Endomorphic metalanguage and abstract planning for real-time intent recognition

Antoine Gréa

Lyon 1

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Endomorphic metalanguage and abstract planning for real-time intent recognition

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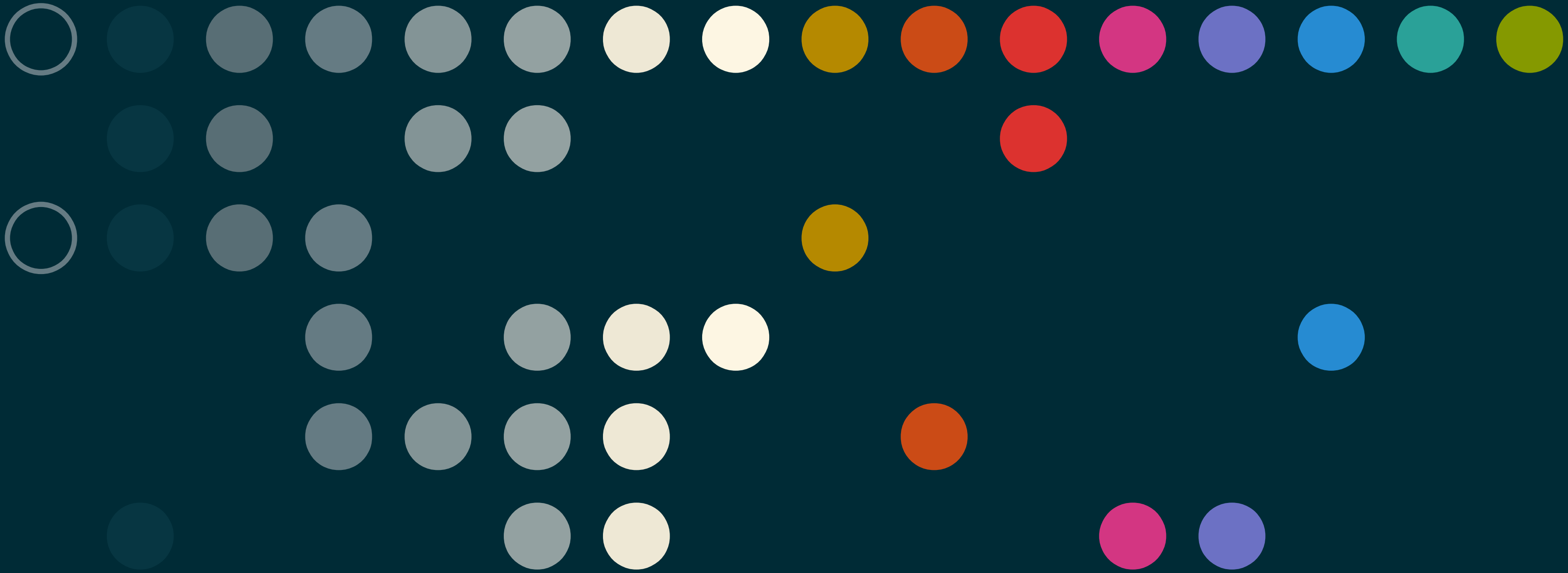
Antoine Gréa

1 Introduction



1.1 A what ?

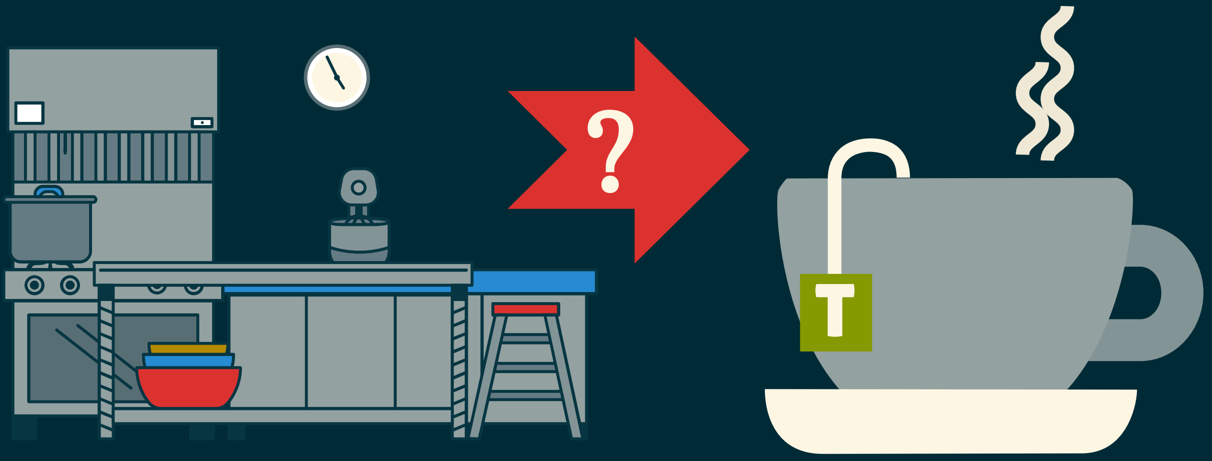
- *Dependent people need help !*
  - Not **annoying** the person
  - Can't see *everything* they are doing
- How to help without asking ?
  - Guessing the intent somehow

- **Intent recognition**
  - Observed behavior → Goal
  - Using action sequences: Plans

1.2 Kitchen Example

- Observation
  - Bob goes in the kitchen
- Possible goals
  - Bob cleans the dishes
  - Bob makes tea
  - …
- Infer the correct goal

