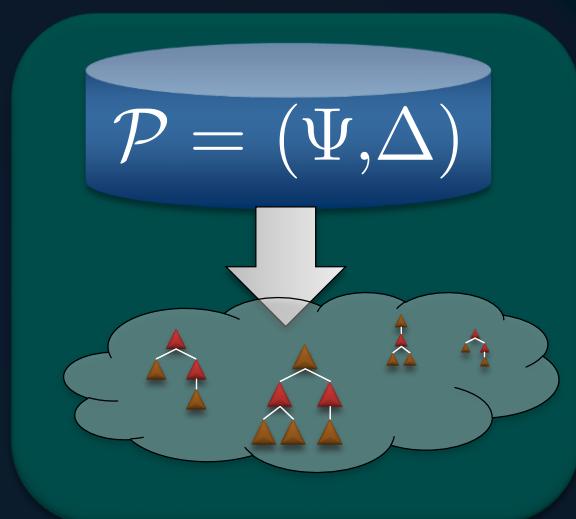
debts
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Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂

Client₁



Ψ

debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

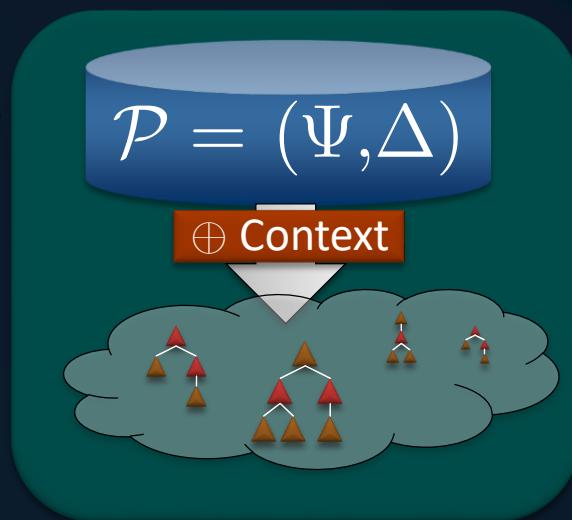
 Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

(add) oneWeekVacation
(eliminate) debts

Client₂

travel?



Client₁

$[(\Phi^+, \Theta^-), Q] = [(\{\text{oneWeekVacation}\}, \{\text{debts}\}), \text{spend}]$

Ψ

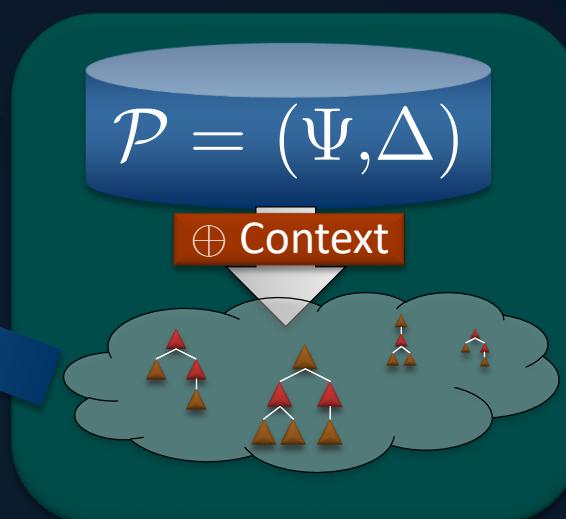
debts
savings
girlfriend
goodSalary
 \sim afraidToFlight
oneWeekVacation

 Δ

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

Client₂

travel?

Answer
Yes

$$[(\Phi^+, \Theta^-), Q] = [(\{\text{oneWeekVacation}\}, \{\text{debts}\}), \text{spend}]$$

Contextual Queries

Therefore, the contextual query $[(\Phi^+, \Theta^-), Q]$ is warranted from $\mathcal{P} = (\Psi, \Delta)$ iff

- $C(\Phi^+) = \{\overline{L} \mid L \in \Phi^+\},$
- $R(\Theta^-) = \{r_i \mid r_i = L_k \prec L_1, \dots, L_n \in \Delta \text{ and } L_k \in \Theta^-\},$

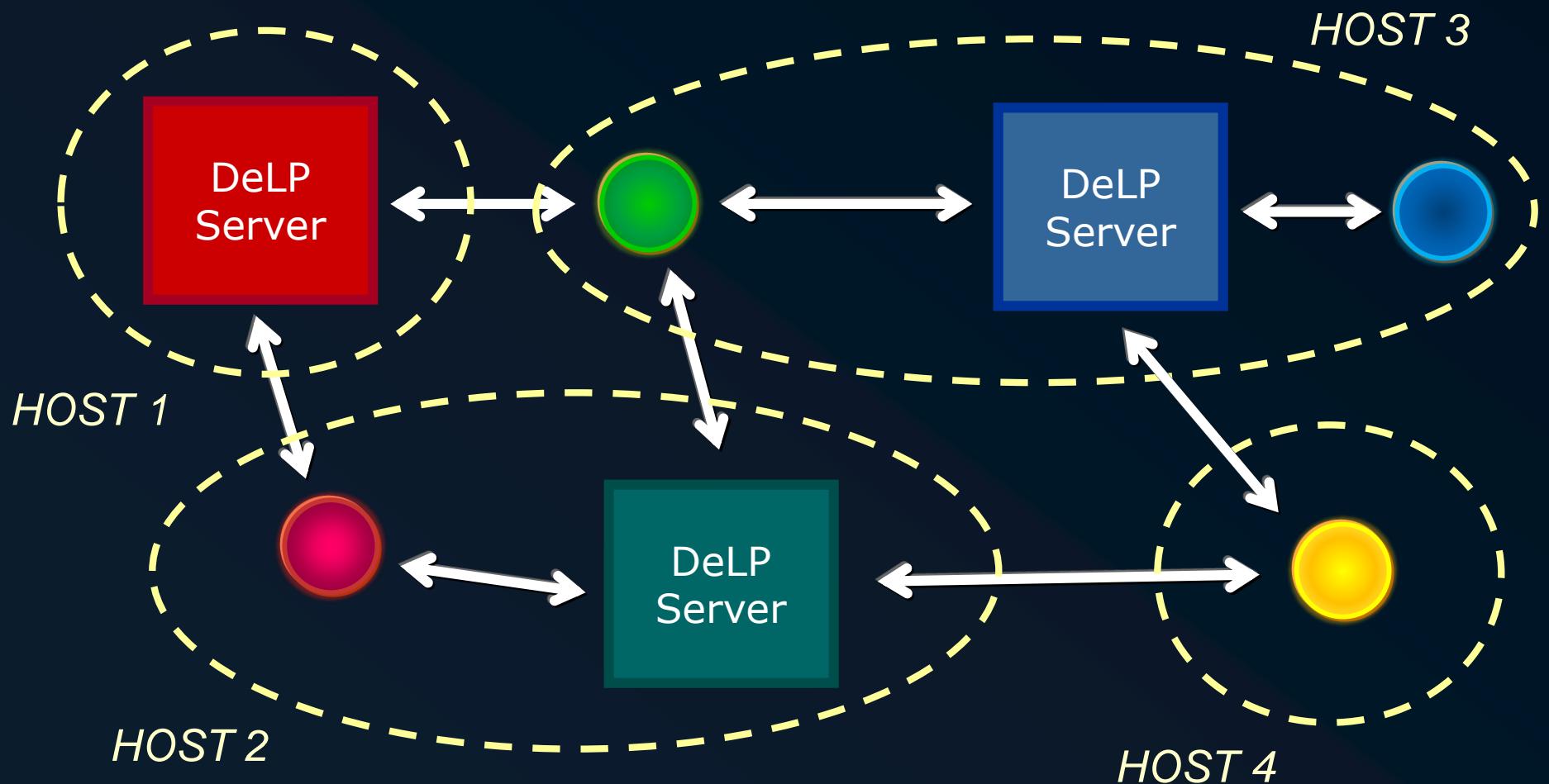
$$((\Psi \setminus C(\Phi^+) \cup \Phi^+) \setminus \Theta^-) \cap (\Delta \setminus R(\Theta^-)) \sim_w Q$$

Adds consistently the elements of Φ^+ and removes the elements of Θ^-

Removes d-rules such that the head is in Θ^-

This will be noted $\mathcal{P} \sim_w [(\Phi^+, \Theta^-), Q]$

Local and Remote Reasoning Service



*Agents could access and query different services
with different knowledge bases.*

APL-DeLP

BDI Basic Concepts

Beliefs: local knowledge base, can be updated.

Desires/goals: what the agent is trying to do.

Actions: elementary things the agent can do to communicate, or change the environment.

Plans: predetermined sequences of actions (or calls to other plans) for specified tasks.

