

# Towards a System Architecture for Recognizing Domestic Activity by Leveraging a Naturalistic Human Activity Model

M. Dominici, M. Fréjus, J. Guibourdenche, B. Pietropaoli, F. Weis  
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# Outline

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- ▶ Introduction and basic assumptions
- ▶ Research problem
- ▶ Proposed approach

# Smart Home

- ▶ Promotes
  - ▶ Comfort
  - ▶ Security
  - ▶ Energy savings
  - ▶ ...
- ▶ Natural interaction
- ▶ Context-aware services



- ▶ **Activity recognition is a fundamental feature**

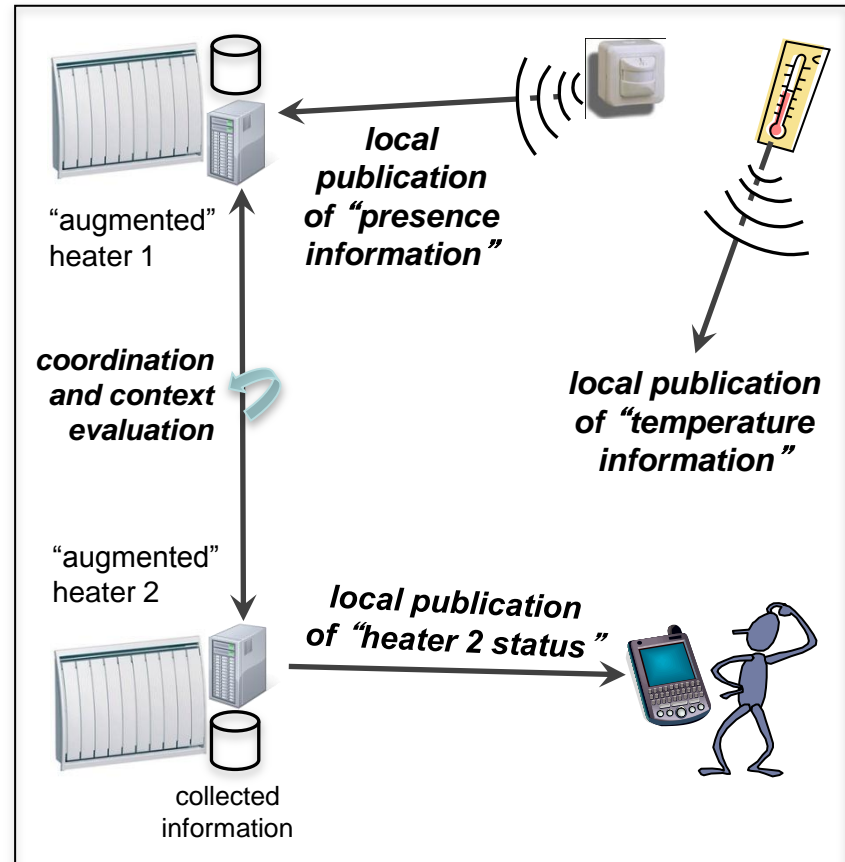
# Smart Home project

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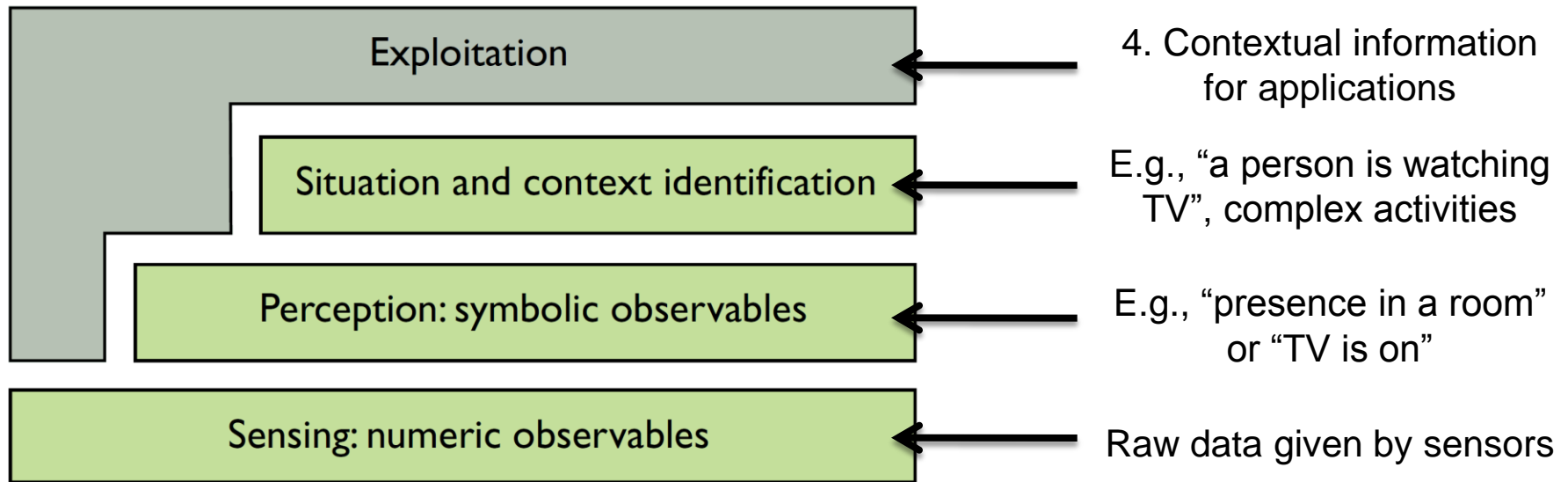
- ▶ Three-year academia-industry collaboration
- ▶ Goal
  - ▶ Prevent energy waste and preserve inhabitants' comfort
- ▶ An interdisciplinary project
  - ▶ Ubiquitous computing + cognitive ergonomics
- ▶ Challenge
  - ▶ Being aware of the **unavoidable “gap”** between activity recognition mechanisms and real-world activity (as seen by naturalistic human activity models)
- ▶ Constraints
  - ▶ Design and experimentation of a prototype system using off-the-shelf non-invasive technologies

# Physical approach

- ▶ Local context + local processing
- ▶ Physical objects
  - ▶ Bring pertinent information
  - ▶ Realize the application logic in a distributed fashion
- ▶ “Augmented” appliances and sensors