- Issues
  - Multiple goals
  - Interleaving actions
  - Partial observations



Plan

1 Introduction

2 Intent Recognition

3 Knowledge Representation

4 General Planning

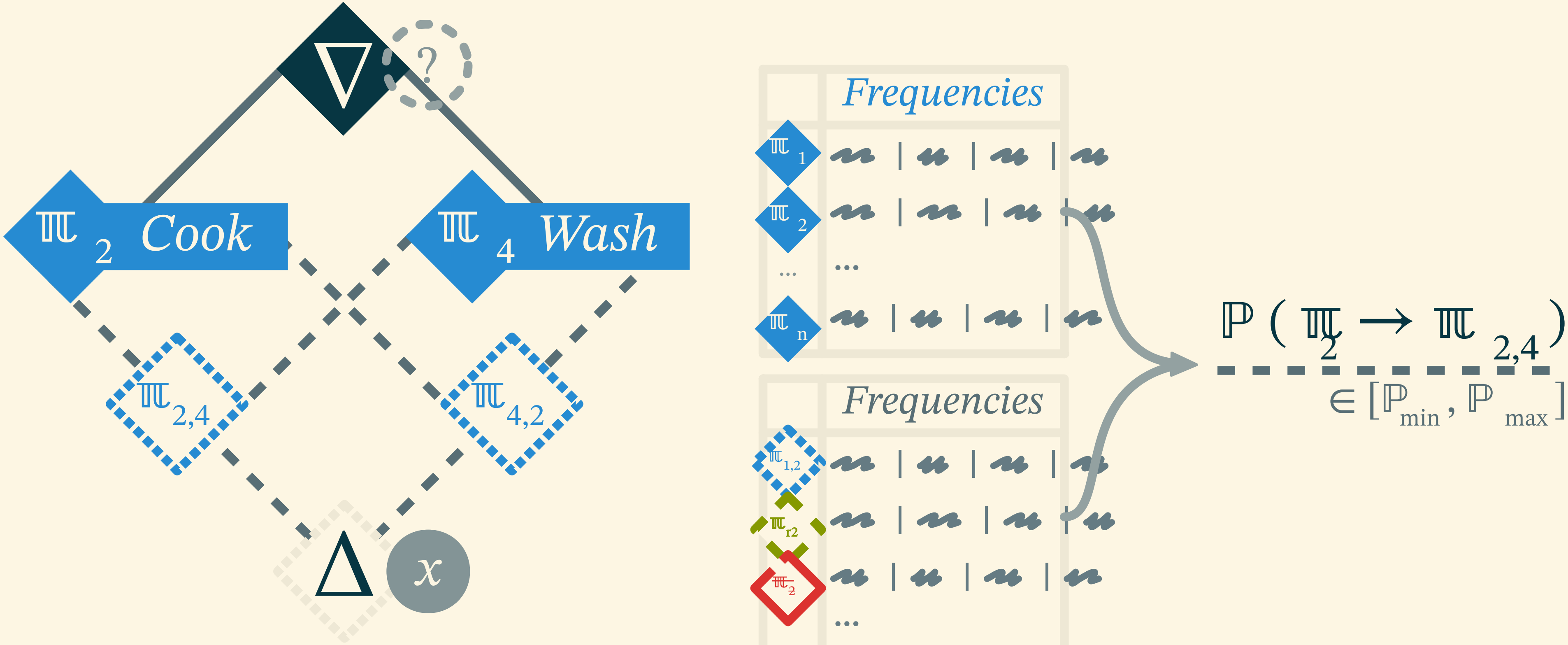
5 Flexible Online Planning

6 Conclusion

2 Intent Recognition

2.1 Logic Approach

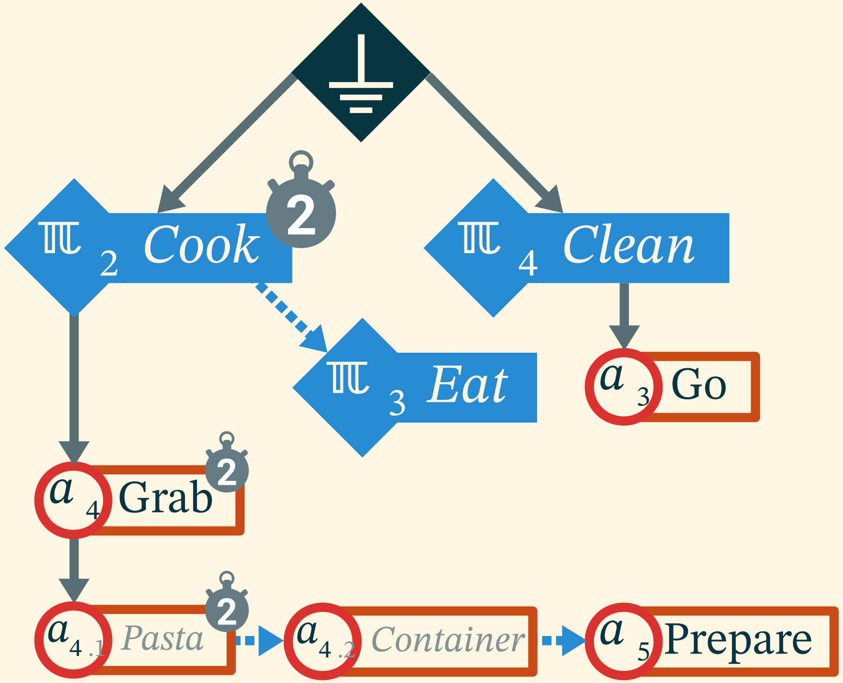
- Lattice Based : ✓ Fast computations ✘ Exponential growth

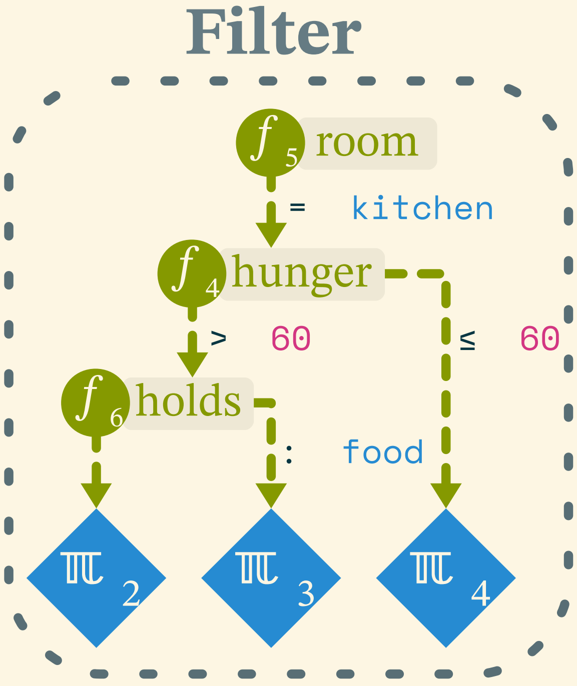


(Bouchard et al. 2006)

2.2 Stochastic Approach

- And/Or and decision tree
  - ✓ Accurate & efficient
  - ✘ Handmade plan library & tree

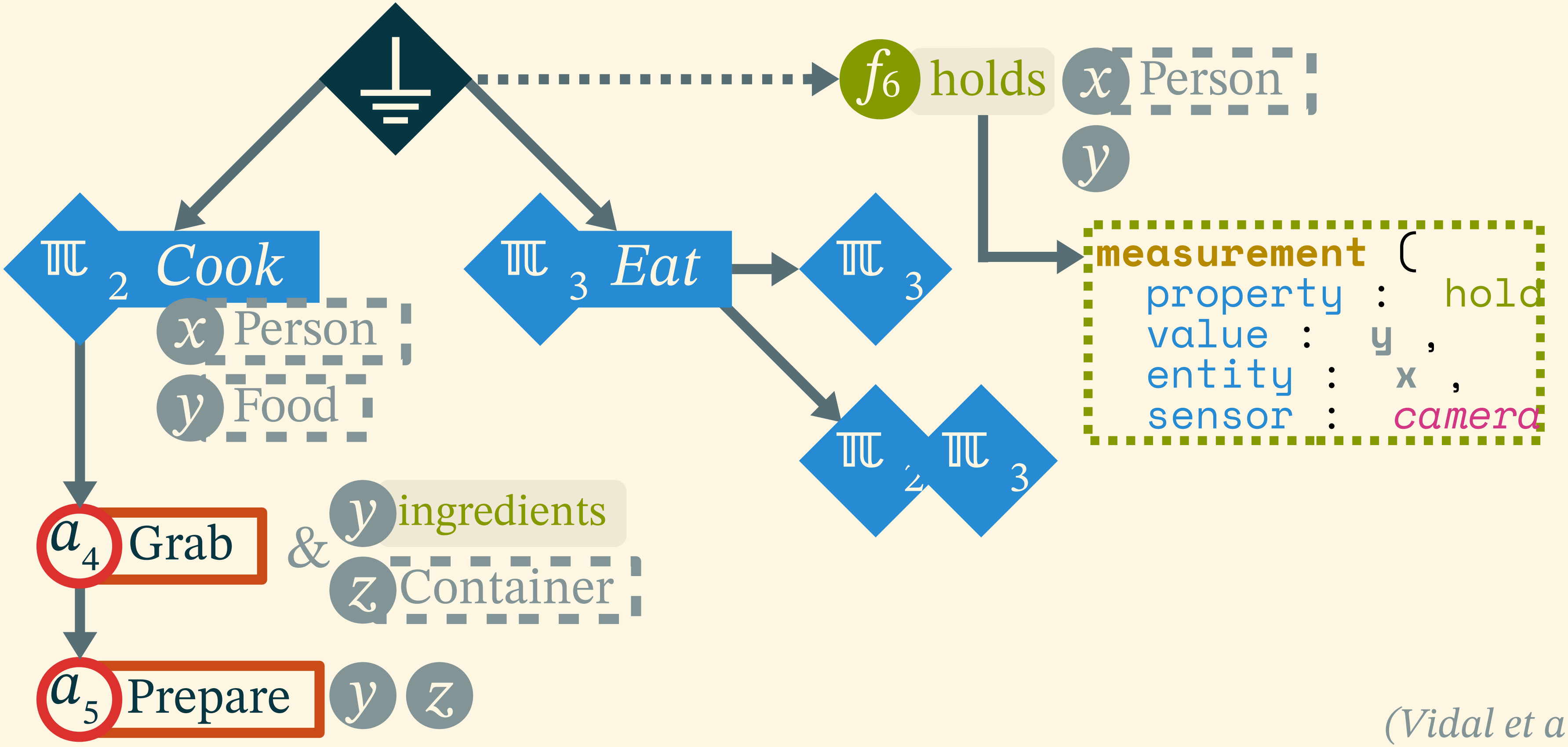




(Avrahami et al. 2006)

2.3 Grammatical Approach

- Valued Grammar : ✓ Versatile ✘ Slow refresh rate (~40s)