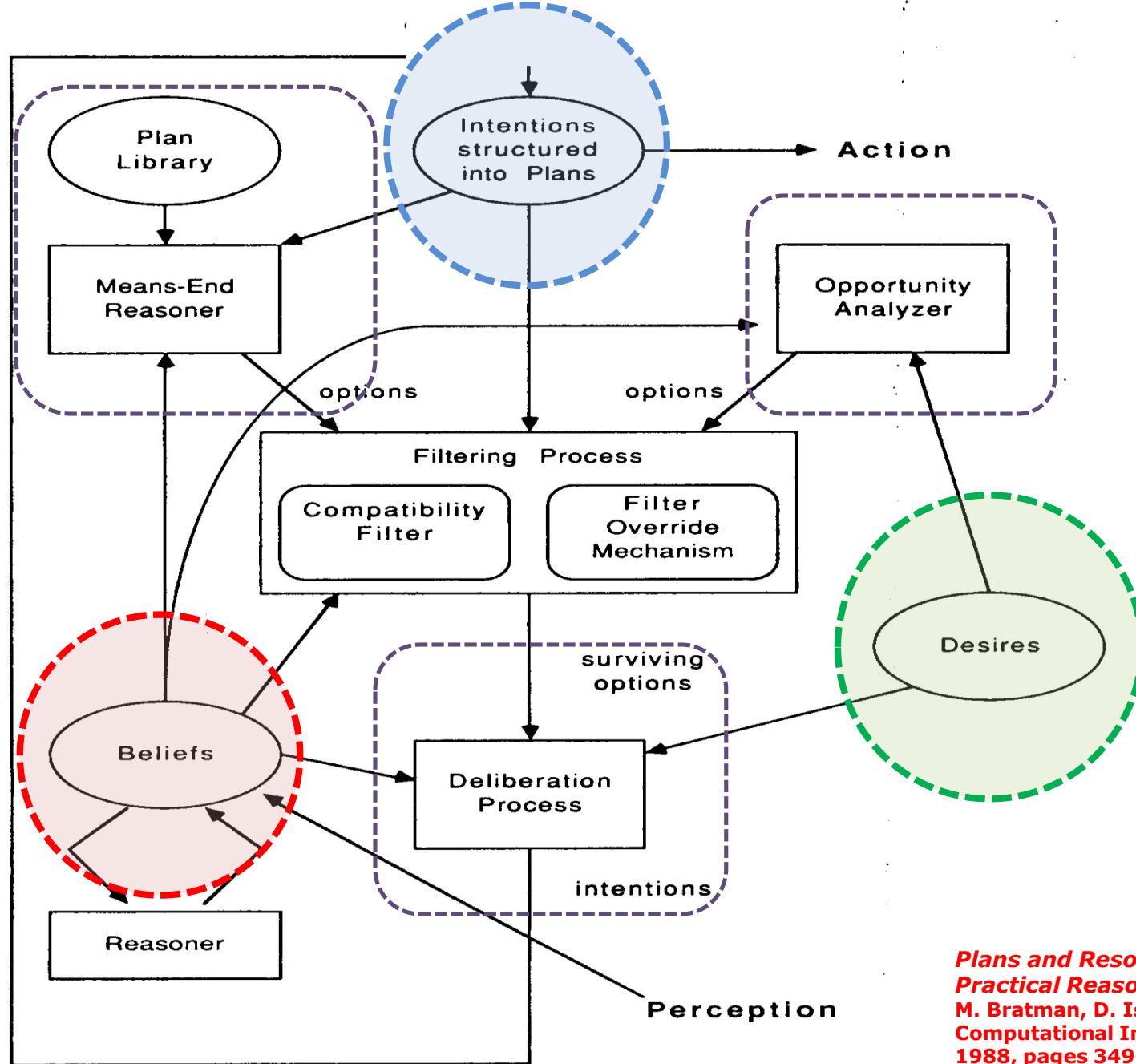
Intentions: currently “adopted” plans - multiple concurrently.

Events: things that ‘happen’ (internal or external).

IRMA: Bratman, Israel, Pollack

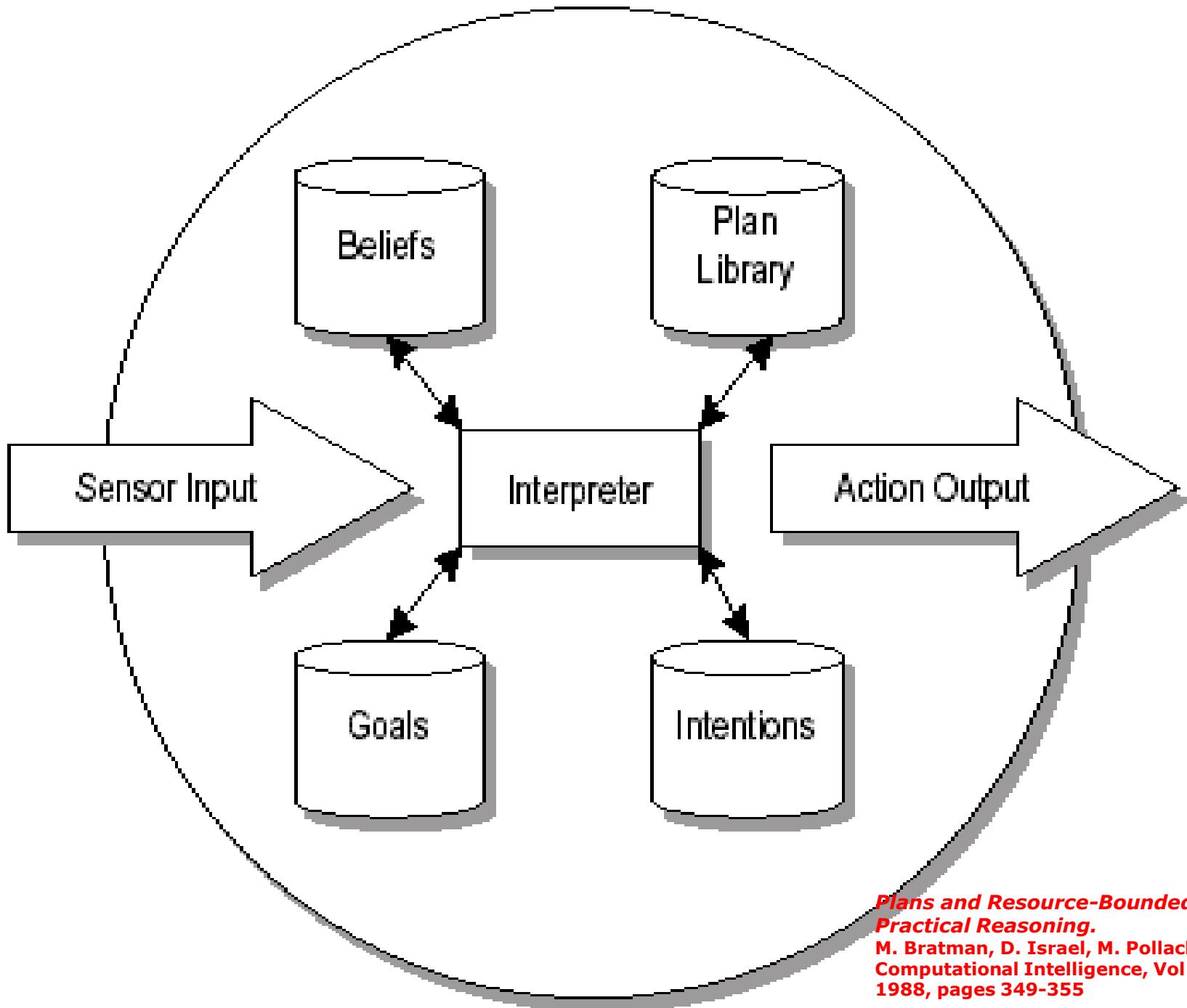
It has four key symbolic data structures:

- A *Plan Library*.
- *Explicit representations of Beliefs: information available to the agent.*
- *Desires: those things the agent would like to make true.*
- *Intentions: desires that the agent has chosen and it is committed.*



Plans and Resource-Bounded Practical Reasoning.
 M. Bratman, D. Israel, M. Pollack
 Computational Intelligence, Vol 4
 1988, pages 349-355

FIG. 1. An architecture for resource-bounded agents.



*Plans and Resource-Bounded
Practical Reasoning.*
M. Bratman, D. Israel, M. Pollack
Computational Intelligence, Vol 4
1988, pages 349-355

Agent Programming Language (APL)

APL Formal Concepts

- *Beliefs*
- *Goals*
- *Actions and Plans*
- *Plan Rules*
- *Execution Model*

3APL Modules

- *Belief base*
*a subset of first-order predicate language
(prolog like facts and rules)*
- *Goal base*
*expressions of an imperative language
(procedural or to-do goals)*
- *Plan base*
*Built from basic actions composed through
program operators sequential “;”, iteration
“while-do”, conditional “if-then-else”*

3APL Modules (cont.)

- **Action base (capabilities)**

Triplets consisting of action name, pre-conditions (under which action can be performed) and post-conditions (effect of the action after it is performed).