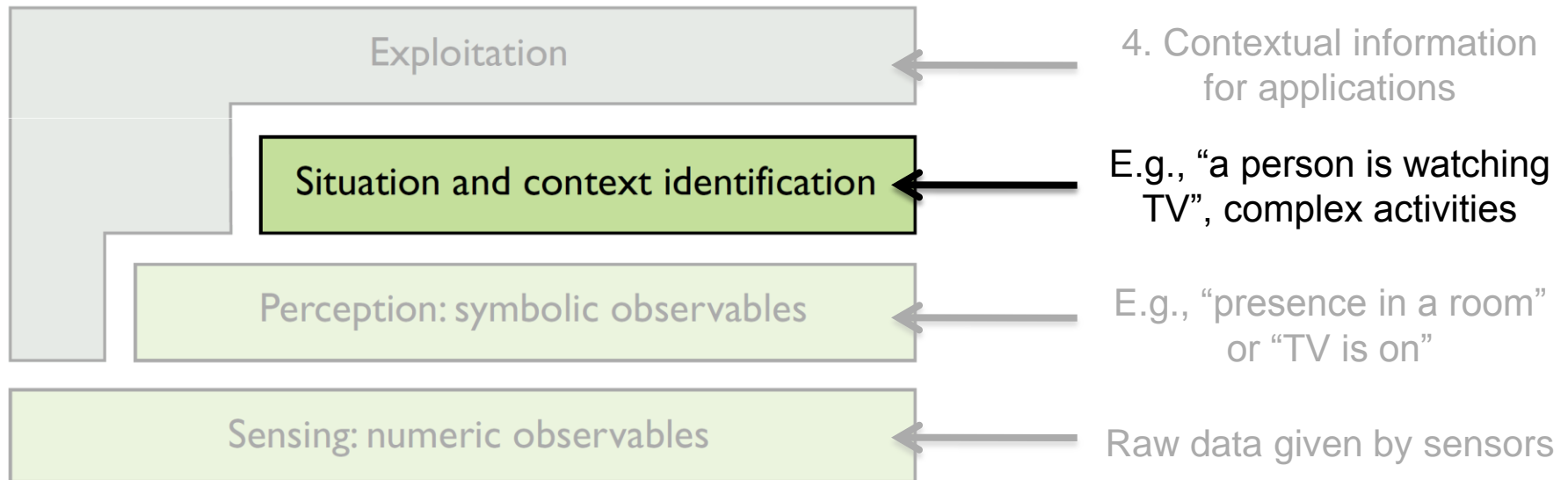


# Four layers for context awareness



*Layered architecture suggested by J. Coutaz et al. in "Context is key", 2005*

# Four layers for context awareness

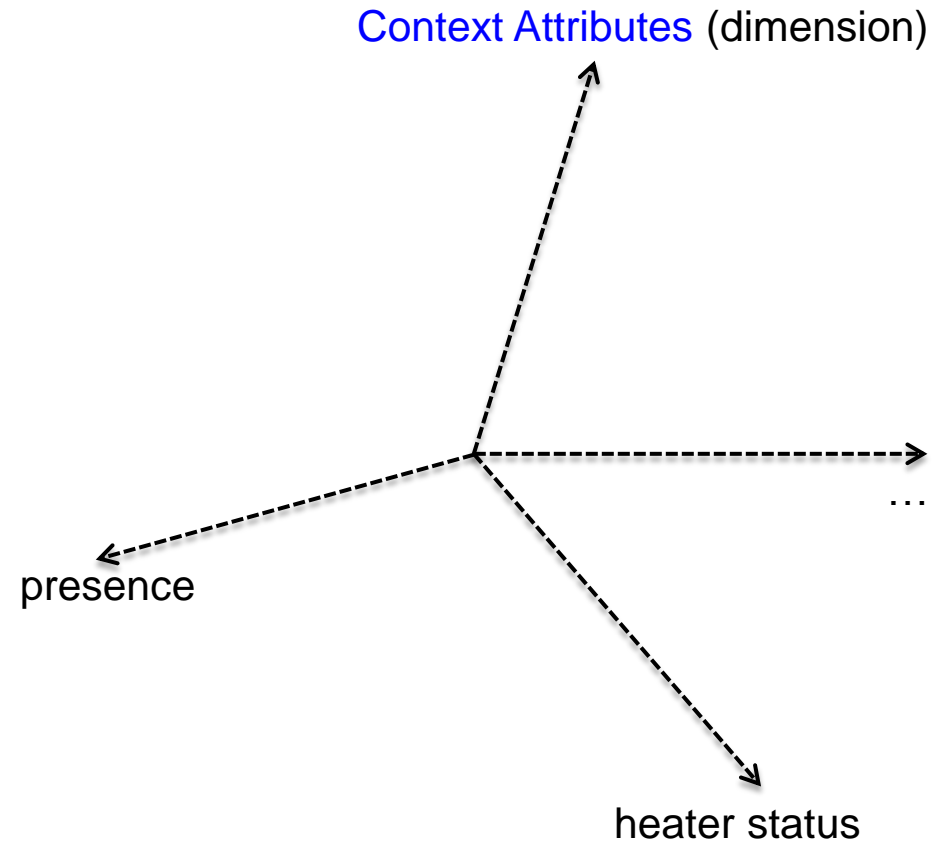


*Layered architecture suggested by J. Coutaz et al. in “Context is key”, 2005*

# Context and situation inference

## ► Context Spaces Theory

- Using geometrical metaphors to describe context and situations
- Input: *Context Attributes*
  - Presence, movement, equipment status, etc.

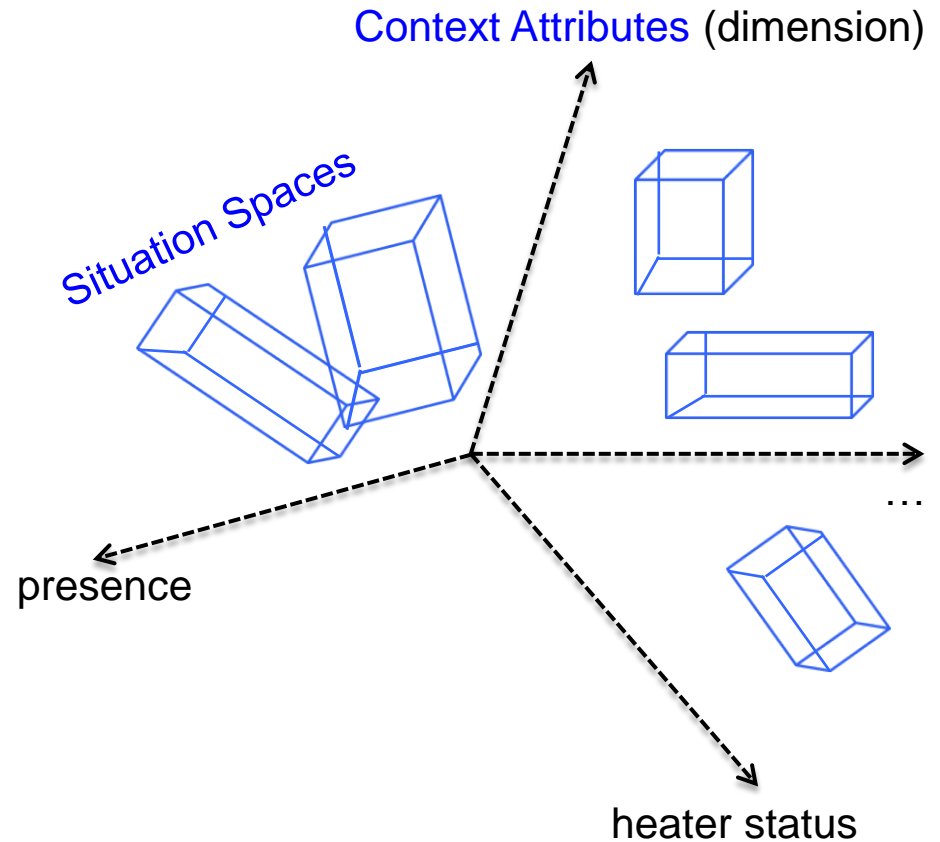




# Context and situation inference

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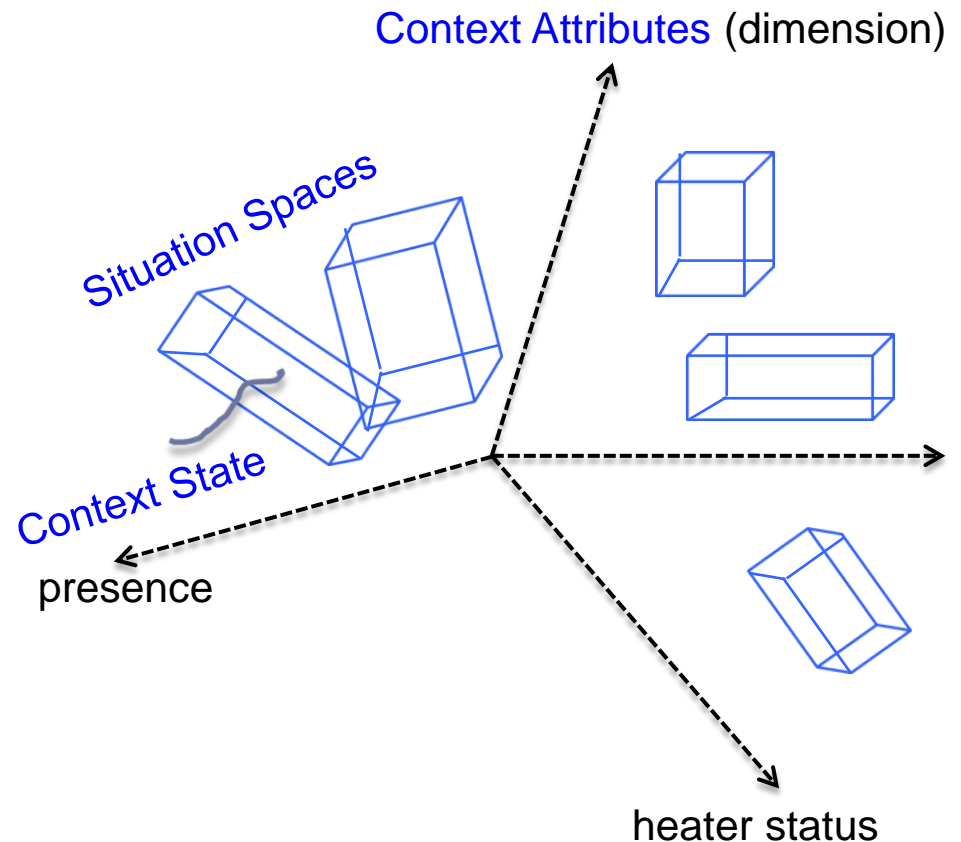
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  - Watching TV, ironing, etc.