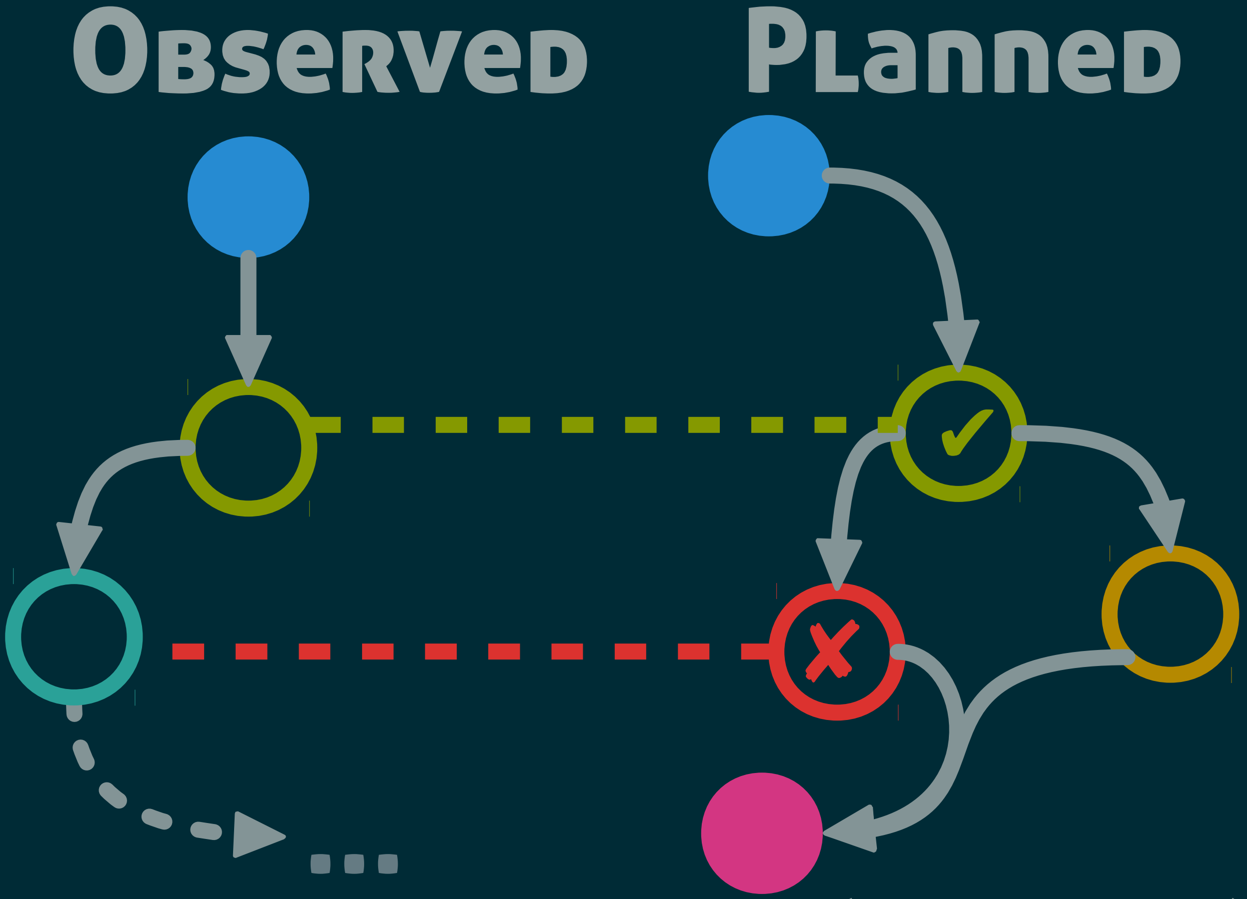


```
measurement (
  property :  hold
  value :  y ,
  entity :  x ,
  sensor :  camera
```

(Vidal et al. 2010)

2.4 Inverted Planning

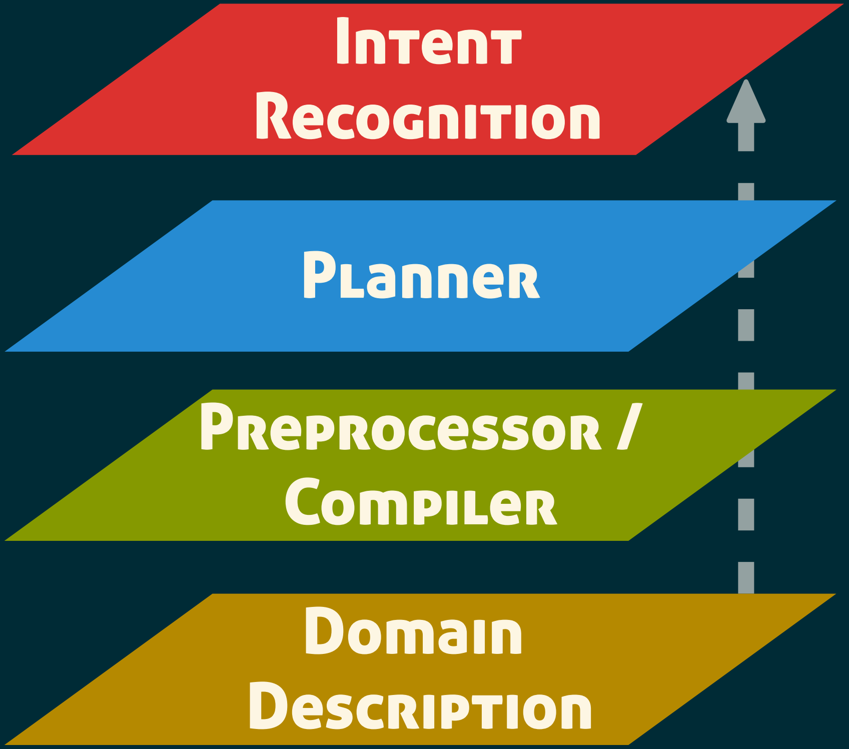
- Intent Recognition
  - Find the goal of a plan
- **Planning**
  - Find the plan to a goal
- *Theory of Mind*
  - The easier the plan, the more likely the goal



(Ramirez et al. 2010)

2.5 Framework Stacks

- Existing



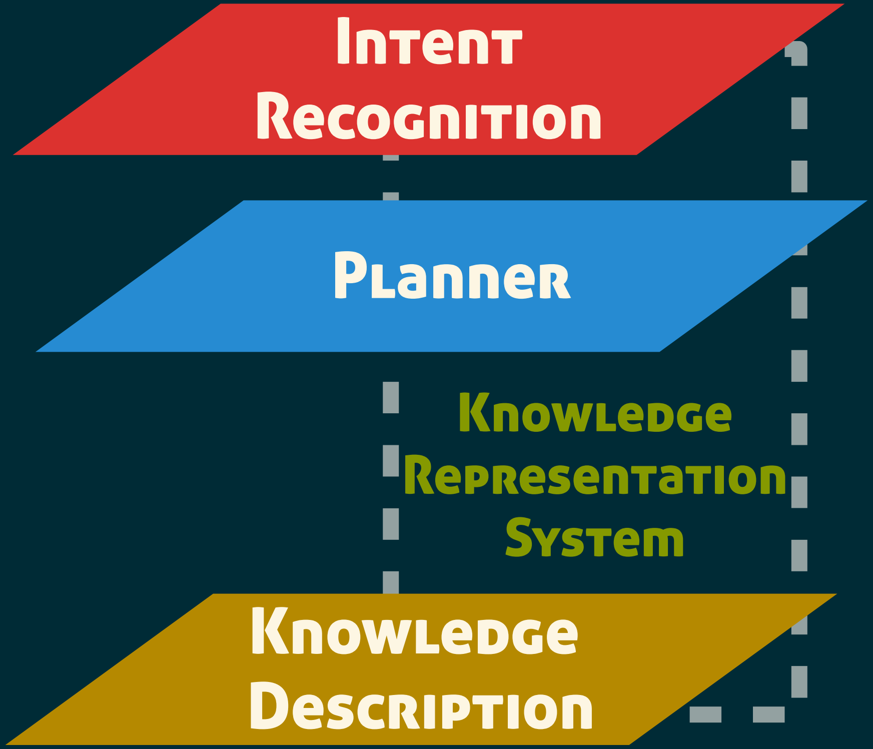
Intent Recognition

Planner

Preprocessor / Compiler

Domain Description

- Contribution



Intent Recognition

Planner

Knowledge Representation System

Knowledge Description

3 Knowledge Representation

3.1 Knowledge in Planning

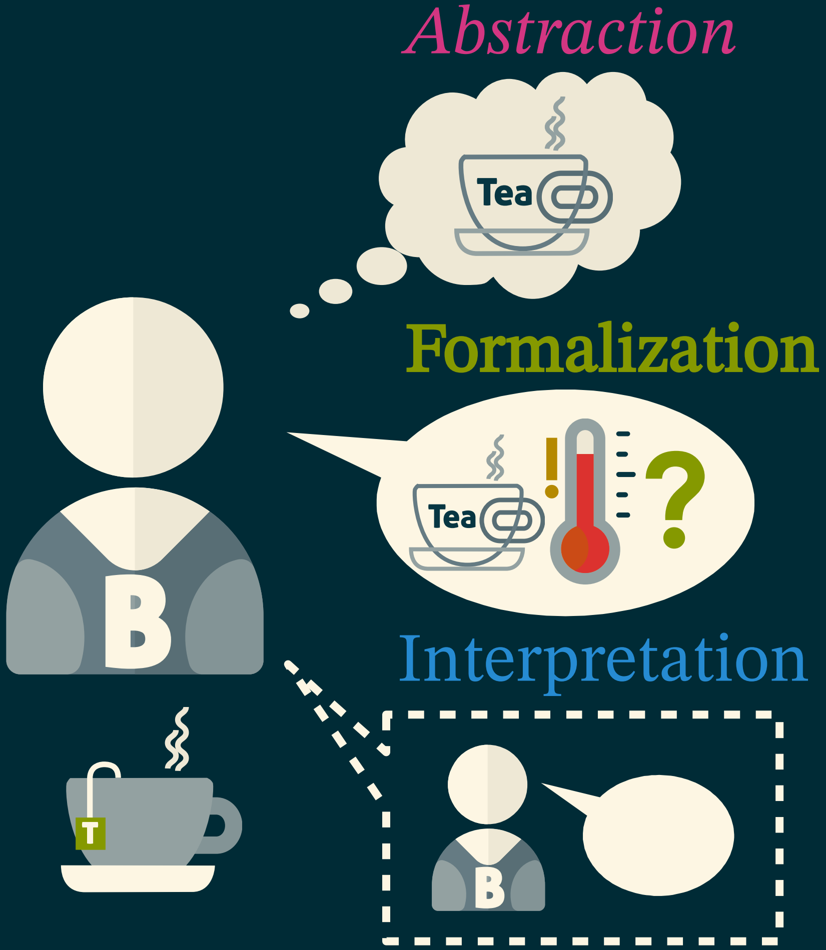
- **Reification** *(Cambridge Dictionary)*