- **Goal plan rules**

Revision blocked actions, not achievable goals, generation/optimize goals

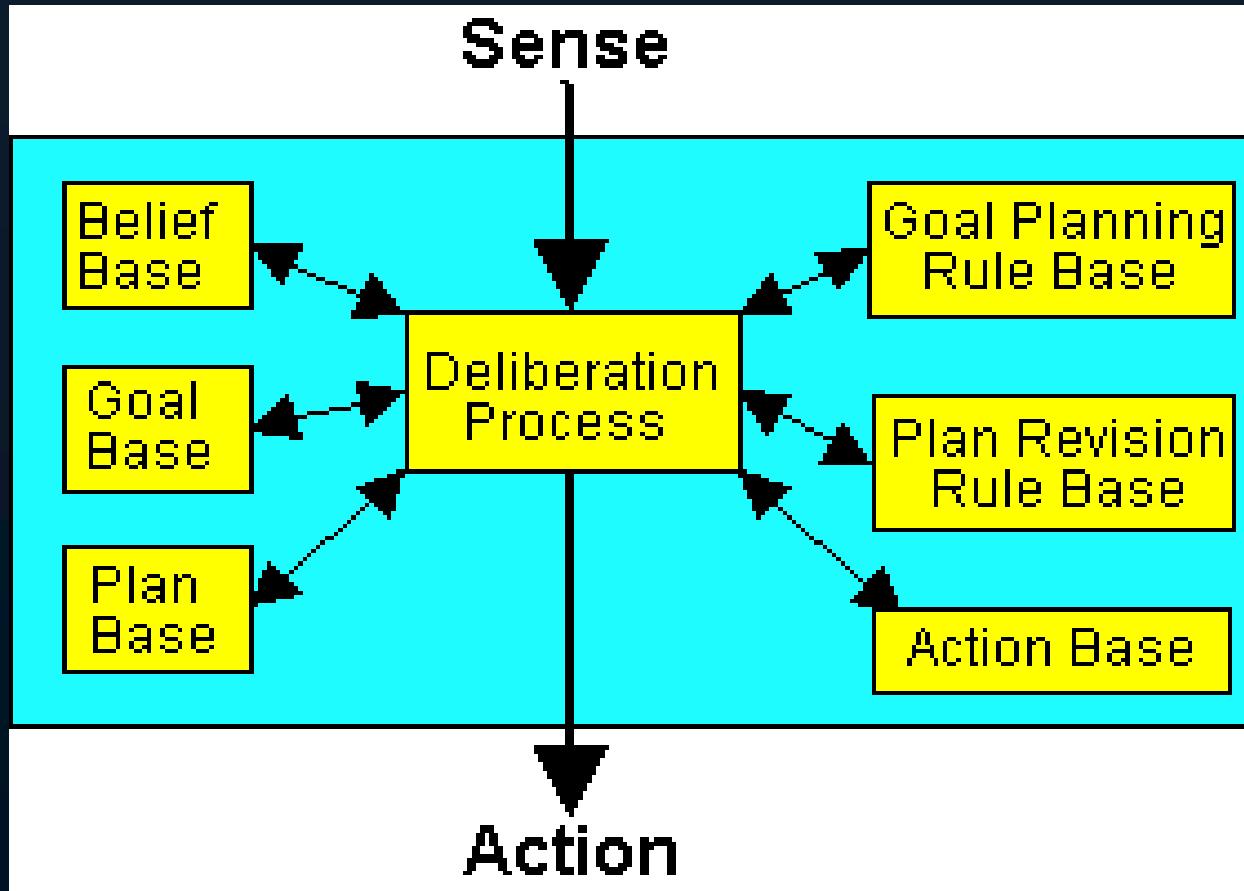
- **Plan revision rules**

Used to revise, adopt, and drop plans

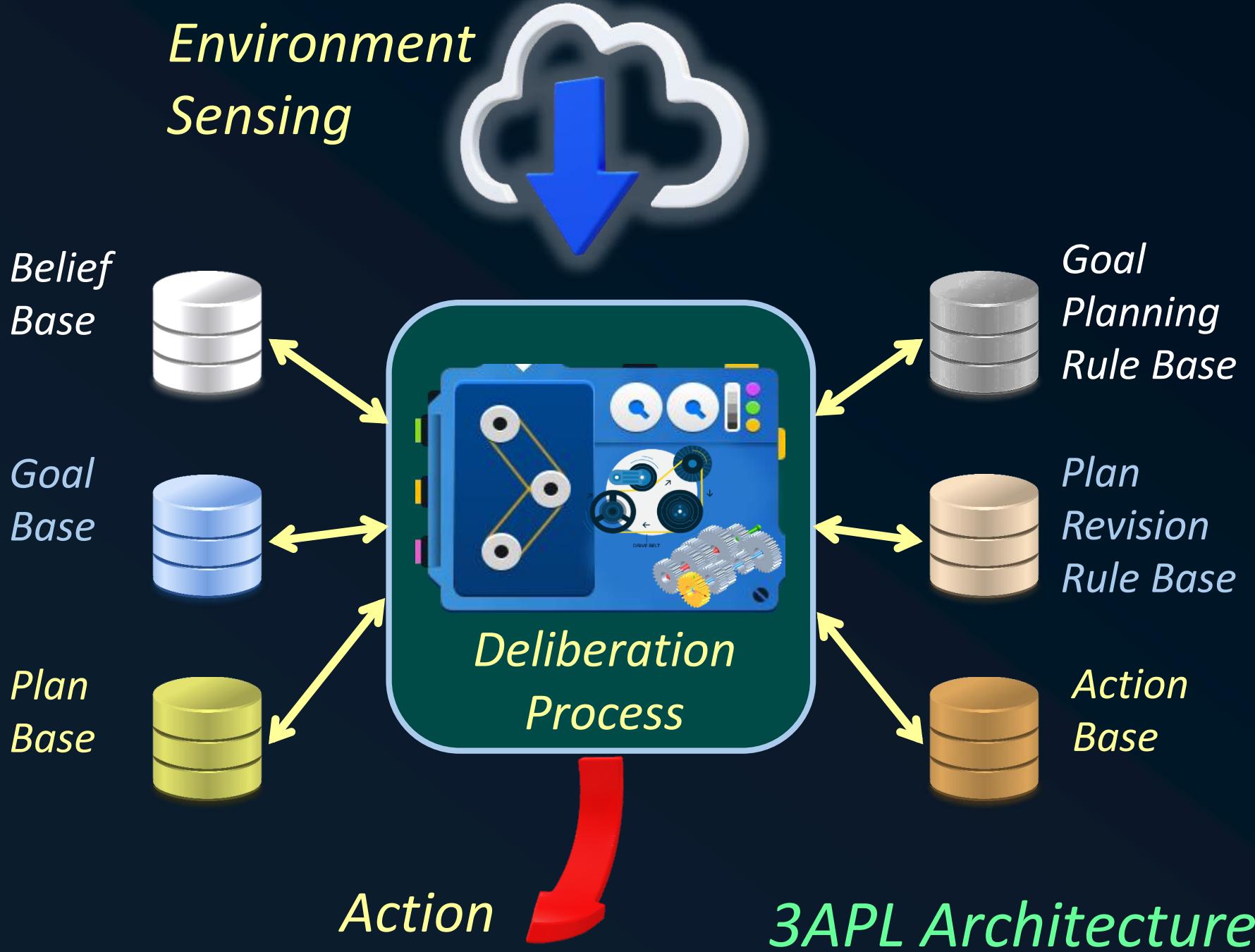
- **Interpreter**

Implementing the deliberation process; applying reasoning rules, selecting goals and actions.

3APL Architecture



<http://www.cs.uu.nl/3apl/>



APL-DeLP is based in 3APL, a declarative APL based in the BDI model, a APL-DeLP Agent is composed by:

- *Perception set* E
- *Belief Base* \mathcal{PB}
- *Goal Base* \mathcal{GB}
- *Set of Actions*
- *Set of Plan Rules*
- *Plan Base* Π

Interactions between these components go through

APL – General

- An agent *State* or *Configuration* depicts a snapshot of the agent components in a given time of its execution.
- It is characterized by a Set of perceptions, a Belief base, Goal base and a Plan base.

Agent Configuration

Perception set

E

\mathcal{PB}

\mathcal{GB}

Π

Plan Base

Belief Base

Goal Base

APL – Beliefs

- It is a *DeLP program* $\mathcal{PB} = (\Psi^B, \Delta^B)$ stored in a *DeLP-server*

Ψ^B

debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

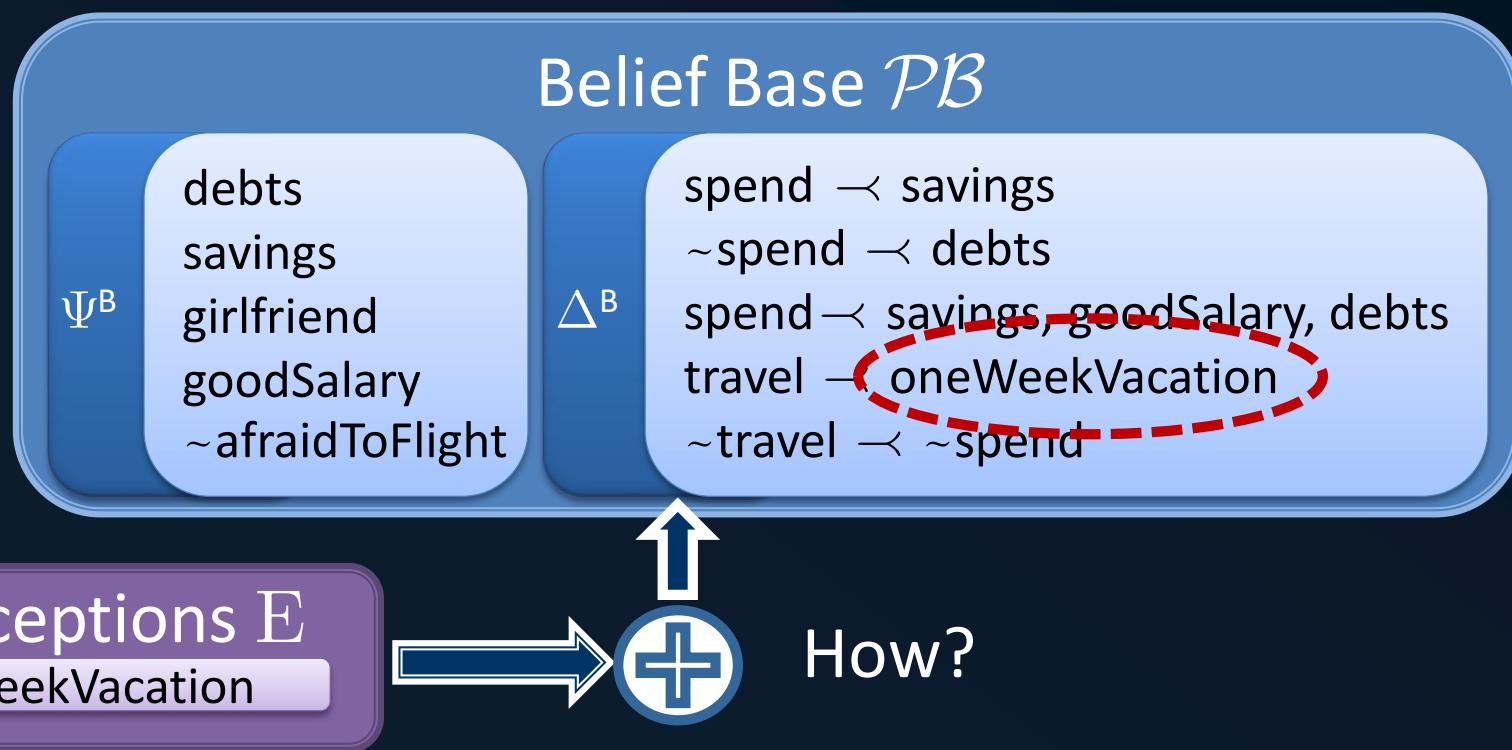
Δ^B

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation, spend
 \sim travel \prec \sim spend

- A Literal *L* warranted from the belief base is a *Current Belief*, noted $B(L)$

APL – Beliefs and Perception

- However, since perceptual literals can be used in Δ^B in the body of d-rules, it is necessary to combine the perception set with the belief base.