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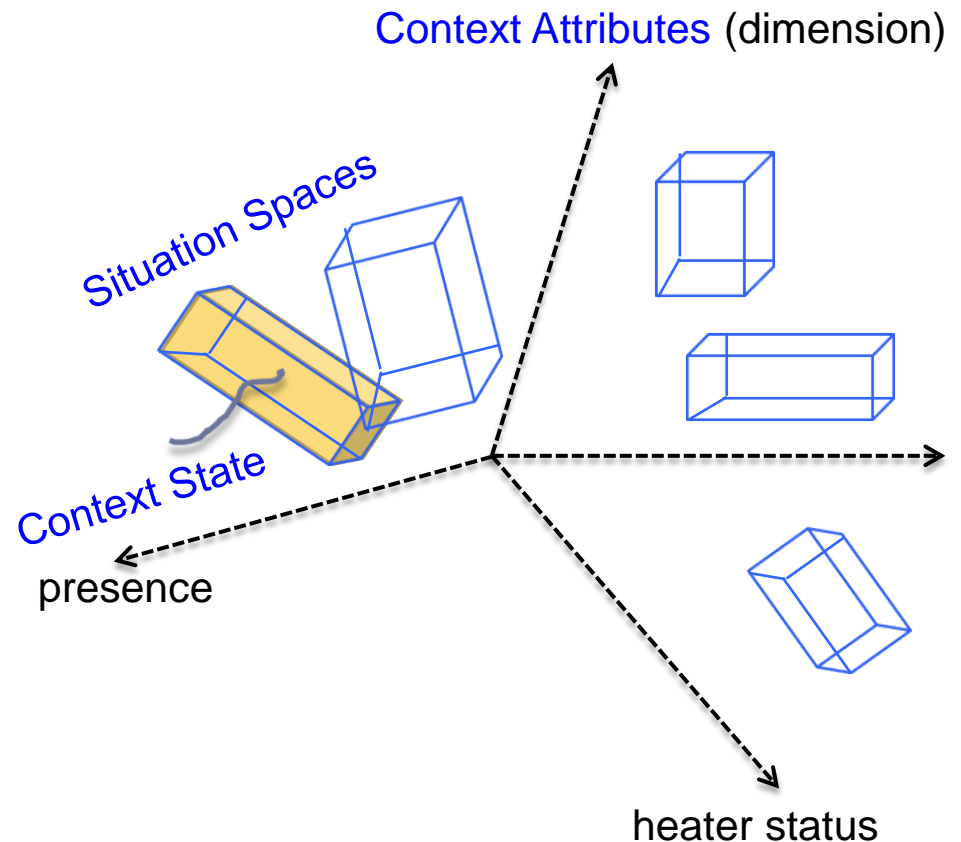
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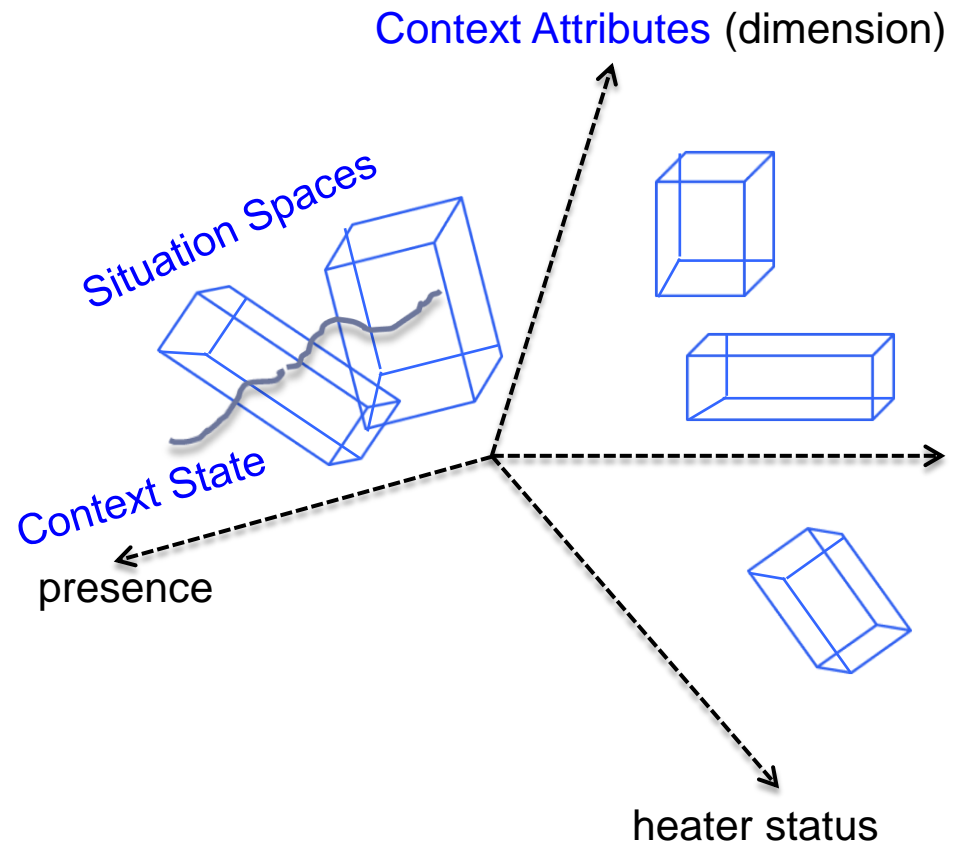
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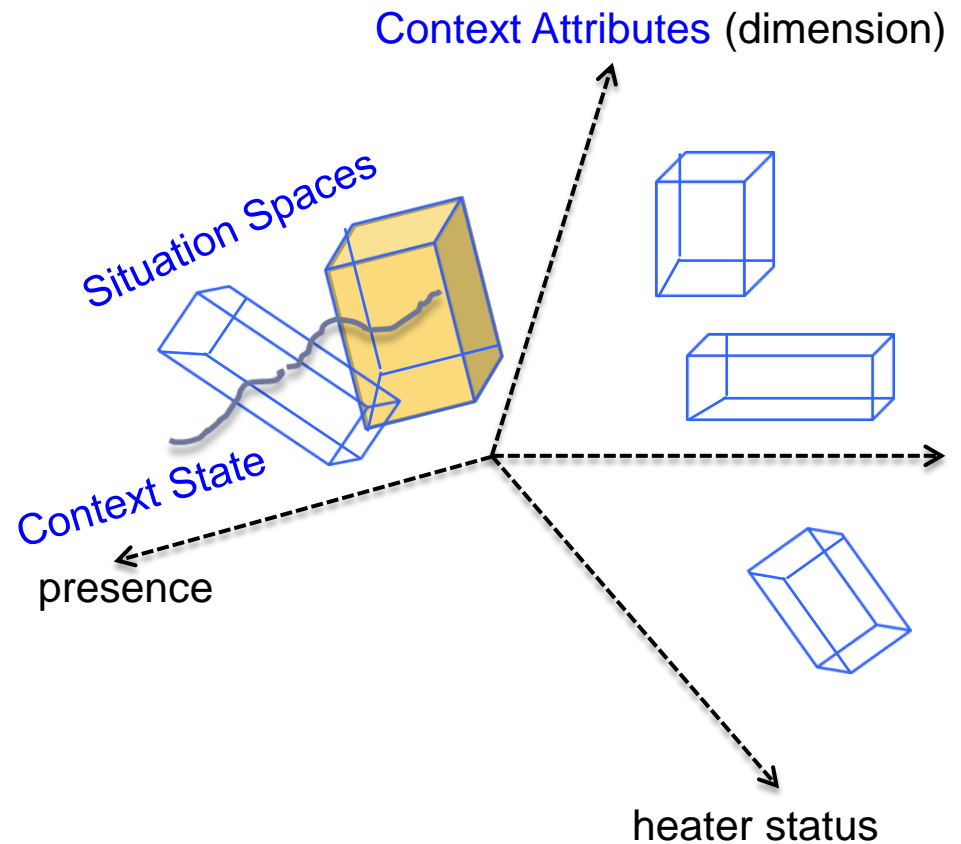
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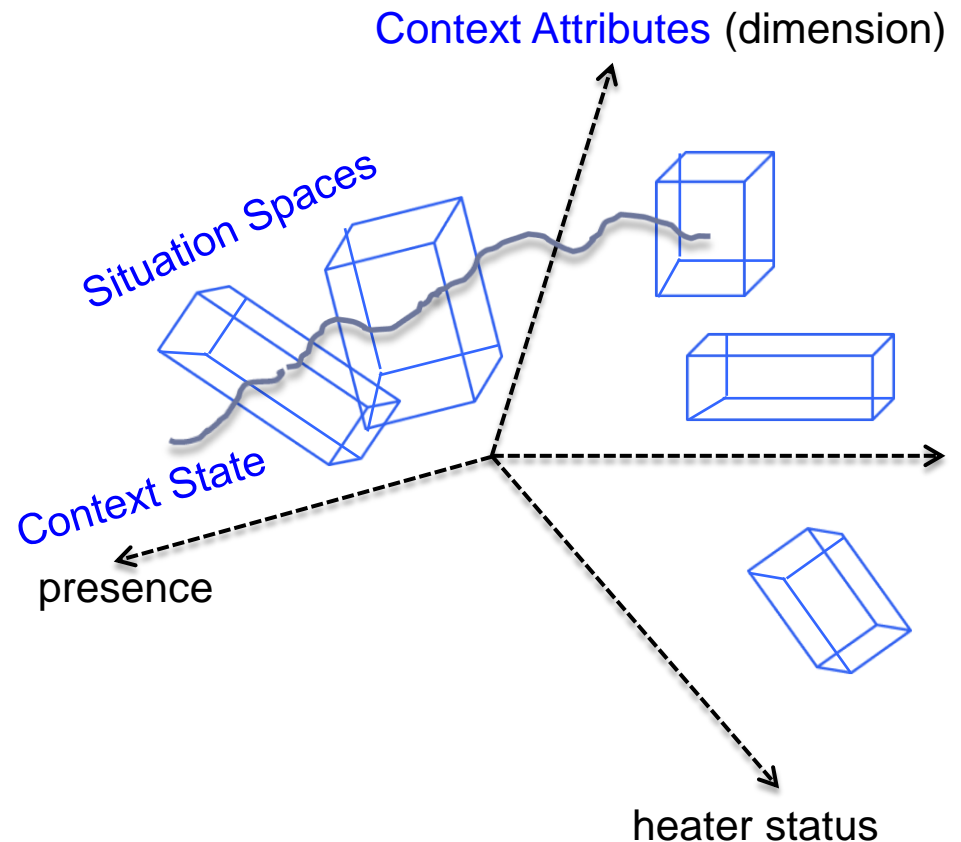
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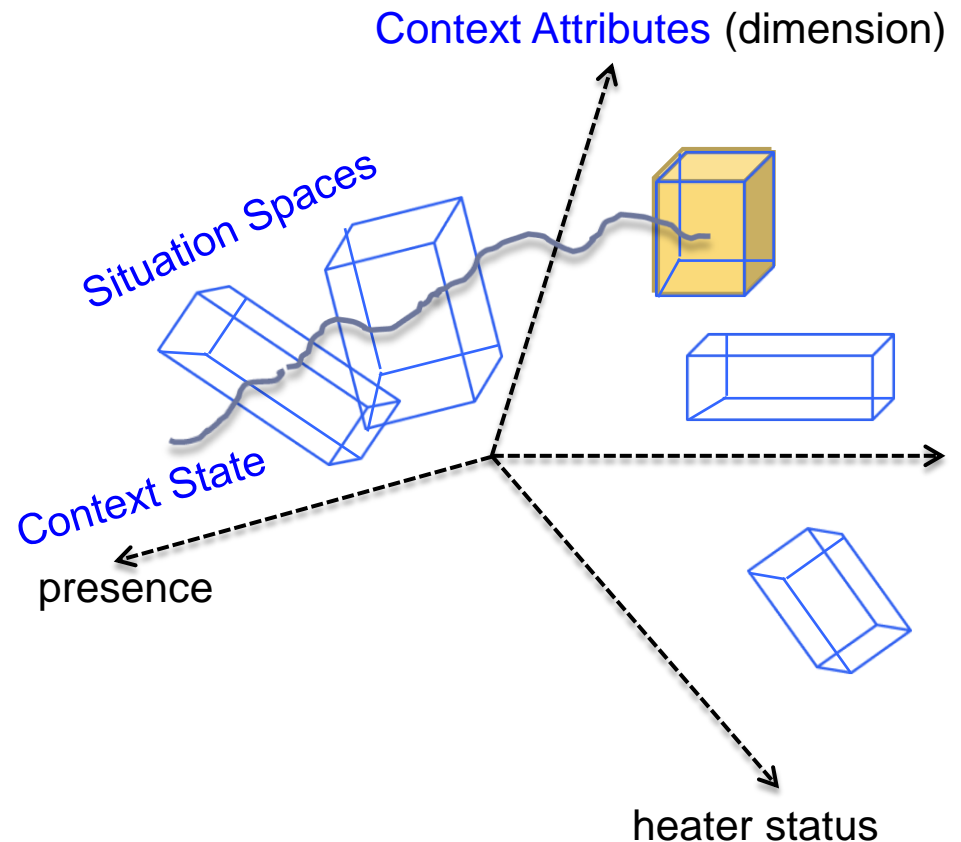
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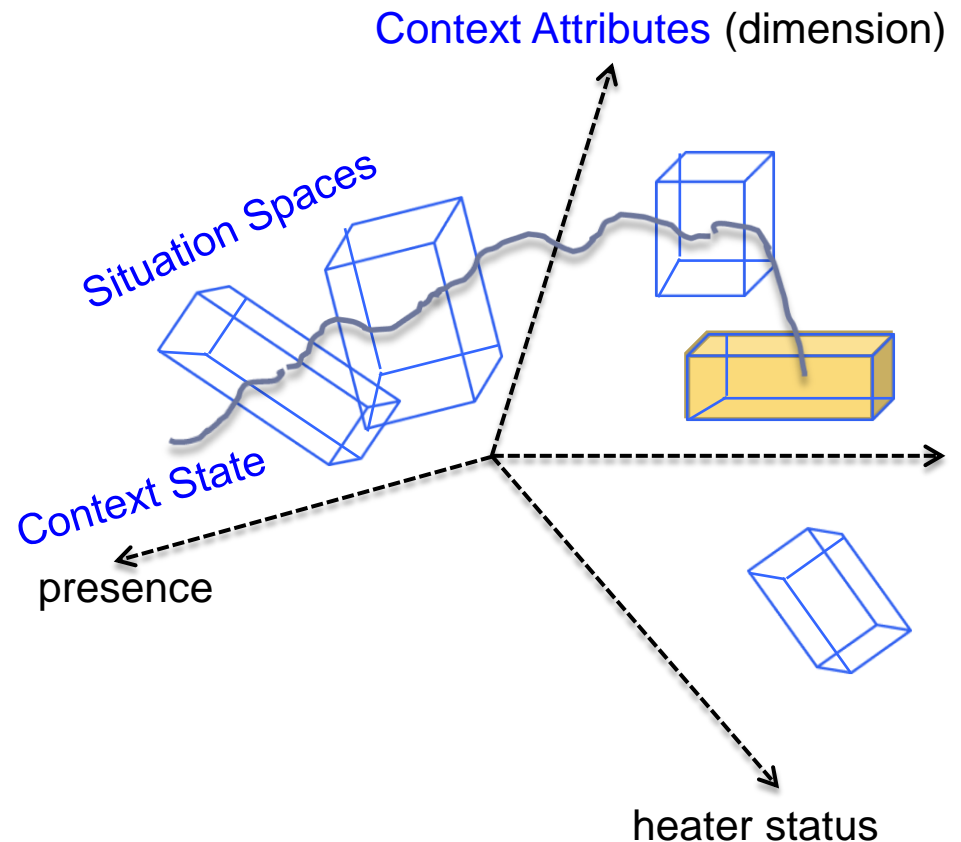
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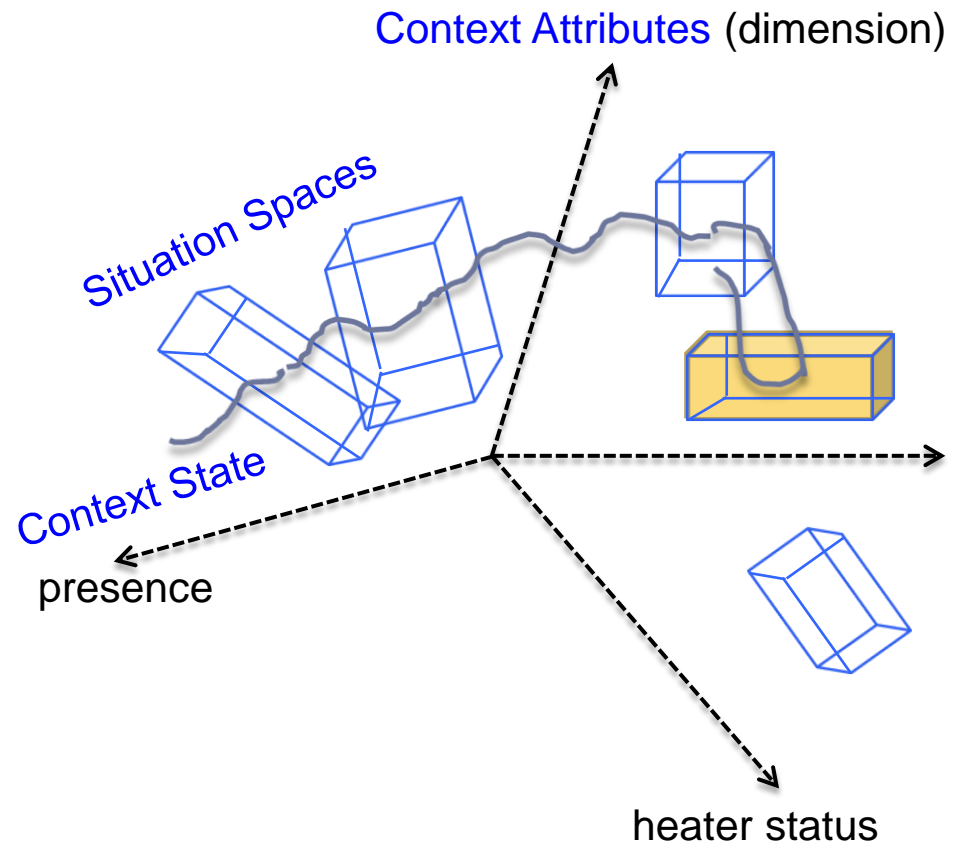