> “*The act of changing something abstract into something real*

tea *is* **not** hot;

a *eff* (tea *is* hot);

method {(a_1 → a_2)};



3.2 Existing Tools

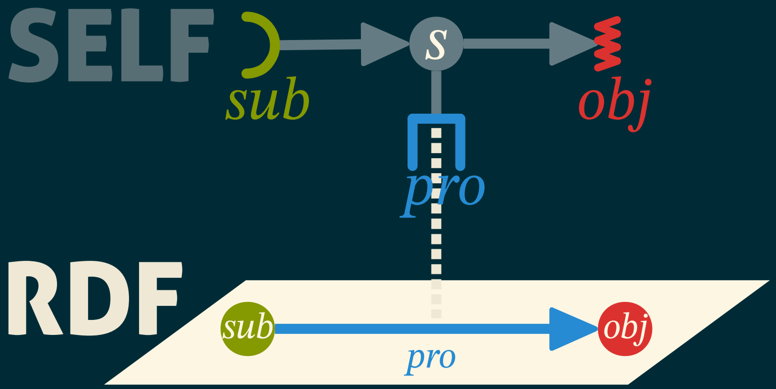
- Ontologies
  - Based on Description Logic

```
<?xml version="1.0"?>

<RDF>
  <Description about="Bob">
    <likes>Tea</likes>
    <location>Kitchen</location>
  </Description>
</RDF>
```

- Languages
  - RDF
  - OWL-(Lite, DL, Full)
  - ...
- Issues
  - Reification inefficient
  - Higher order knowledge
  - Flexibility of the structure

3.3 SELF Structurally Expressive Language Framework

- Minimal definition
  - Structure is meaning
  - **Ex:** `∀x = x;`
- More expressive
- Native reification
  - Express fluents and states in higher order spaces
  - Methods for hierarchical planning



Examples:

```
s = (bob @ kitchen);
a pre s;
a methods
{go(kitchen) → take(cup)};
```

(Gréa et al. 2020)

4 General Planning

4.1 Classical Planning

- Domain
  - Fluents
    - Formulas over objects
  - States
    - Properties of the world
    - Formulas over fluents
  - Actions
    - Preconditions
    - Effects

- Problem
  - Initial state
  - Goal state
- Plan (solution)
  - Action sequence
  - Order
    - Total
    - Partial

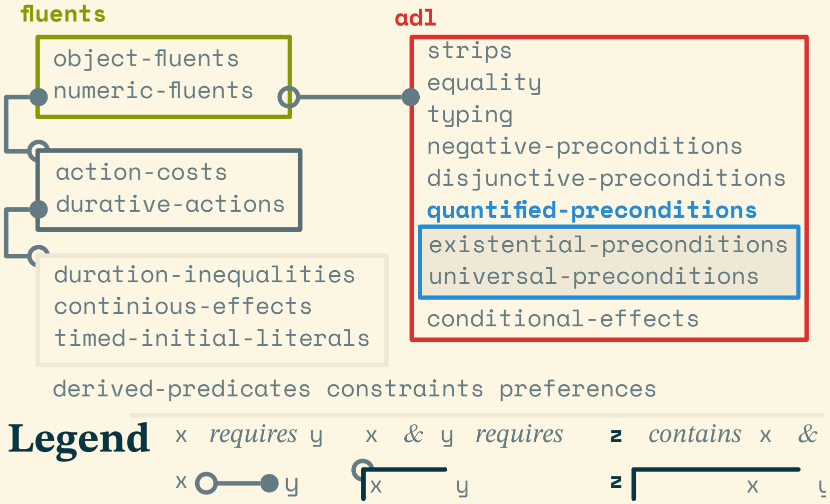
4.2 Example

- Fluents
  - thing *taken*
  - *hot* water, tea *ready*
- Actions
  - take, brew, boil, …

T
Sugar
Sugar
Initial State
T
Goal State

4.3 Existing Frameworks

- Standard language: **PDDL**
  - Numerous extensions to the language
  - Not used in probabilistic or hierarchical planning
  - Most of the time translated into an intermediate language for planners



fluents

object-fluents
numeric-fluents

action-costs
durative-actions

duration-inequalities
continious-effects
timed-initial-literals

adl

strips
equality
typing
negative-preconditions
disjunctive-preconditions
quantified-preconditions
existential-preconditions
universal-preconditions
conditional-effects

derived-predicates constraints preferences

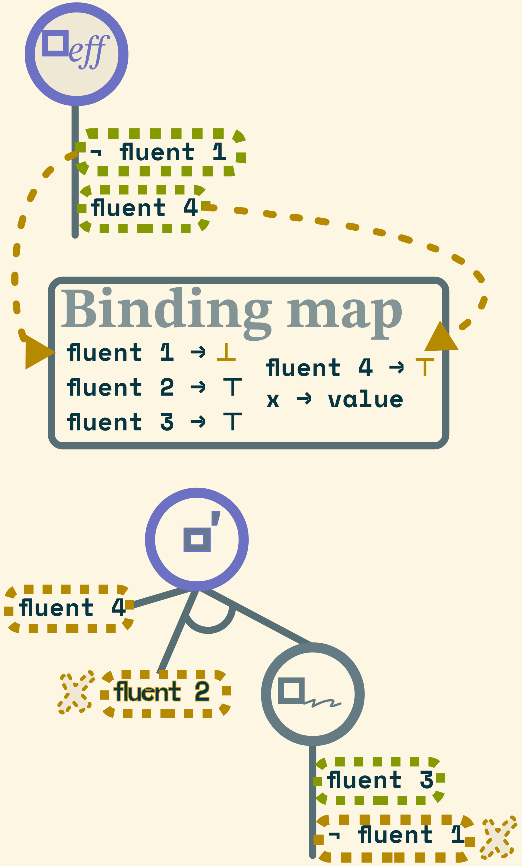
Legend *x requires y* *x & y requires* *z contains x &*

- Temporal
  - PDDL+
  - ANML
- Probabilistic
  - PPDDL
  - **RDDL**
- Multi-Agent
  - MAPL
  - MA-PDDL

- Hierarchical
  - UMCP
  - SHOP2
  - **HDDL**
  - HPDDL
- Ontological
  - *WebPDDL*
  - *OPT*
- Hybrids
  - SIADEX

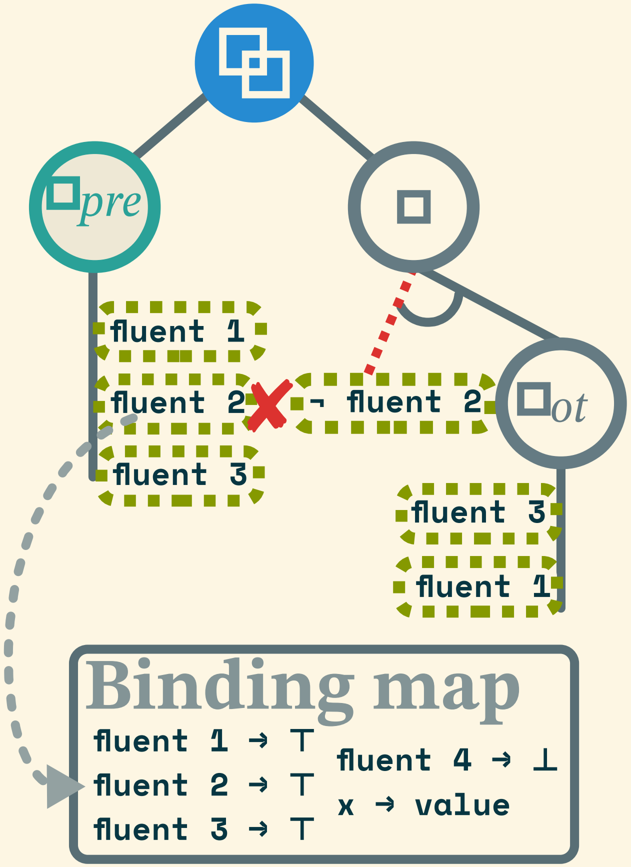
4.4 Factorizing Planning States

States: And/Or trees of Fluents



Binding map

fluent 1 → ⊥
fluent 2 → ⊤
fluent 3 → ⊤
fluent 4 → ⊤
x → value



Binding map

fluent 1 → ⊤
fluent 2 → ⊤
fluent 3 → ⊤
fluent 4 → ⊥
x → value

(Gréa et al. 2020)