APL – Obtaining Current Beliefs

- *The context of contextual queries is used to combine perception and hold the integrity of the belief base*
- *Therefore, contextual queries will be the medium to determine what the agent believes in a given state; formally:*

$\langle E, \mathcal{PB}, \mathcal{PG}, \Pi \rangle \vdash B(L)$ iff

$$\mathcal{PB} \sim_w [(E, \emptyset), L]$$

APL – Obtaining Current Beliefs

Perceptions E

oneWeekVacation

Belief Base \mathcal{PB}

Ψ^B

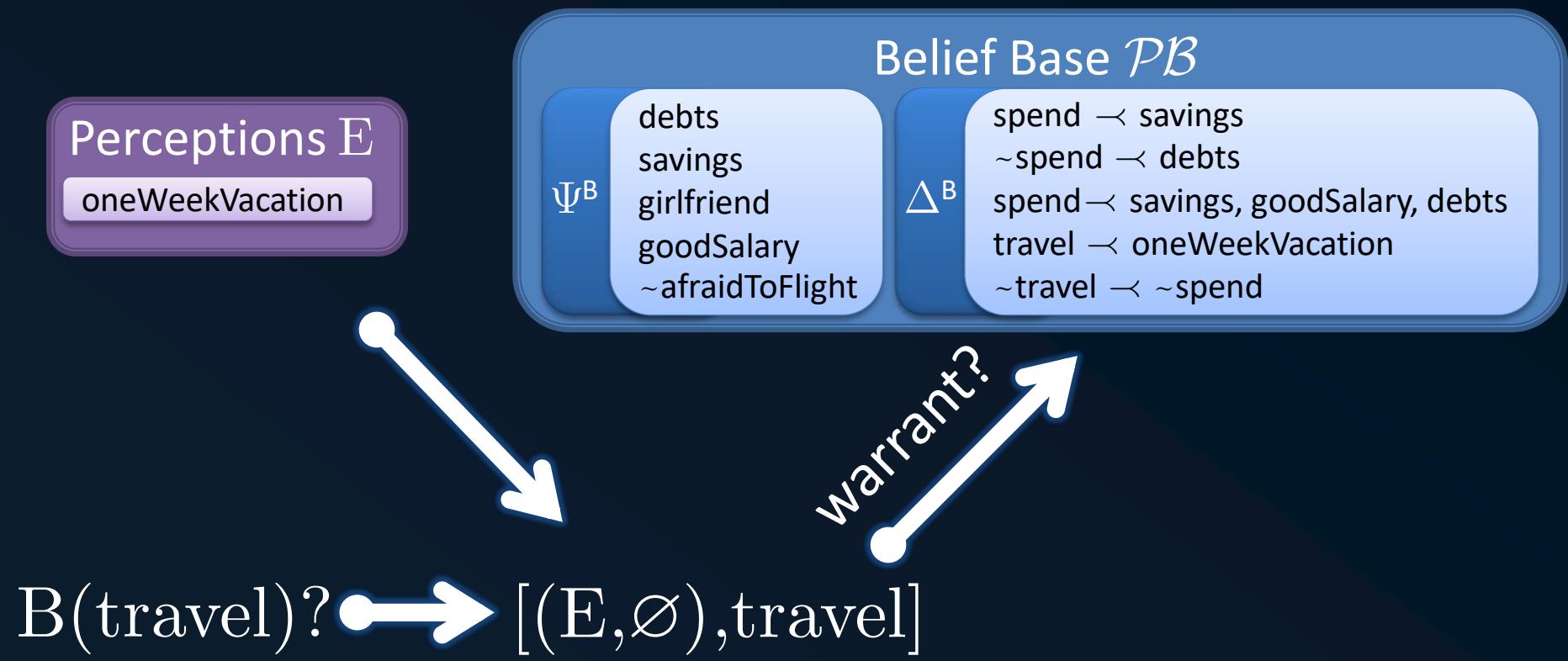
debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

Δ^B

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation
 \sim travel \prec \sim spend

B(travel)?

APL – Obtaining Current Beliefs



APL – Obtaining Current Beliefs

Perceptions E

oneWeekVacation

Ψ^B

debts
savings
girlfriend
goodSalary
 \sim afraidToFlight
oneWeekVacation

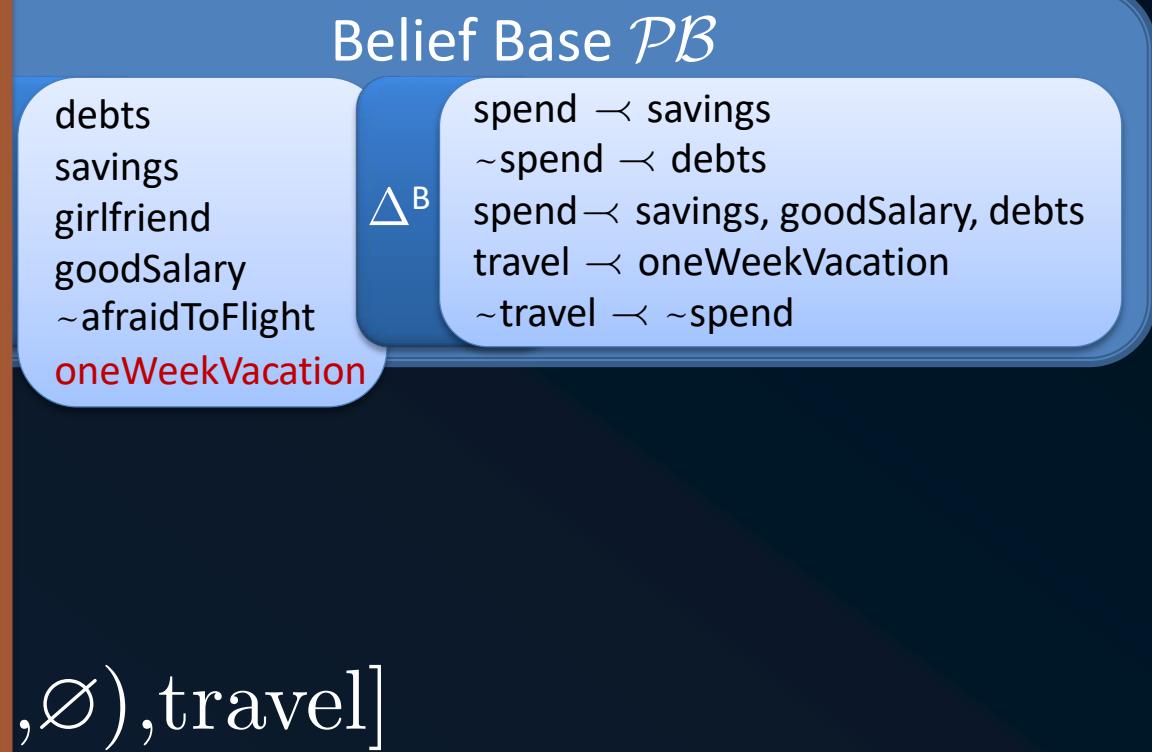
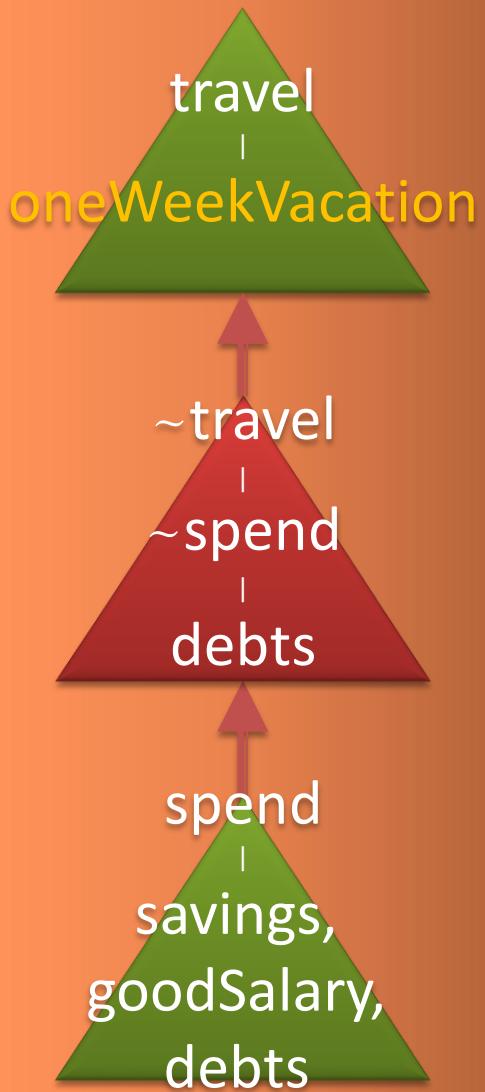
Δ^B

Belief Base \mathcal{PB}

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation
 \sim travel \prec \sim spend

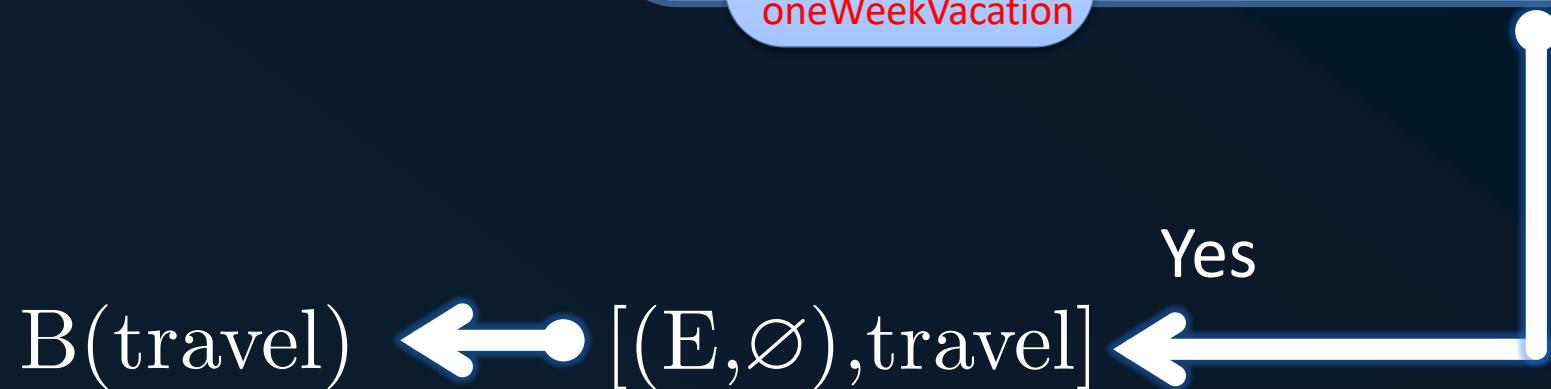
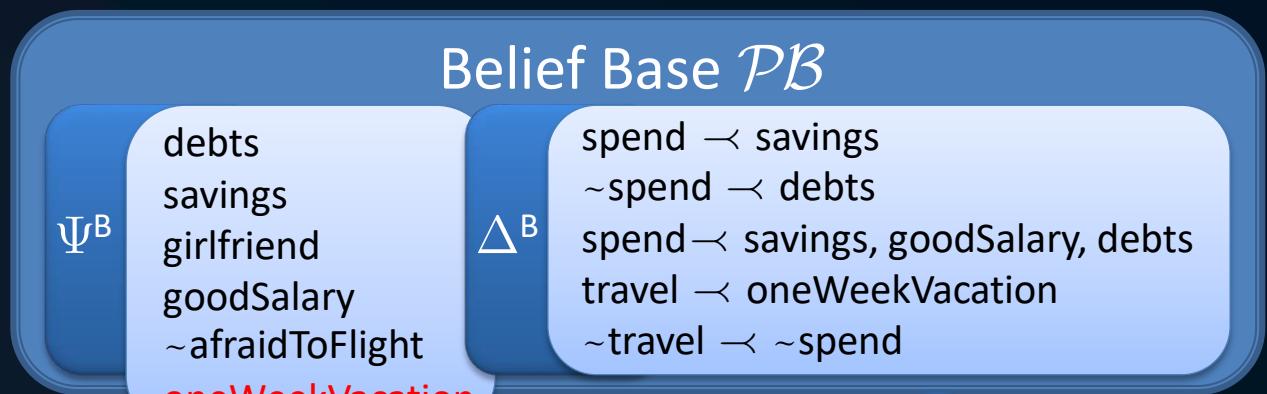
$B(\text{travel})$ $[(E, \emptyset), \text{travel}]$