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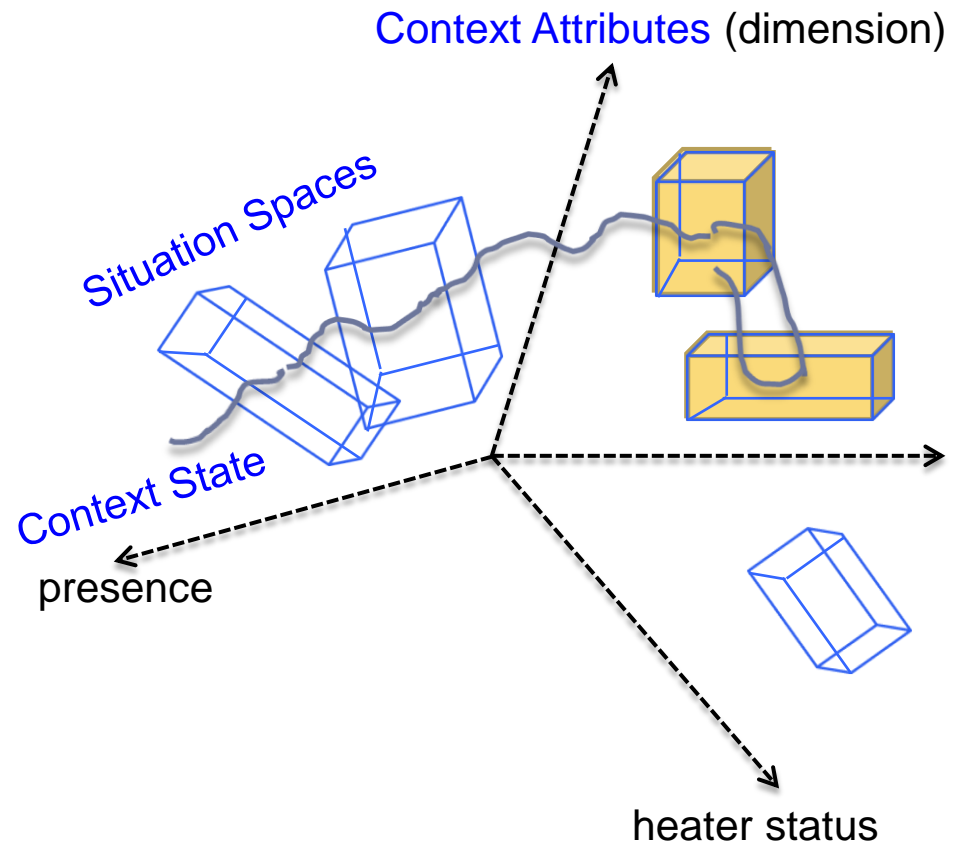
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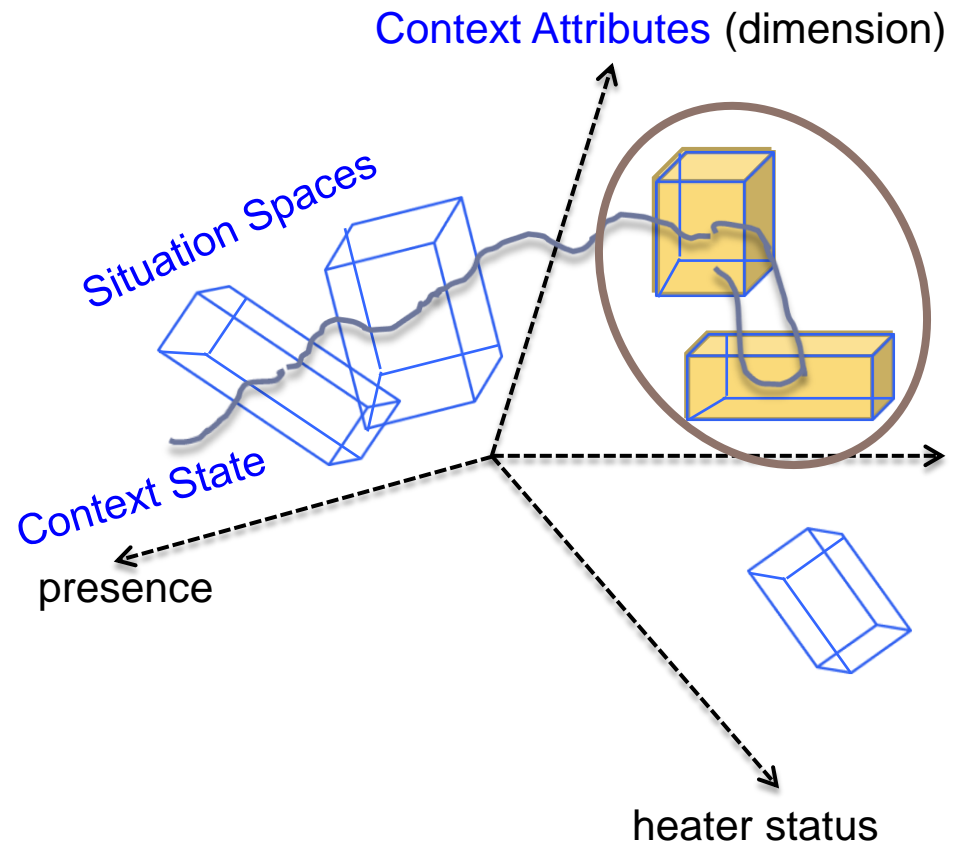
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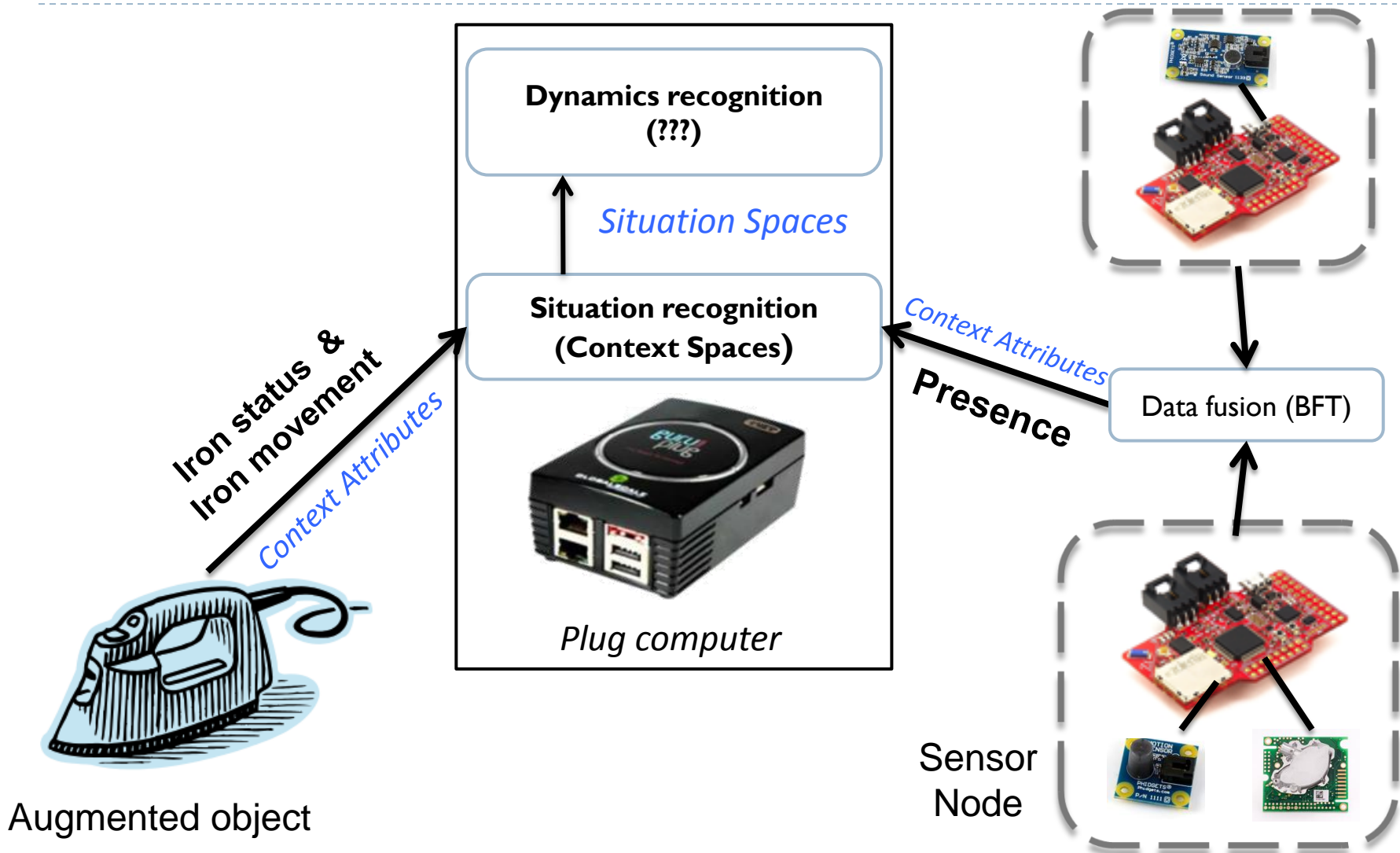