4.5 Planning Formalism Revisited

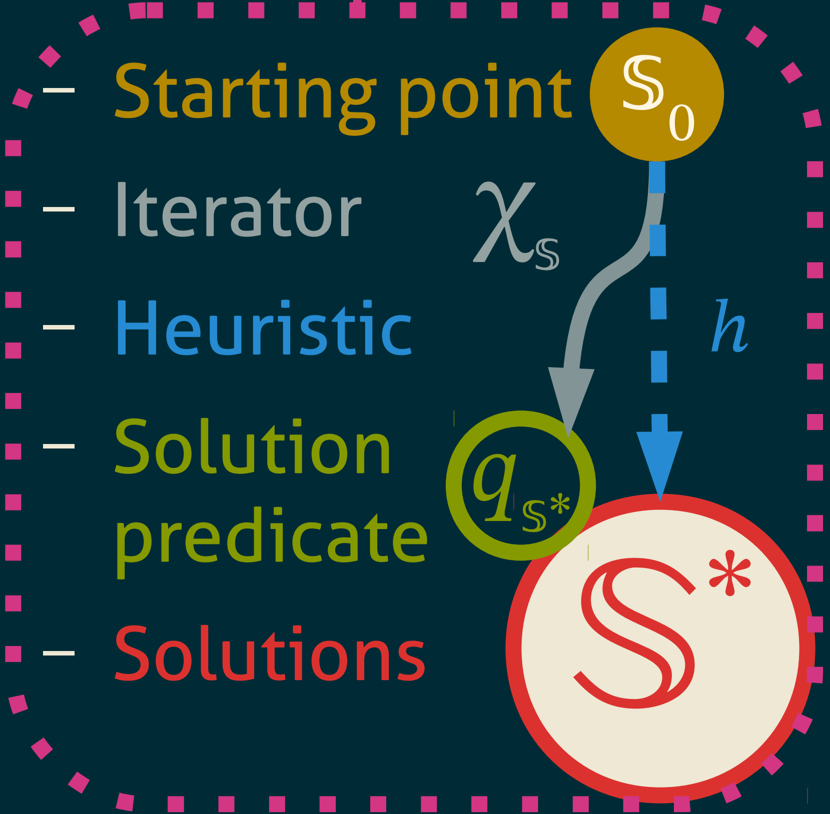
- Actions
  - Preconditions, Effects
  - Constraints
  - Cost, Duration, Probability
  - Methods
    - $(\mathit{eff} \to \mathit{pre})$

- Problem
  - Root Action ω
    - $\mathit{pre}(\omega) = a^0$
    - $\mathit{eff}(\omega) = a^*$

(Gréa et al. 2020)

4.6 General Planning Framework

- Search Space



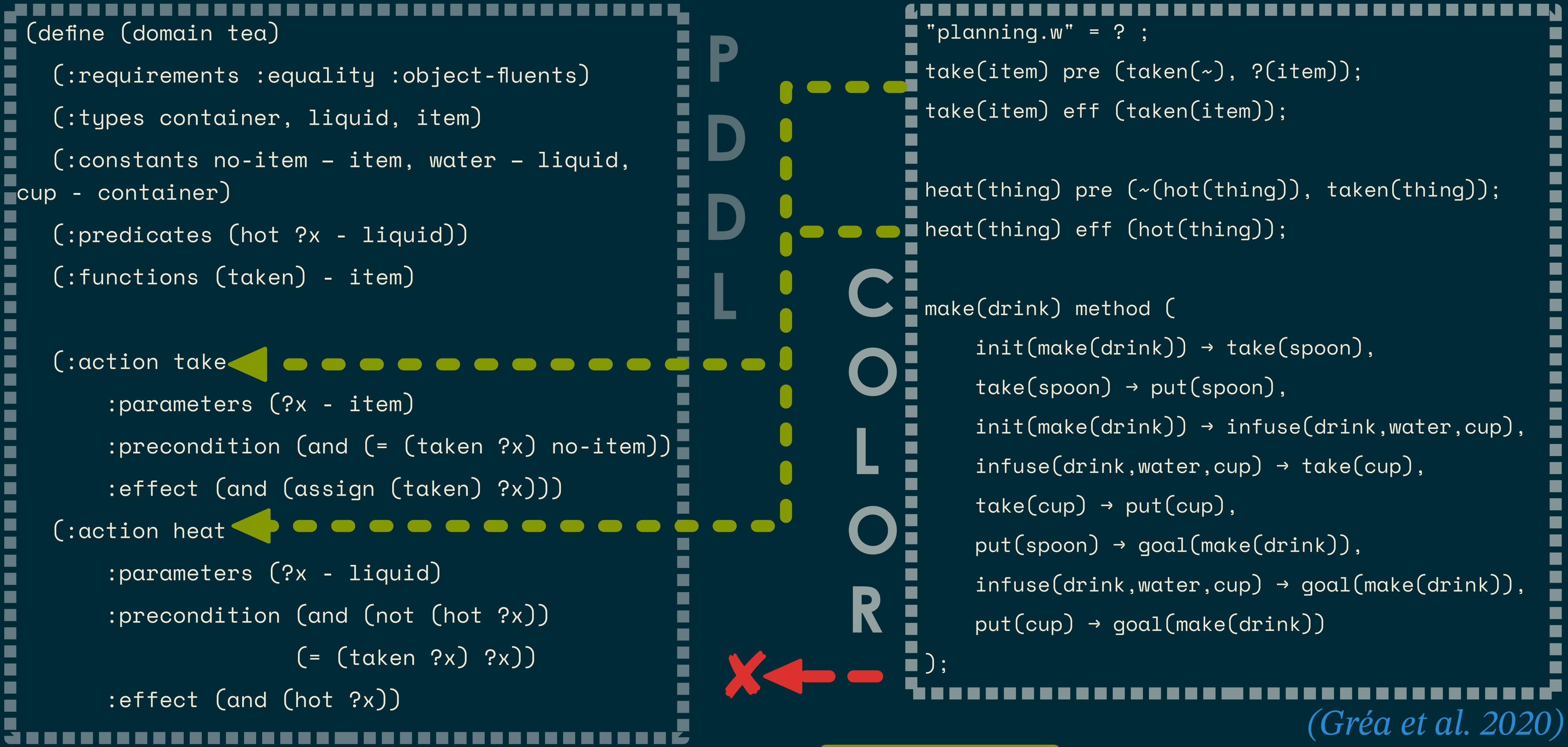
  - Starting point
  - Iterator
  - Heuristic
  - Solution predicate
  - Solutions

- Instances for
  - **State-transition**
  - Plan space
  - Case based
  - Probabilistic
  - Hierarchical

$$\mathbb{S}_0 = \mathit{eff}(\omega) \text{ (initial)}$$
$$\chi_{\mathbb{S}} = a \in A \text{ (actions)}$$
$$q_{\mathbb{S}^*} = (\models pre(\omega)) \text{ (goal)}$$
$$\mathbb{S} = \square \text{ (states)}$$

(Gréa et al. 2020)

4.7 PDDL vs COLOR



```
(define (domain tea)
  (:requirements :equality :object-fluents)
  (:types container, liquid, item)
  (:constants no-item - item, water - liquid,
cup - container)
  (:predicates (hot ?x - liquid))
  (:functions (taken) - item)

  (:action take
      :parameters (?x - item)
      :precondition (and (= (taken ?x) no-item))
      :effect (and (assign (taken) ?x)))
  (:action heat
      :parameters (?x - liquid)
      :precondition (and (not (hot ?x))
                         (= (taken ?x) ?x))
      :effect (and (hot ?x))
```

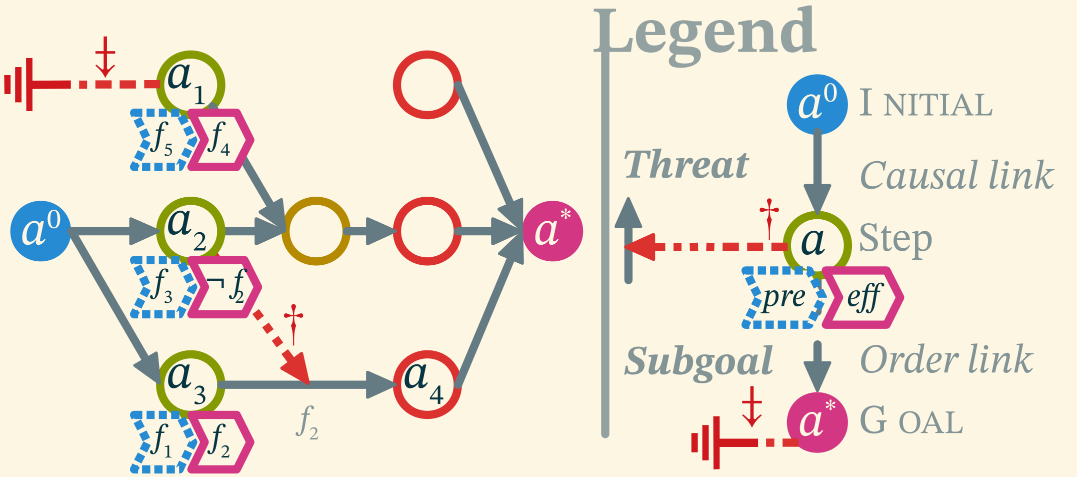
```
"planning.w" = ? ;
take(item) pre (taken(~), ?(item));
take(item) eff (taken(item));

heat(thing) pre (~(hot(thing)), taken(thing));
heat(thing) eff (hot(thing));

make(drink) method (
    init(make(drink)) → take(spoon),
    take(spoon) → put(spoon),
    init(make(drink)) → infuse(drink,water,cup),
    infuse(drink,water,cup) → take(cup),
    take(cup) → put(cup),
    put(spoon) → goal(make(drink)),
    infuse(drink,water,cup) → goal(make(drink)),
    put(cup) → goal(make(drink))
);
```