API – Obtaining Current Beliefs



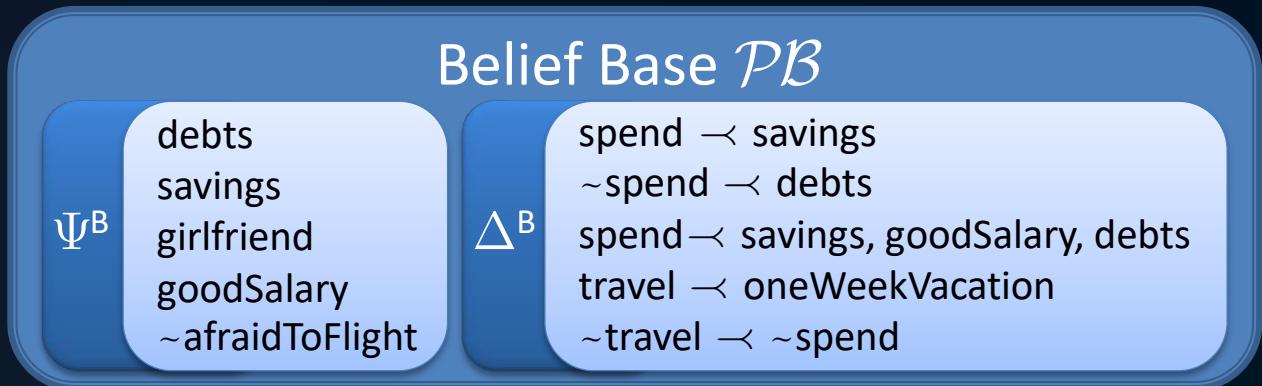
APL – Obtaining Current Beliefs

Perceptions E
oneWeekVacation



APL – Obtaining Current Beliefs

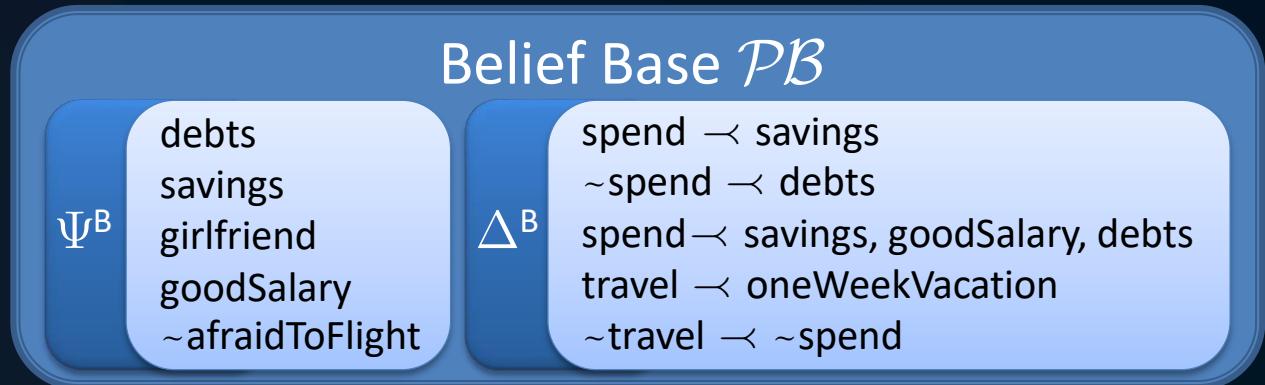
Perceptions E
oneWeekVacation



B(oneWeekVacation), B(debts), B(savings),
B(girlfriend), B(goodSalary), B(\sim afraidToFlight),
B(spend), B(travel)

APL – Obtaining Current Beliefs

Perceptions E
oneWeekVacation

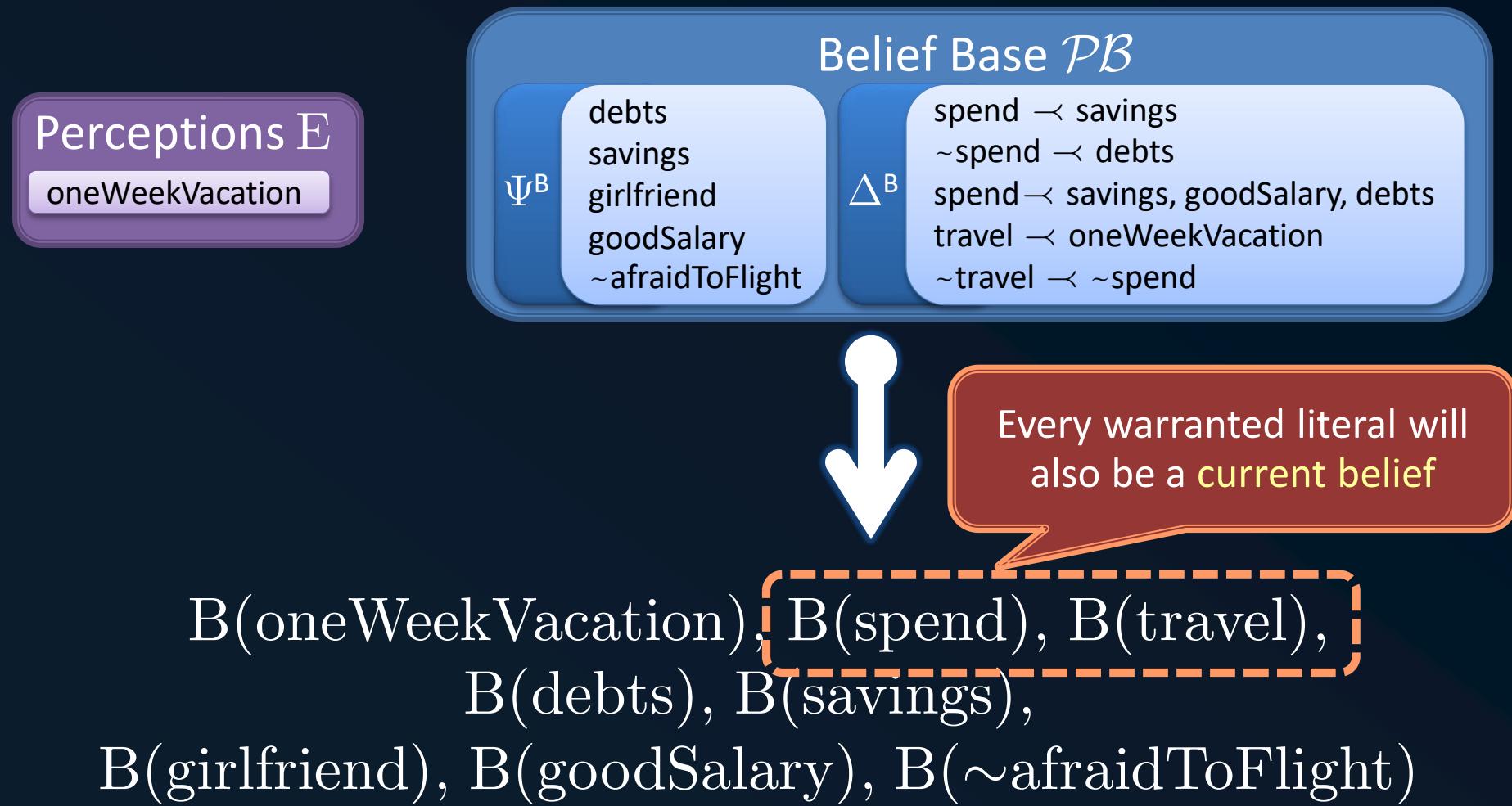


Every literal in the perception set
will be a current belief



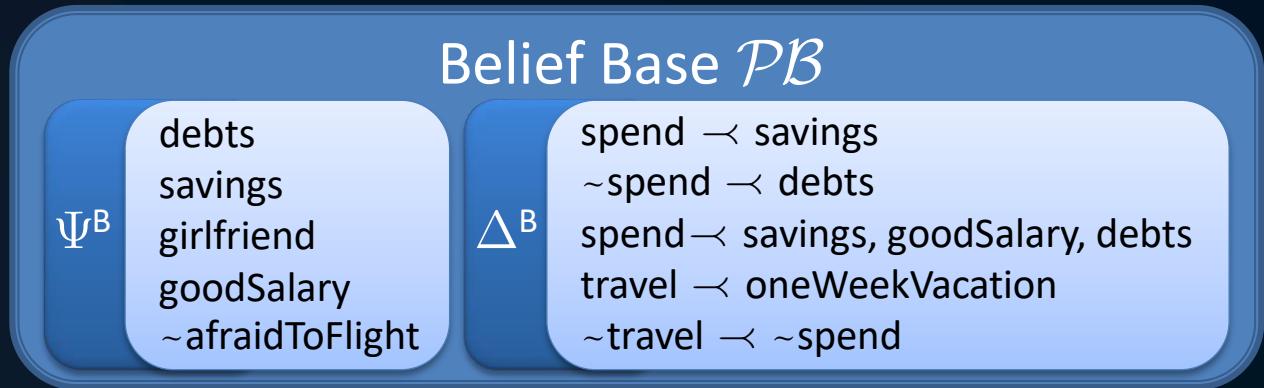
$B(\text{oneWeekVacation})$, $B(\text{spend})$, $B(\text{travel})$,
 $B(\text{debts})$, $B(\text{savings})$,
 $B(\text{girlfriend})$, $B(\text{goodSalary})$, $B(\sim \text{afraidToFlight})$