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# Overview of the architecture



# Activity VS Plan

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“The distinction to be made between activity recognition and plan recognition is the difference between recognizing a single (possibly complex) activity and recognizing the relationships between a set of such activities that result in a complete plan.”

C. W. Geib & R. P. Goldman

A probabilistic plan recognition algorithm based on plan tree grammars

*Artificial Intelligence*, **2009**, 173, 1101 - 1132

Either Activity or Plan... human stuff!

# Domestic... stuff

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- ▶ Opportunistic
- ▶ Involvement in multiple activities
- ▶ Asymmetrical relation between environment and activity
- ▶ Can't be strictly associated with a specific space
- ▶ Routines are just the recurrence of concerns, not the execution of schemes of action
- ▶ Individual and collective scales of activity are intertwined
  
- ▶ Can we talk about “plans”?



## Best-effort

No plan library can **entirely** model the complexity of real-world human activity

Provide **uncertainty** management and **take-over**

Use plan recognition techniques in a **feasibility-driven** way



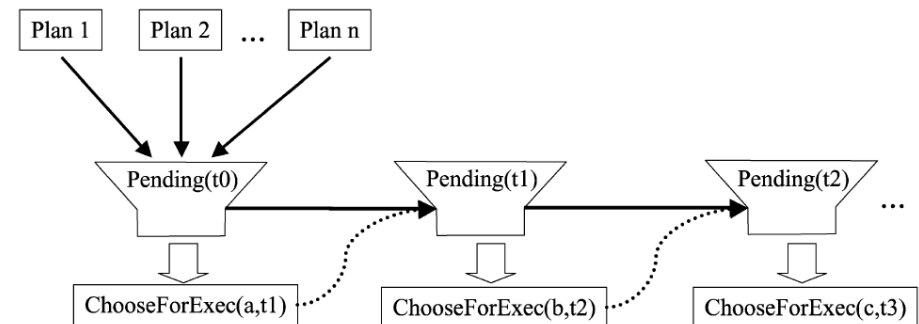
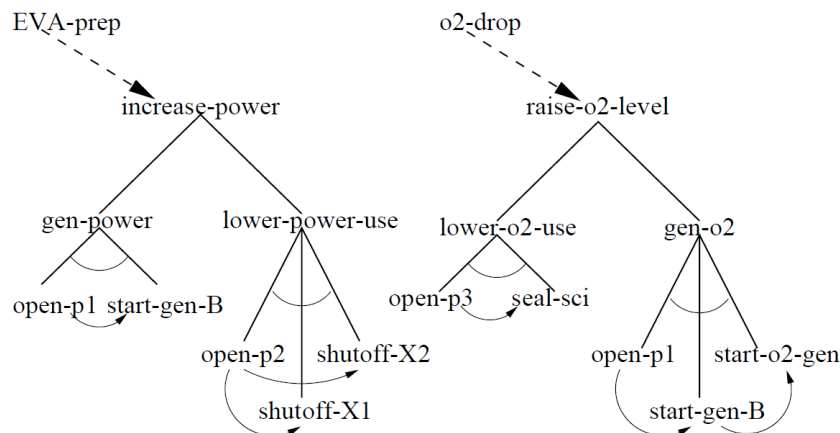
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# Plan recognition