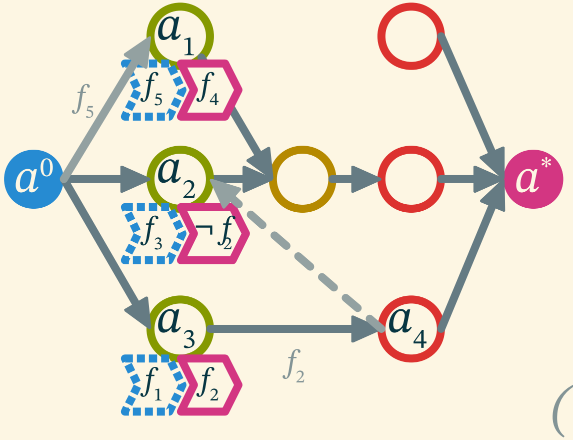
(Gréa et al. 2020)

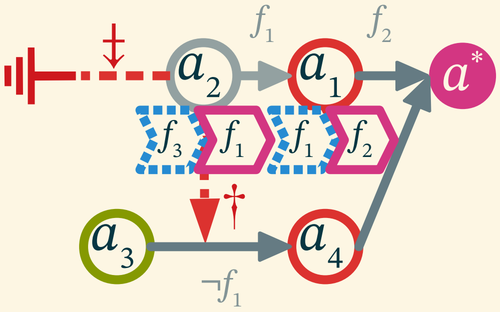
5 Flexible Online Planning

5.1 Plan Space Planning

- Exploration by refinements
- Flaws
  - Subgoals
  - Threats
- Resolvers
  - Side effects
- May need backtracking





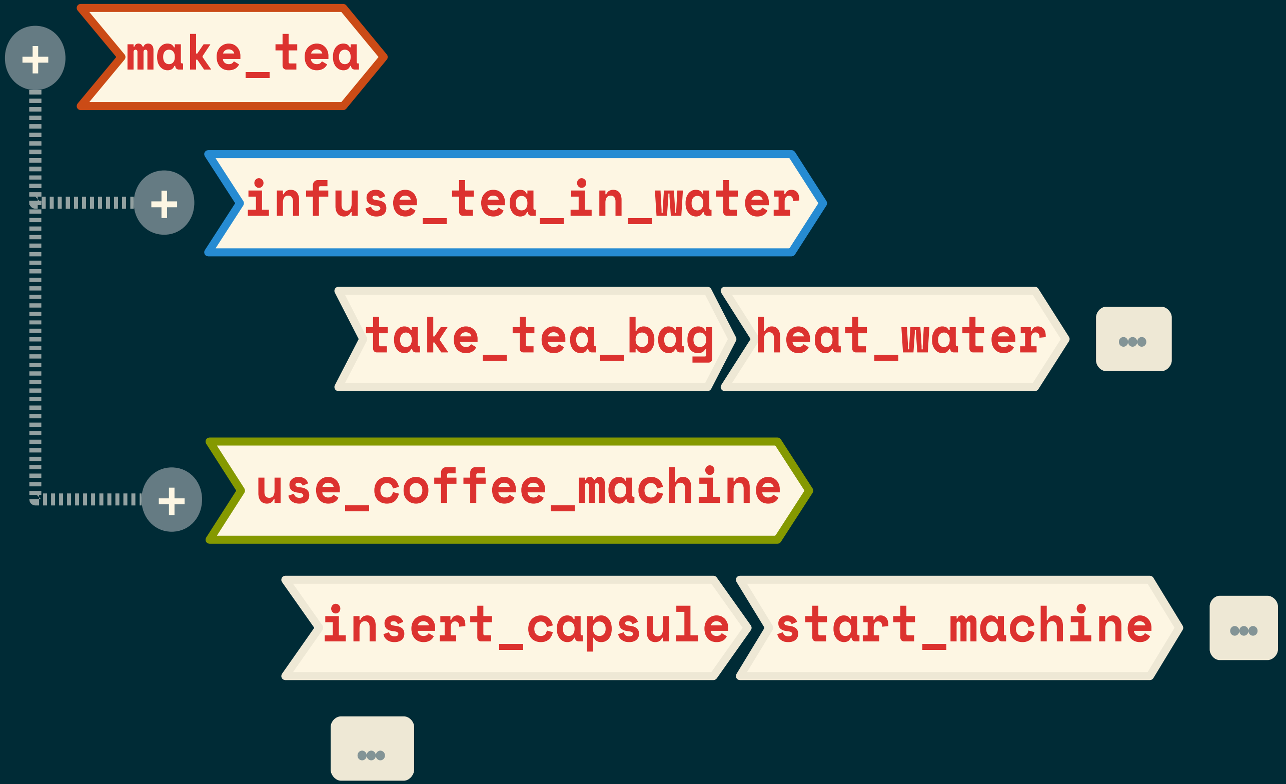


(Ghallab et al. 2004)

5.2 Hierarchical Task Networks

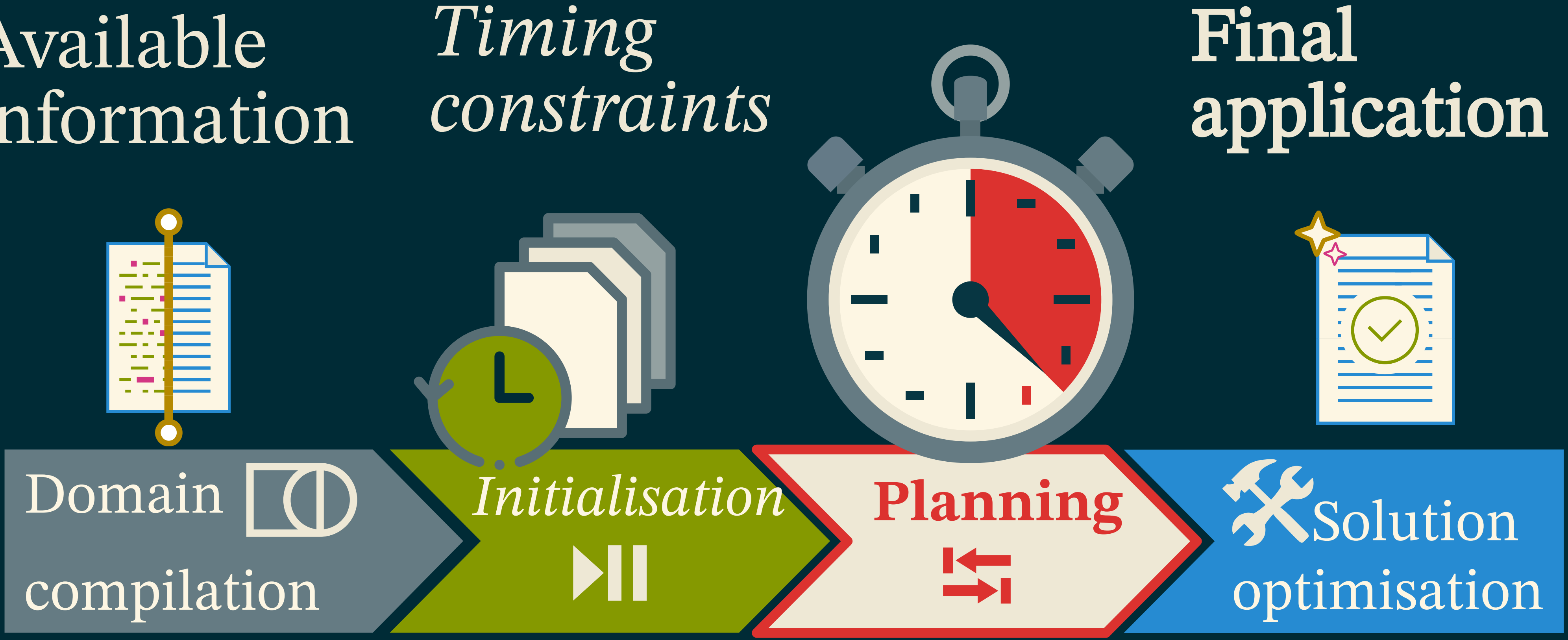
> "*In an HTN planner, the objective is not to achieve a set of goals but instead to perform some set of tasks.*
> (Ghallab et al. 2004)

- Based on tasks decomposition
  - Replace task with method
- Numerous approaches



(Ghallab et al. 2004)