APL – Current Beliefs



APL – Current Beliefs

Perceptions E
oneWeekVacation



Every fact is a trivially warranted literal and it will also be a *current belief*

$B(\text{oneWeekVacation})$, $B(\text{spend})$, $B(\text{travel})$,

$B(\text{debts})$, $B(\text{savings})$,

$B(\text{girlfriend})$, $B(\text{goodSalary})$, $B(\sim \text{afraidToFlight})$

APL – Obtaining Goals

- Goals are situations of the world that the agent wants to realize.
- The Goal Base is specified through a special DeLP program $\mathcal{PG} = (\emptyset, \Delta^G)$ stored in a DeLP-server

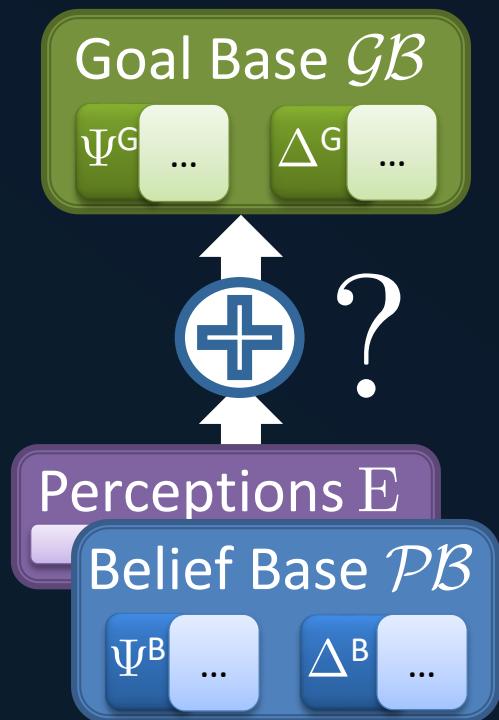
Δ^G

paris \leftarrow B(travel), B(oneWeekVacation), B(girlfriend)
hongKong \leftarrow B(travel), B(oneWeekVacation)
 \sim hongKong \leftarrow paris, B(oneWeekVacation)
 \sim paris \leftarrow hongKong, B(oneWeekVacation)

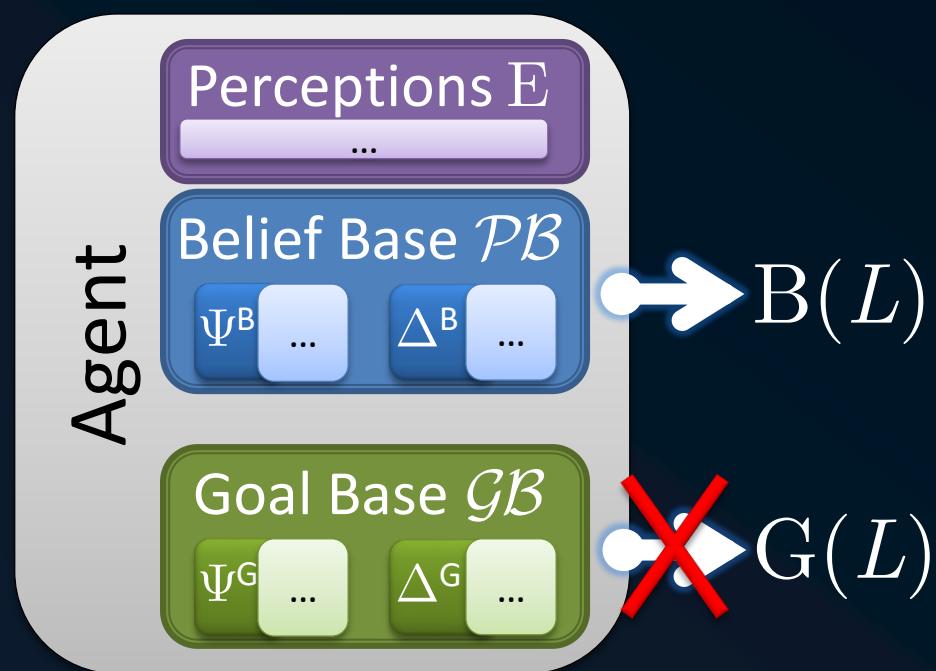
Current Beliefs can appear in
the body of Δ^G rules

APL – Current Goals

- A Literal L warranted through the goals base is a **Current Goal**, noted $G(L)$
- There are two things to consider in this process:



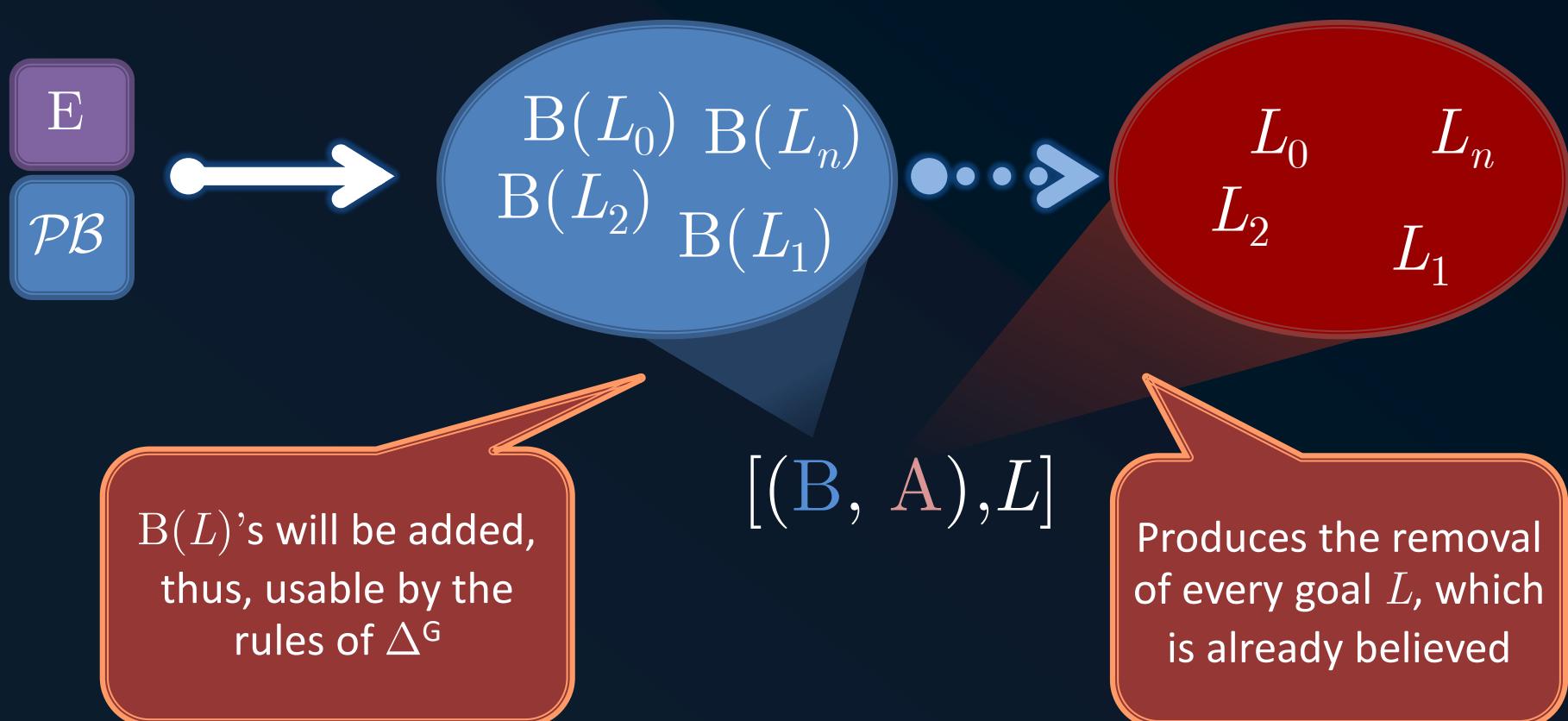
How the beliefs are handled



How the beliefs affect the goals

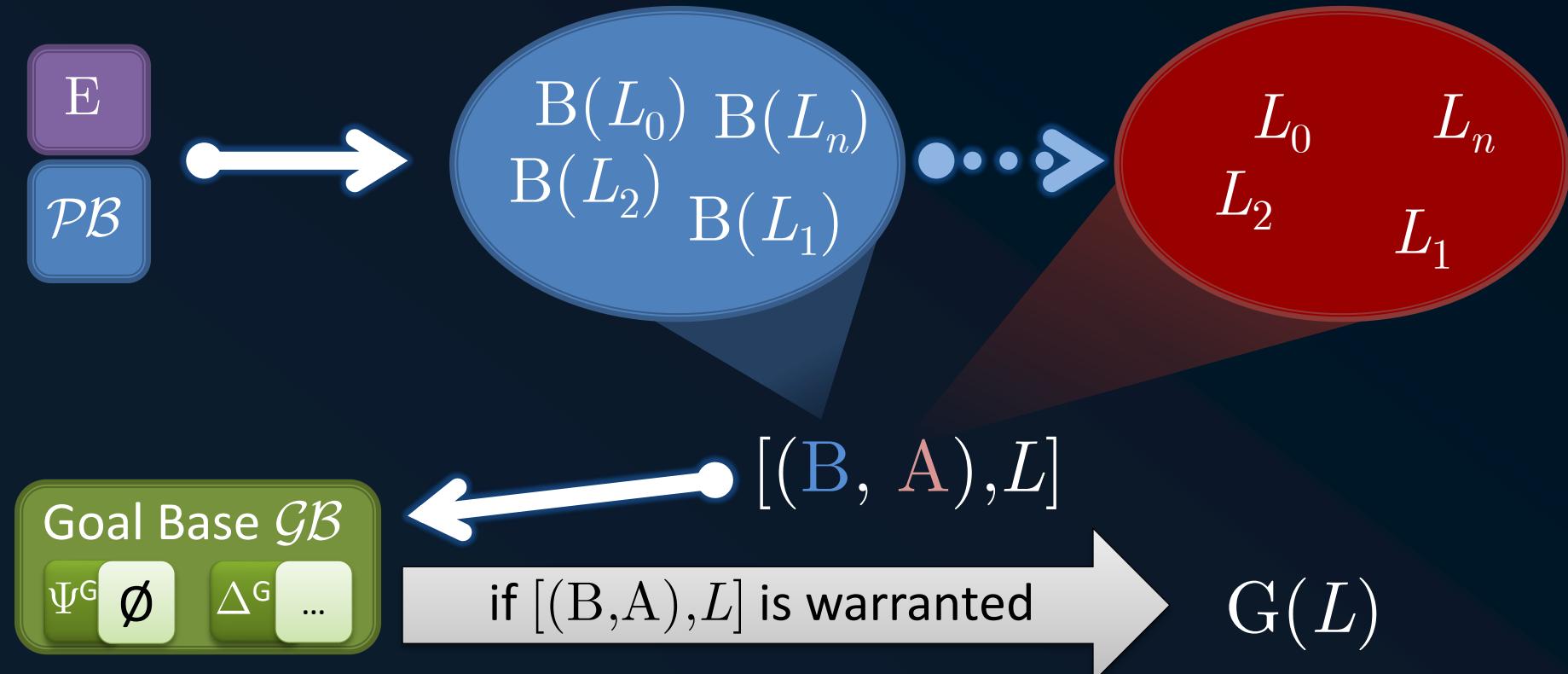
APL – Current Goals

Contextual queries are used to address these issues.



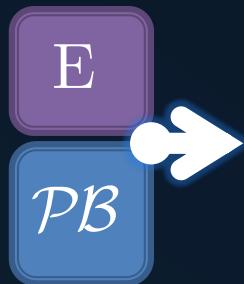
APL – Current Goals

Contextual queries are used to address these issues.



$$\langle E, \mathcal{PB}, \mathcal{PG}, \Pi \rangle \vdash G(L) \text{ iff } \mathcal{GB} \vdash_w [(B, A), L]$$

APL – Current Goals



B(oneWeekVacation),
B(debts), B(savings),
B(girlfriend),
B(goodSalary),
B(~afraidToFlight),
B(spend), B(travel)

Goal Base \mathcal{GB}

Δ^G

paris \prec B(travel), B(oneWeekVacation),
B(girlfriend)
hongKong \prec B(travel), B(oneWeekVacation)
 \sim hongKong \prec paris, B(oneWeekVacation)
 \sim paris \prec hongKong, B(oneWeekVacation)

$G(\text{paris})?$

APL – Current Goals

B(oneWeekVacation),
B(debts), B(savings),
B(girlfriend),
B(goodSalary),
B(~afraidToFlight),
B(spend), B(travel)

Goal Base \mathcal{GB}

Δ^G

paris \prec B(travel), B(oneWeekVacation),
B(girlfriend)
hongKong \prec B(travel), B(oneWeekVacation)
 \sim hongKong \prec paris, B(oneWeekVacation)
 \sim paris \prec hongKong, B(oneWeekVacation)



G(paris)?  $[(B, A), \text{paris}]$

APL – Current Goals

Ψ^G

B(oneWeekVacation),
B(debts), B(savings),
B(girlfriend),
B(goodSalary),
B(~afraidToFlight),
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paris \leftarrow B(travel), B(oneWeekVacation),
B(girlfriend)
hongKong \leftarrow B(travel), B(oneWeekVacation)
 \sim hongKong \leftarrow paris, B(oneWeekVacation)
 \sim paris \leftarrow hongKong, B(oneWeekVacation)

G(paris)  [(B,A),paris]

APL – Current Goals

Ψ^G

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B(debts), B(savings),
B(girlfriend),
B(goodSalary),
B(~afraidToFlight),
B(spend), B(travel)

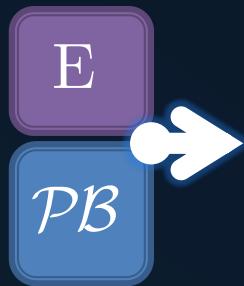
Δ^G

paris \leftarrow B(travel), B(oneWeekVacation),
B(girlfriend)
hongKong \leftarrow B(travel), B(oneWeekVacation)
 \sim hongKong \leftarrow paris, B(oneWeekVacation)
 \sim paris \leftarrow hongKong, B(oneWeekVacation)

G(paris) \leftarrow [(B,A),paris]



APL – Current Goals



B(oneWeekVacation),
B(debts), B(savings),
B(girlfriend),
B(goodSalary),
B(~afraidToFlight),
B(spend), B(travel),
B(paris)

Goal Base \mathcal{GB}

Δ^G

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G(paris)?

APL – Current Goals

B(oneWeekVacation),
B(debts), B(savings),
B(girlfriend),
B(goodSalary),
B(~afraidToFlight),
B(spend), B(travel),
B(paris)

Goal Base \mathcal{GB}

Δ^G

paris \leftarrow B(travel), B(oneWeekVacation),
B(girlfriend)
hongKong \leftarrow B(travel), B(oneWeekVacation)
 \sim hongKong \leftarrow paris, B(oneWeekVacation)
 \sim paris \leftarrow hongKong, B(oneWeekVacation)



G(paris)? \rightarrow $[(B, A), \text{paris}]$

APL – Current Goals

Goal Base \mathcal{GB}

Ψ^G

B(oneWeekVacation),
B(debts), B(savings),
B(girlfriend),
B(goodSalary),
B(~afraidToFlight),
B(spend), B(travel),
B(paris)

Δ^G

~~paris \leftarrow B(travel), B(oneWeekVacation),
B(girlfriend)~~
hongKong \leftarrow B(travel), B(oneWeekVacation)
 \sim hongKong \leftarrow paris, B(oneWeekVacation)
 \sim paris \leftarrow hongKong, B(oneWeekVacation)

~~G(paris)~~



$[(B, A), \text{paris}]$



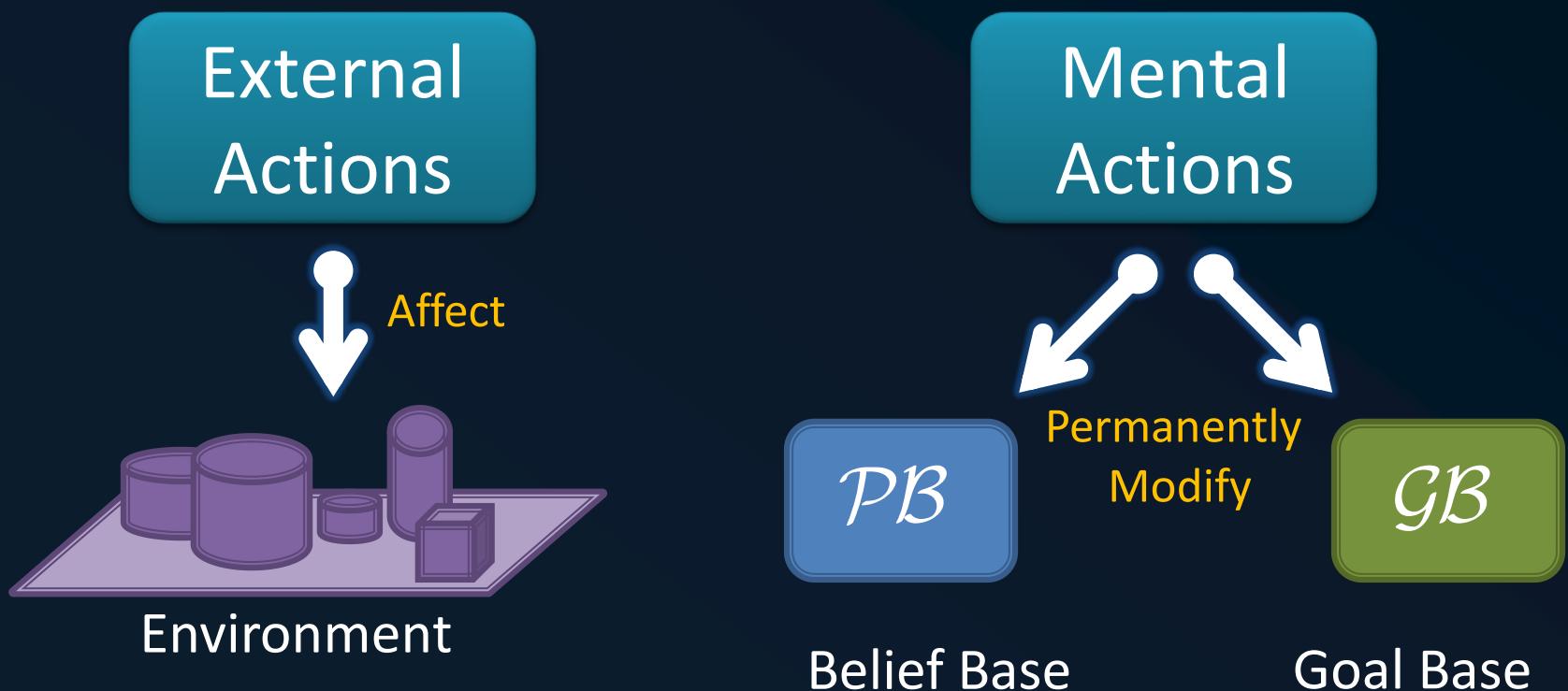
APL – Belief and Goals

The set of warranted literals of a DeLP program is non-contradictory, therefore:

The set current beliefs and the current goals of a given state will be non-contradictory.