- ▶ PHATT (Probabilistic Hostile Agent Task Tracker)
  - ▶ Introduced by R. P. Goldman, C.W. Geib & C.A. Miller
- ▶ Given a sequence of observations, abductively build the possible explanations and calculate probabilities
  - ▶ HTN-like plan library + model of plan execution



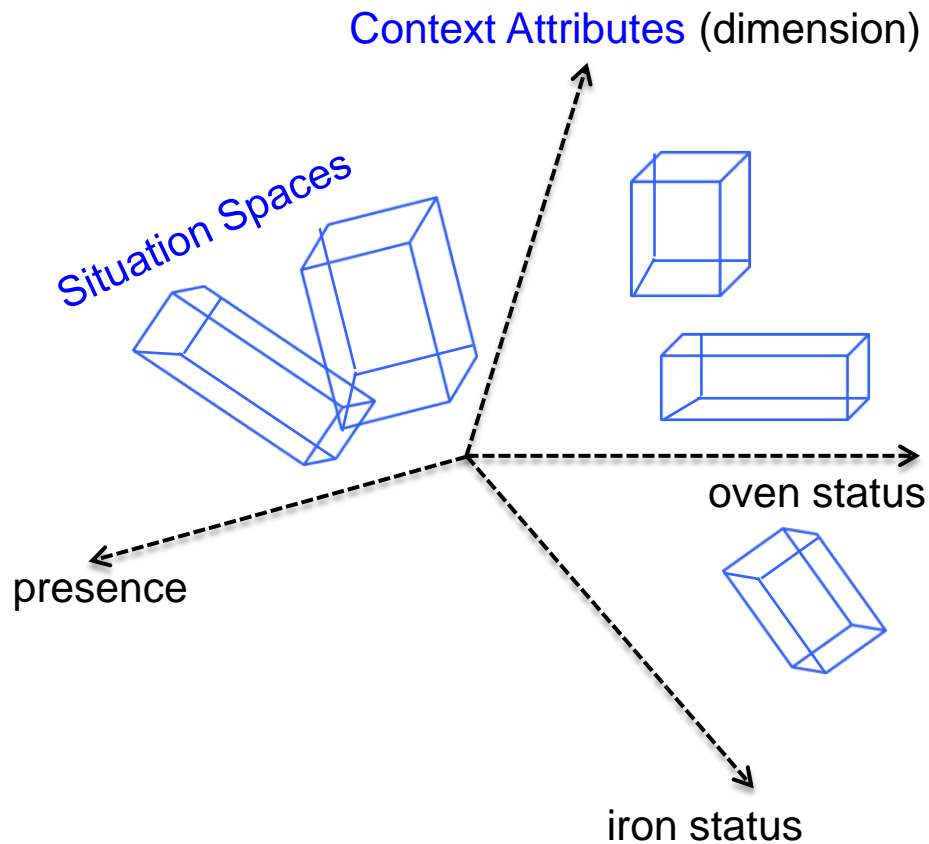
# Advantages of PHATT

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- ▶ Multiple-goal recognition
  - ▶ Opportunistic, multiple activities
- ▶ *Overloaded*-action modeling
  - ▶ Concurrent activities
- ▶ Partial ordering in task modeling
  - ▶ Irregularities of routines
- ▶ *State-of-the-world* influence on goal probabilities
  - ▶ Appliance status, emerging patterns
- ▶ *For-own-sake* tasks
  - ▶ Filtering out “noise”
- ▶ Unobserved-actions inference
  - ▶ Flexibility, feedback