5.3 Planning Phases



Available information

Timing constraints

Final application

Domain compilation

Initialisation

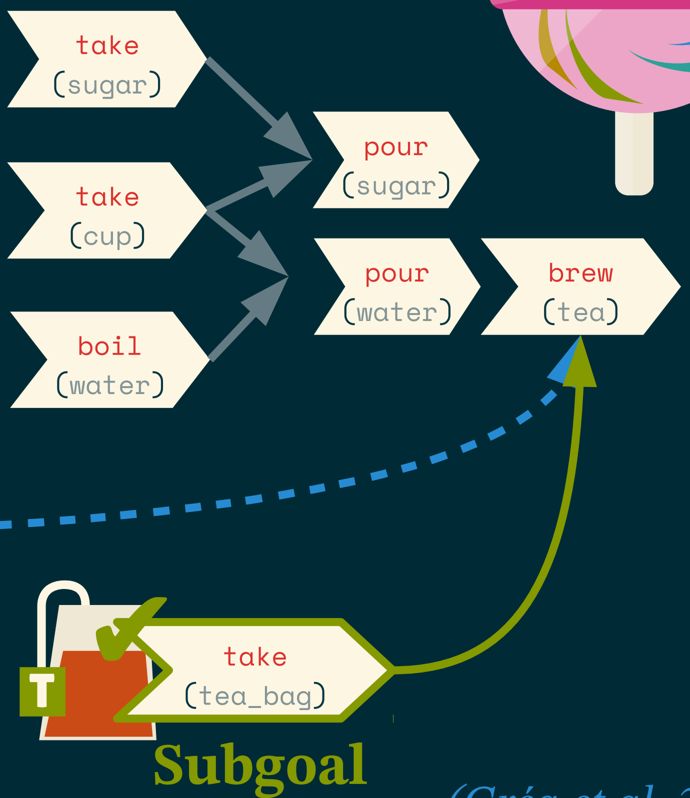
Planning

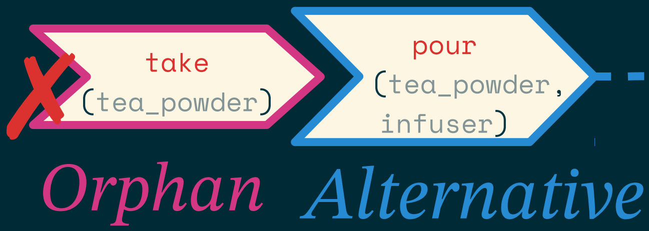
Solution optimisation

5.4 Plan Repair Prototype

- Partial Order Planner (POP)
- Operator dependency graph
- Negative refinements
- Alternatives & Orphans

LolliPop





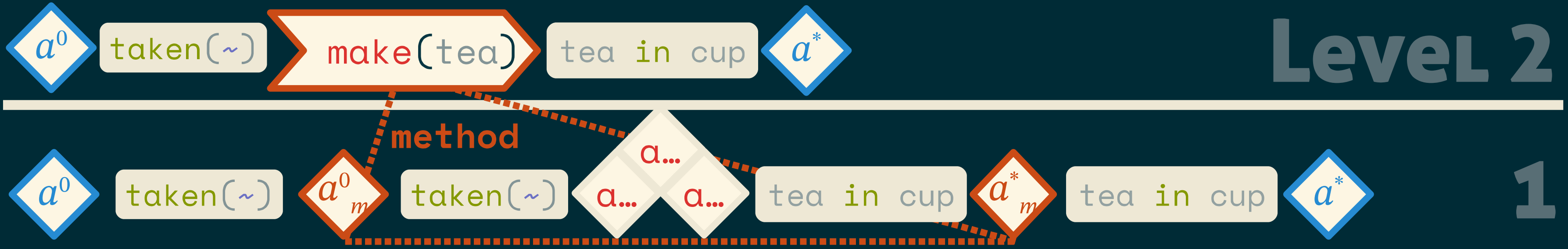
- Utility Heuristics

(Gréa et al. 2016)

5.5 Abstract Planning

- Partial Resolution
  - An abstract solution at every level of abstraction
- Search by level
  - Expansion after completion :

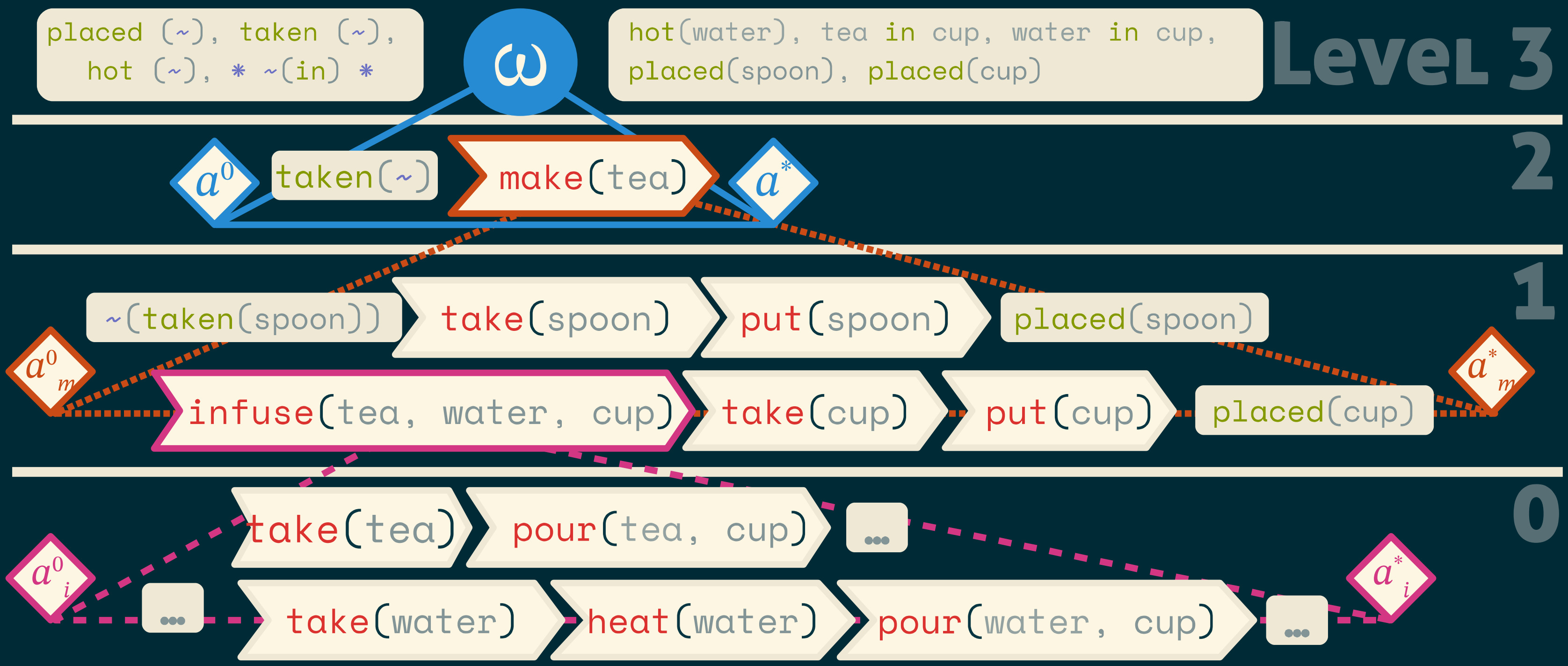
- HTN in PSP
- Decomposition flaw
  - Resolver : Decompose one composite action in the plan
  - *(Bechon et al. 2014)*



(Gréa et al. 2019)

5.6 HEART

- Low priority for expansion
- Each level is a plan (abstract solution)
- Change of level
  - Propagation of atomic actions
  - Expansion of Composite Equities



placed (~), taken (~), hot (~), * ~(in) *

ω

hot(water), tea in cup, water in cup, placed(spoon), placed(cup)

Level 3

a^0 taken(~) make(tea) a^*

2

~(taken(spoon)) take(spoon) put(spoon) placed(spoon)

1

a^0_m infuse(tea, water, cup) take(cup) put(cup) placed(cup) a^*_m

0

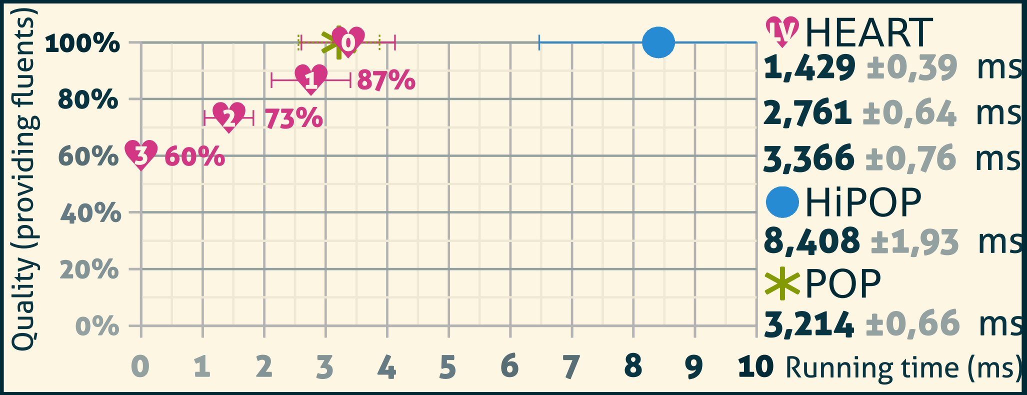
take(tea) pour(tea, cup) ...