Actions and Plans

- To achieve goals a DeLPAP agent can execute plans, which are sequences of actions
- There are two types of actions:



Actions and Plans

- *An External Action is an atom*
- *A Mental Action is an tuple*

(Base, β , Name, Pos)

The **mental component**
to be affected by the
action (\mathcal{PB} or \mathcal{GB})

A set of current beliefs
representing the
precondition of the
action

Literals and Rules to be
added/removed from
Base

Actions and Plans

The effects of executing a mental action with

$$\text{Pos} = \{X_1, \dots, X_n, -Y_1, \dots, -Y_m\}$$

For every X_i and Y_j literals

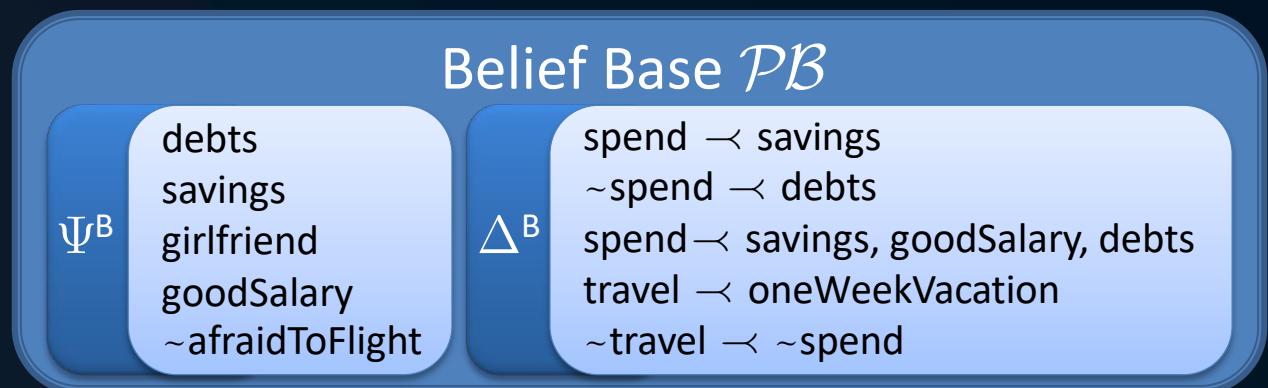
X_i will be added to Ψ , and \bar{X}_i, Y_j will be removed from Ψ

For every X_i and Y_j rules:

X_i will be added to Δ , and Y_j will be removed from Δ

APL – Actions and Plans

Perceptions E
oneWeekVacation



$(\mathcal{PB}, \{B(savings)\}, parisTrip, \{paris, \neg savings\})$

APL – Actual Beliefs



The action is applicable
since $B(\text{savings})$ is an
current belief

$(P\mathcal{B}, \{B(\text{savings})\}, \text{parisTrip}, \{\text{paris}, \neg \text{savings}\})$

APL – Actual Beliefs

Perceptions E
oneWeekVacation

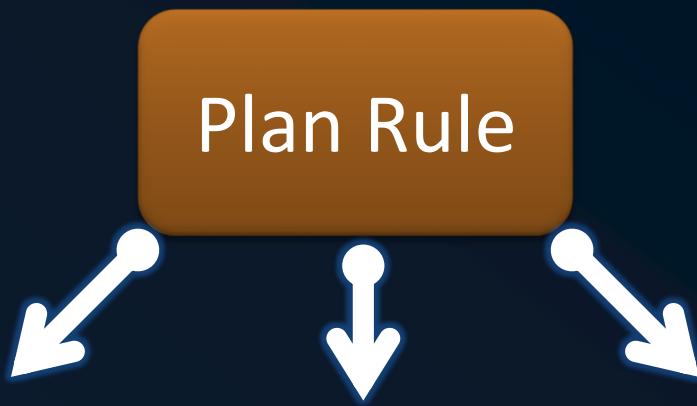


Modifies

$(\mathcal{PB}, \{B(savings)\}, parisTrip, \{\underline{paris}, \underline{\sim}savings\})$

Plan Rules

Plan rules are specified to relate plans with goals, and determine which plan execute.



A set of Current Goals to be achieved with the plan

A set of Current Beliefs representing plan preconditions

A plan that will be executed if Current Goals and Beliefs are warranted

Plan Rules

$G(\text{paris}) \leftarrow B(\neg \text{afraidToFlight}) \text{ [parisTrip]}$

Plan Rules

Perceptions E

oneWeekVacation

Ψ^B

debts
savings
girlfriend
goodSalary
 \sim afraidToFlight

Δ^B

Belief Base \mathcal{PB}

spend \prec savings
 \sim spend \prec debts
spend \prec savings, goodSalary, debts
travel \prec oneWeekVacation
 \sim travel \prec \sim spend

Goal Base \mathcal{GB}

Ψ^G

Δ^G

paris \prec B(travel), B(oneWeekVacation),
B(girlfriend)
hongKong \prec B(travel), B(oneWeekVacation)
 \sim hongKong \prec paris, B(oneWeekVacation)
 \sim paris \prec hongKong, B(oneWeekVacation)

Plan Base Π

G(paris) \leftarrow B(\sim afraidToFlight) [parisTrip]

Plan Rules

Goal Base \mathcal{GB}

Ψ^G

Δ^G

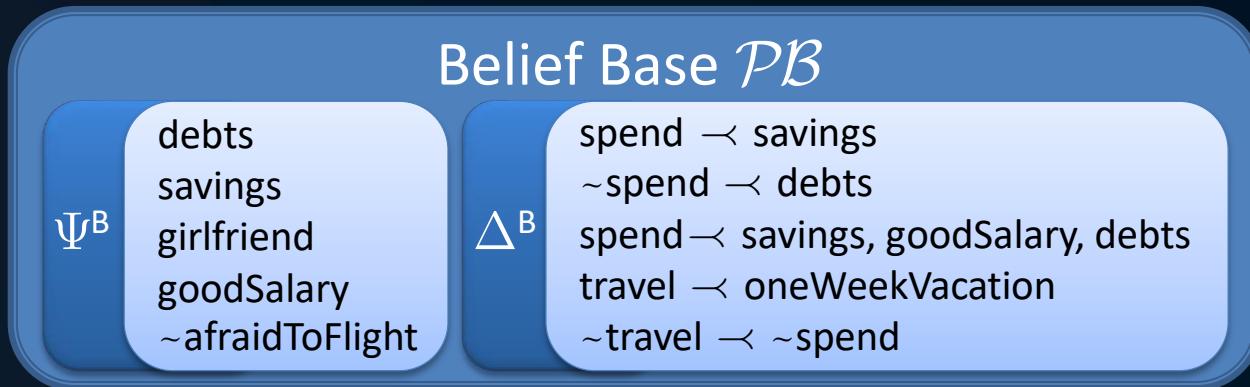
$\text{paris} \leftarrow \text{B(travel)}, \text{B(oneWeekVacation)},$
 B(girlfriend)
 $\text{hongKong} \leftarrow \text{B(travel)}, \text{B(oneWeekVacation)}$
 $\sim \text{hongKong} \leftarrow \text{paris}, \text{B(oneWeekVacation)}$
 $\sim \text{paris} \leftarrow \text{hongKong}, \text{B(oneWeekVacation)}$



$G(\text{paris}) \leftarrow \text{B}(\sim \text{afraidToFlight})$ [parisTrip]

Plan Rules

Perceptions E
oneWeekVacation



$G(\text{paris}) \leftarrow B(\neg \text{afraidToFlight})$ [parisTrip]

Plan Rules

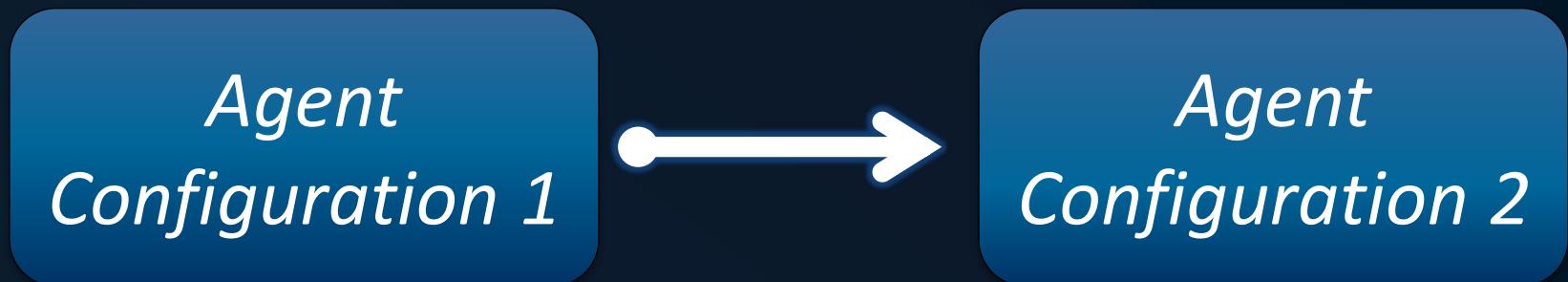
Plan Base Π

([parisTrip], G(paris))

$G(\text{paris}) \leftarrow B(\neg \text{afraidToFlight}) \text{ [parisTrip]}$

Agent Execution Model

- *Each time the agent modifies one of its mental components, it will produce a state change.*
- *These state changes, are known as transitions, and constitute the agent execution model.*



Agent Execution Model

- Then transitions will occur when the agent tries to execute an action or selects a plan for execution.

Aplicable a_1 ?

Agent Configuration

E' \mathcal{PB}' \mathcal{GB}' $[a_2, \dots, a_n]$

Agent Configuration

E \mathcal{PB} \mathcal{GB} $[a_1, a_2, \dots, a_n]$

Yes

No

Agent Configuration

E \mathcal{PB} \mathcal{GB} \emptyset

Agent Configuration

E \mathcal{PB} \mathcal{GB} \emptyset



Agent Configuration

E \mathcal{PB} \mathcal{GB} $[a_1, a_2, \dots, a_n]$

Remarks

- *It is possible to specify conflicting rules in belief and goal bases.*
- *The argumentation mechanism of the agent will prevent obtaining conflicting inferences from these bases.*
- *Contextual queries provide a concrete and useful tool to model component interaction and dynamics*

Work in Progress

- *Introduce different types of goals (maintenance, achievement, etc).*
- *Include in the arquitecture an automatic planner based in defeasible argumentation*
- *Include argumentative reasoning for reconsideration of goals that have been chosen.*

Thank you!

Questions?