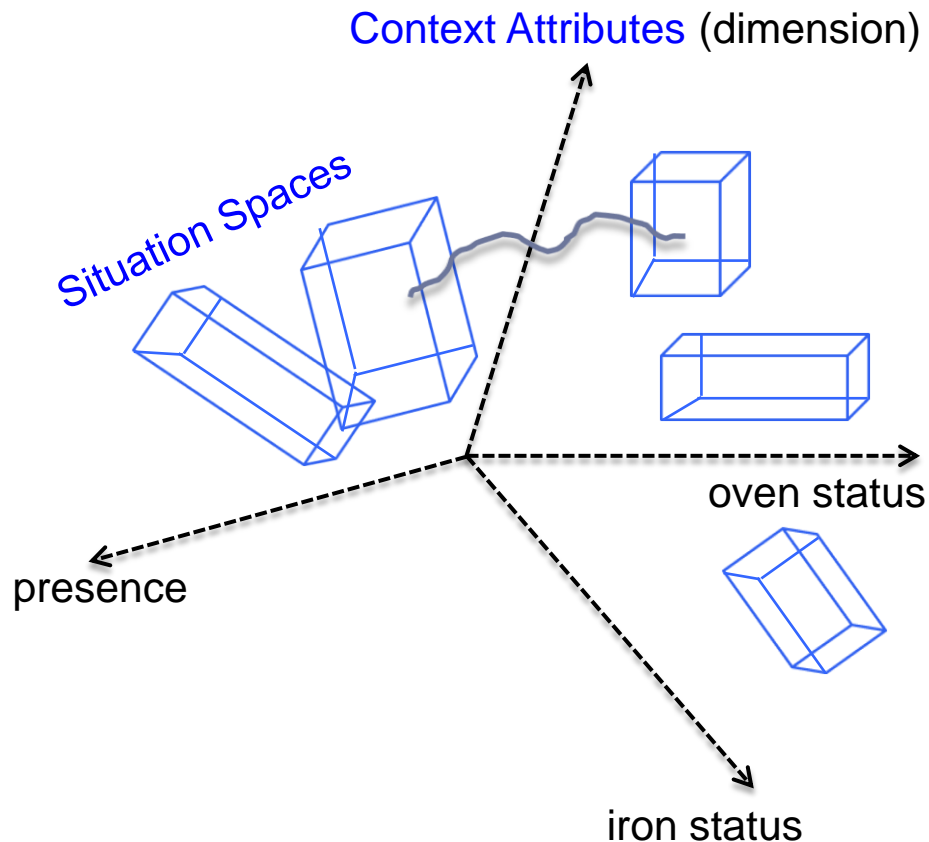
# Dynamics recognition

## ► Input to PHATT: Situation Spaces



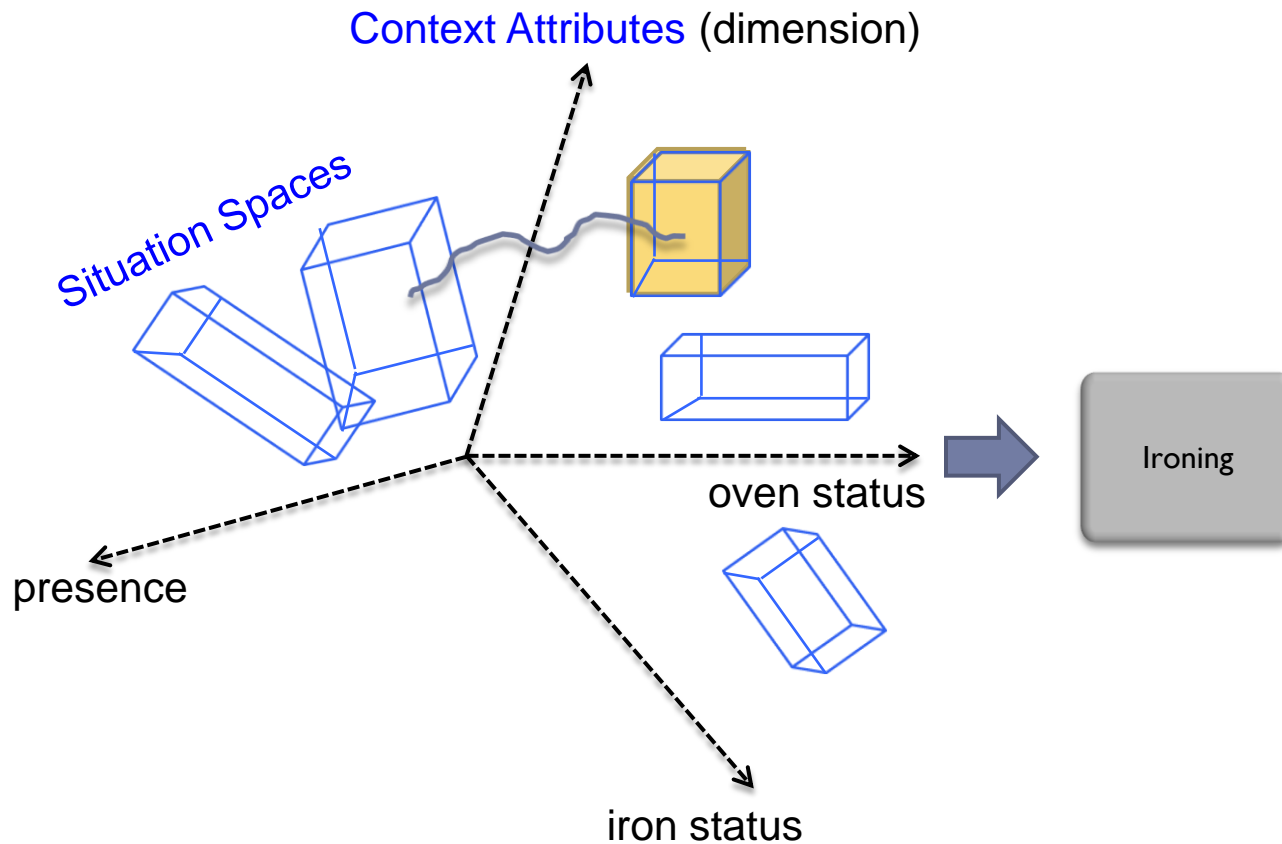
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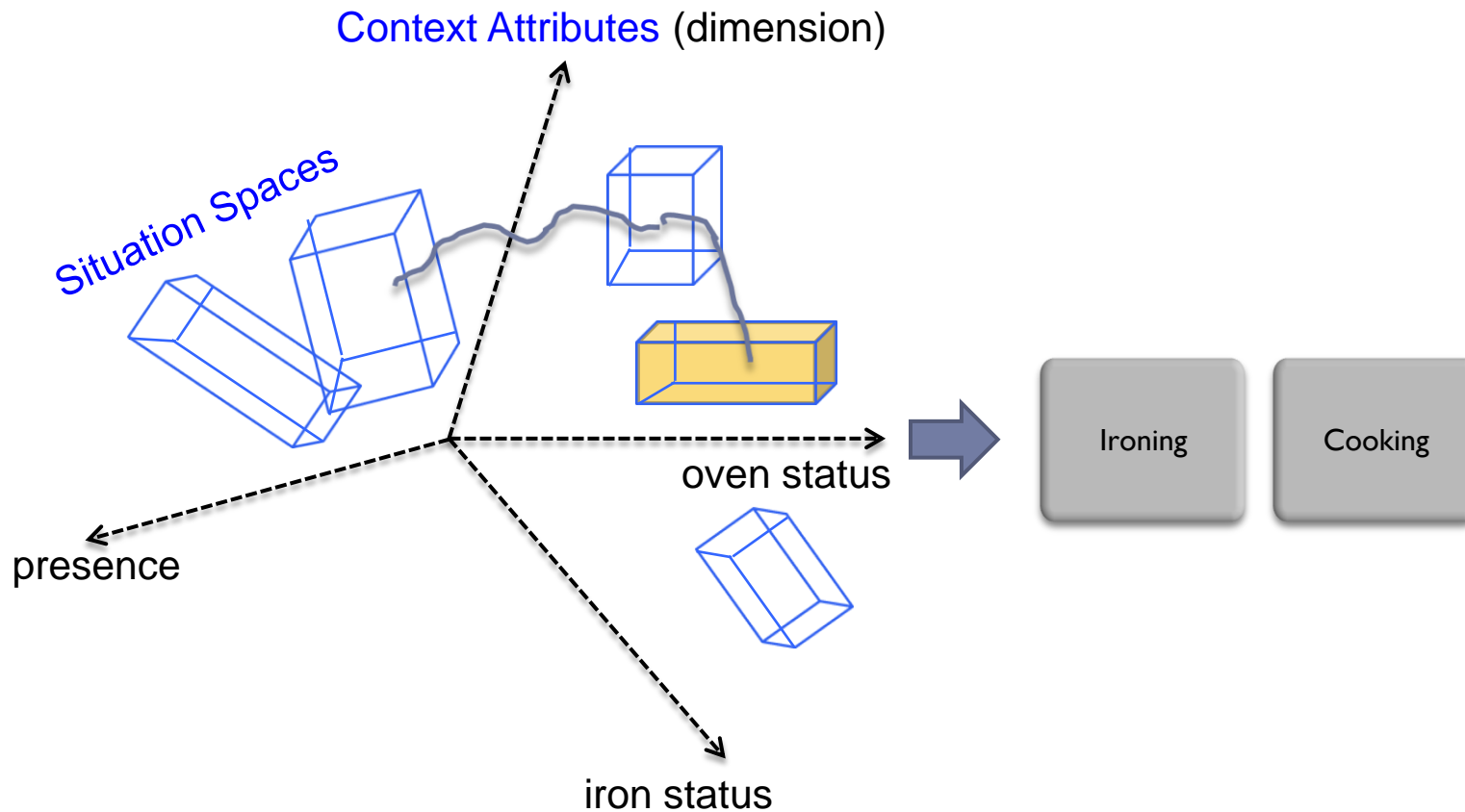
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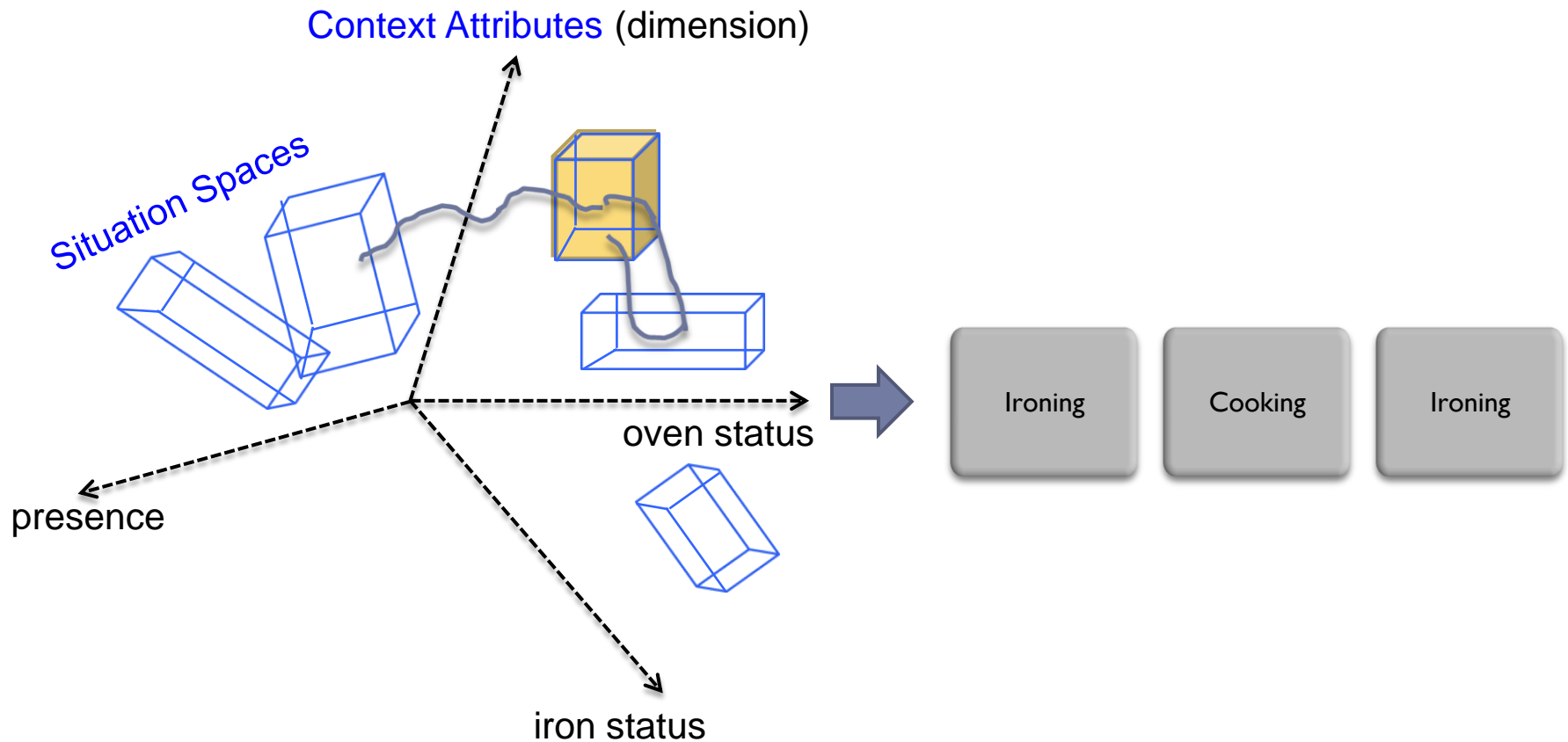
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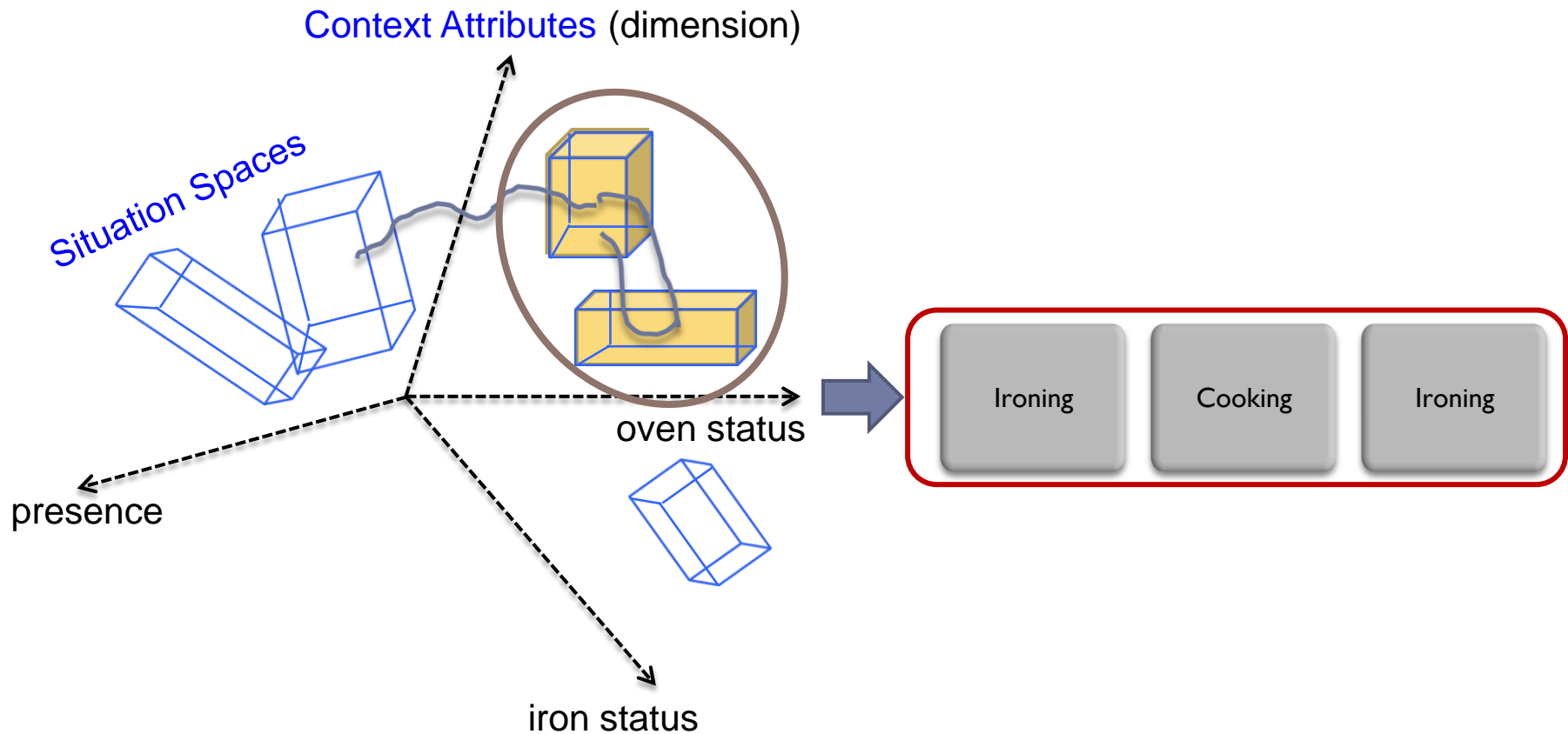
## ► Input to PHATT: Situation Spaces