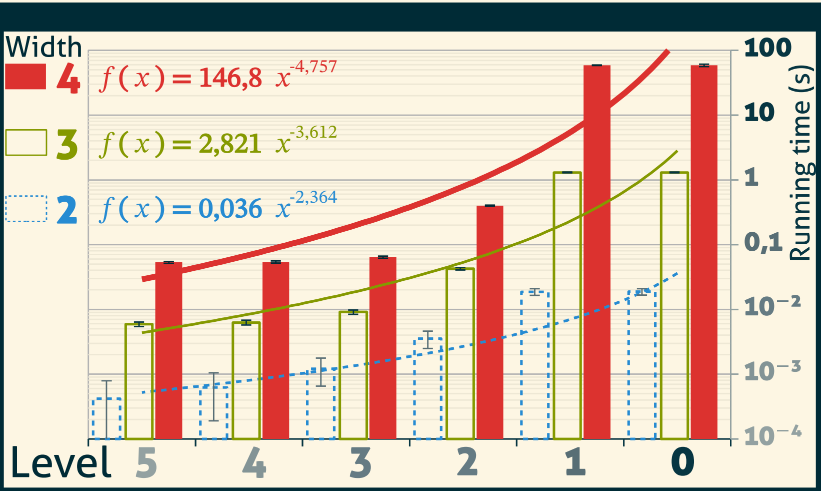
a^0_i ... take(water) heat(water) pour(water, cup) ... a^*_i

(Gréa et al. 2019)

5.7 Results

- 60% of the fluents **before** planning
- Exponentially faster at high abstraction levels
- Faster than HiPOP on some problems
- Common problems solved in milliseconds!

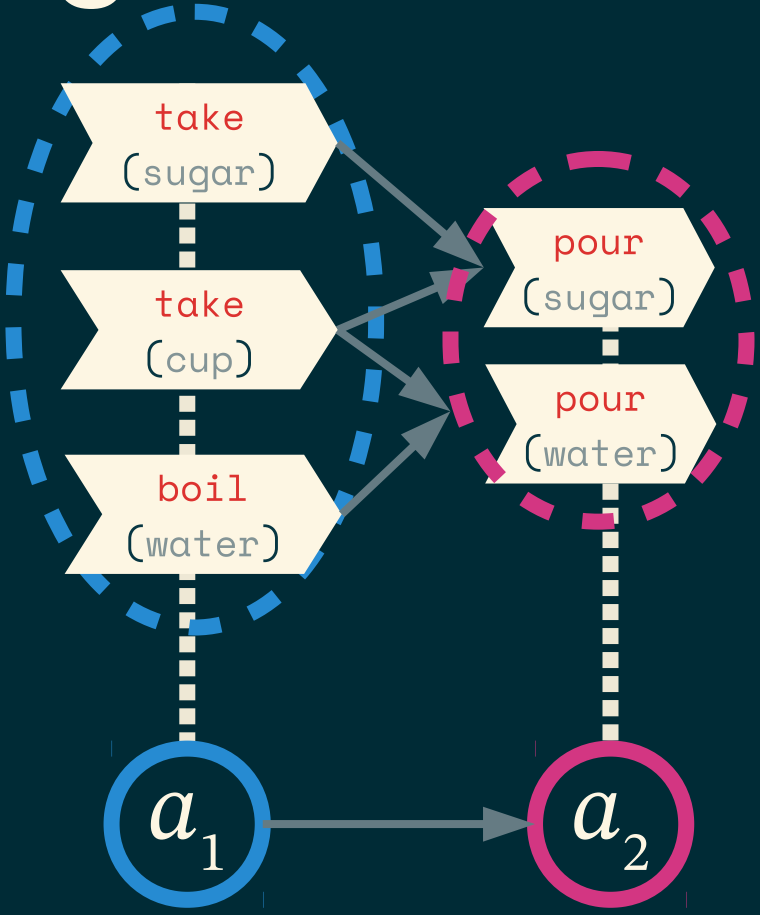




(Gréa et al. 2019)

5.8 Toward Intent Recognition

- Linearized parallel actions using graph quotient
- Abstraction makes it easier (smaller plans)
- Backward chaining is inefficient



(Gréa et al. 2020)

6 Conclusion

6.1 Contributions & Results

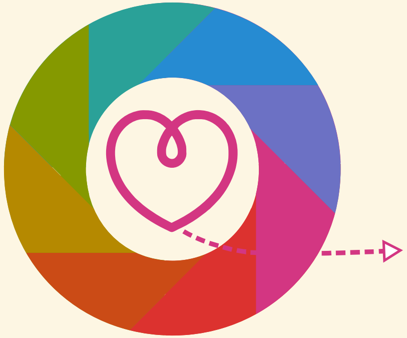
- SELF: A knowledge description language defined by structure
- COLOR: A general framework for planning with its formalization
- LOLLIPOP: A plan repair planner for online planning
- HEART: A flexible approach to real-time planning for abstract planning

(Gréa et al. 2020)

6.2 Perspectives

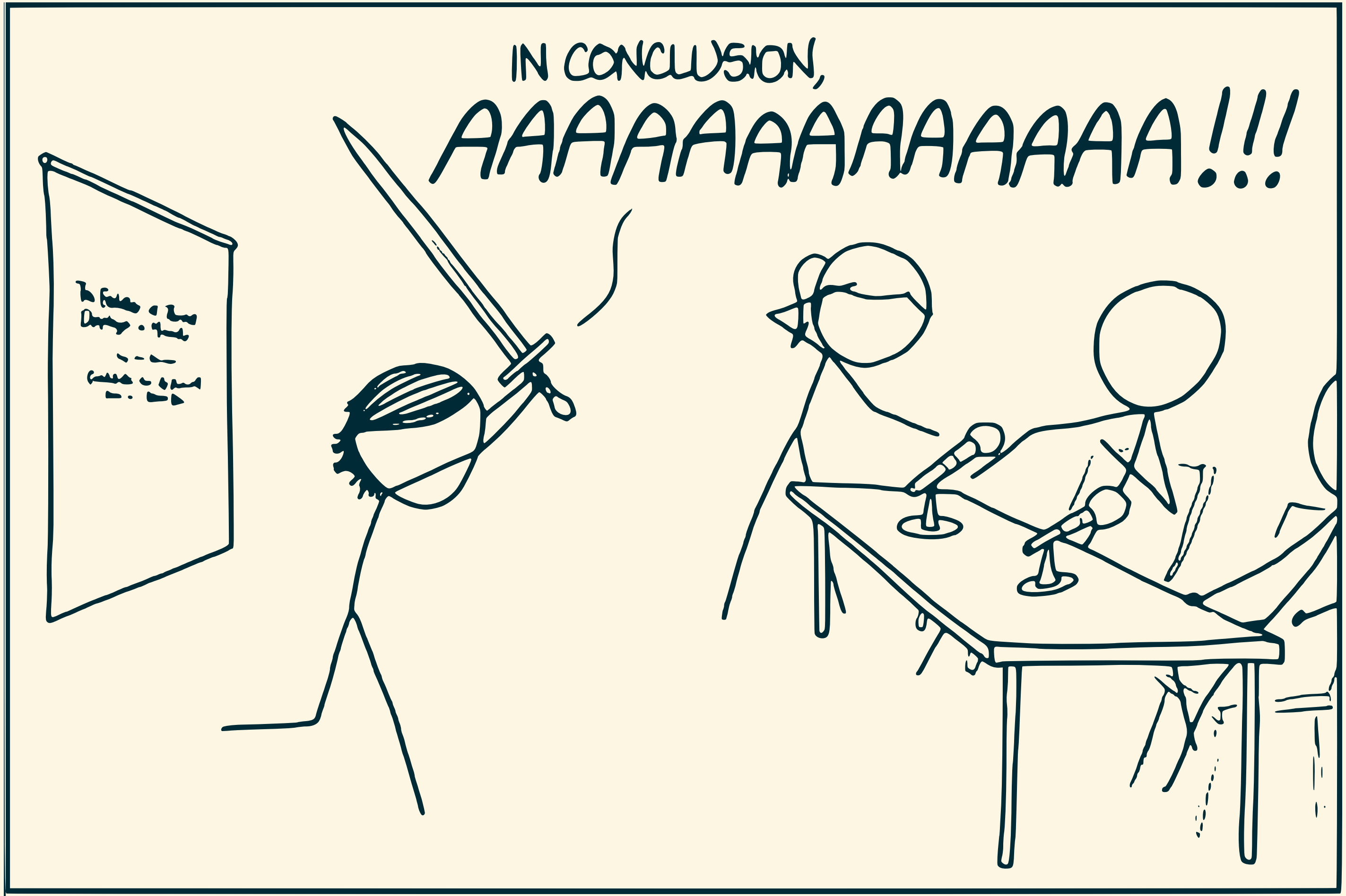
- SELF Improvement
  - Improve the instantiation workflow
  - Parameterize flexibility performances

- Planning Colorized
  - Conversion tool from PDDL



- Fixing Planning Domains
  - Allow HEART to discover new HTN methods (macro-action learning)

Thanks for listening !



THE BEST THESIS DEFENSE IS A GOOD THESIS OFFENSE.