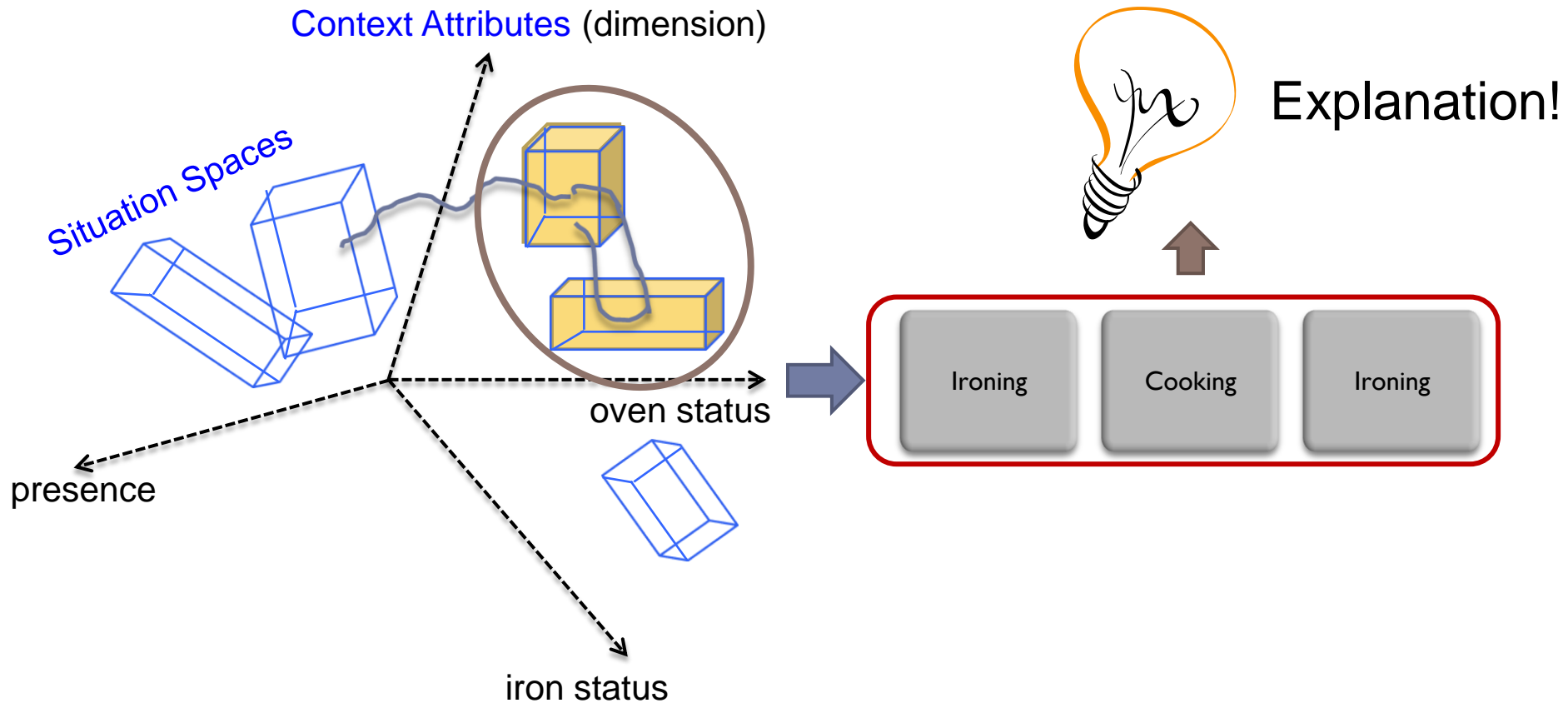
# Dynamics recognition

## ► Input to PHATT: Situation Spaces



# Dynamics recognition

## ► Input to PHATT: Situation Spaces



# Risk assessment – PHATT

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- ▶ Computational complexity and performances
  - ▶ *YAPPR* – an optimized algorithm based on string rewriting
- ▶ HTN modeling may be rigid
  - ▶ *YAPPR* introduced looping and optional actions
- ▶ Needs prior probabilities
  - ▶ Probabilities of goals and heuristics can compensate
- ▶ Goals are not predetermined (opportunistic activity)
  - ▶ Remove *Backpatching*

# Open issues

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- ▶ Implementing!
- ▶ Handling uncertainty
  - ▶ Input: Situation Spaces with *confidence* value
- ▶ Assessing uncertainty and provide feedback
  - ▶ Explanations' probabilities can help
- ▶ Modeling time
- ▶ Modeling collective activities

# Thank you for your attention!

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► Questions?

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France

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# Bibliography

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- ▶ Goldman, R. P.; Geib, C. W. & Miller, C. A.  
A New Model of Plan Recognition  
*Artificial Intelligence*, **1999**, 64, 53-79
- ▶ C. W. Geib & R. P. Goldman  
A probabilistic plan recognition algorithm based  
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# Existing activity recognition approaches

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- ▶ Machine learning techniques
  - ▶ E.g., artificial neural networks
  - ▶ Need big **training** sets, have **overfitting** issues
- ▶ Probabilistic and statistical models
  - ▶ E.g., Hidden Markov Models, Bayesian networks
  - ▶ Difficult to define **probabilities**
- ▶ Logic-based systems
  - ▶ E.g., ontologies
  - ▶ Lack **uncertainty** management, static

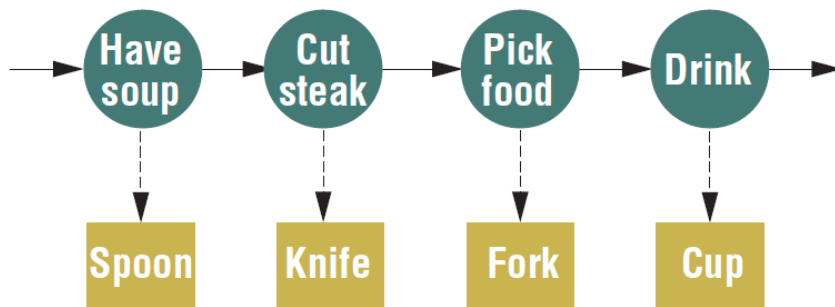
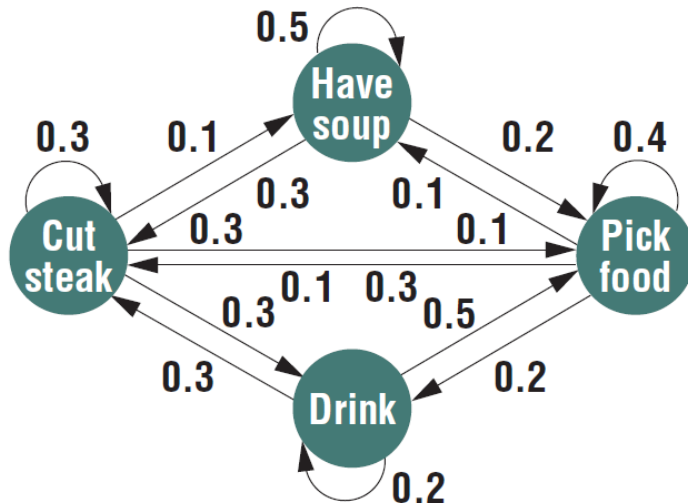


# Existing activity recognition approaches

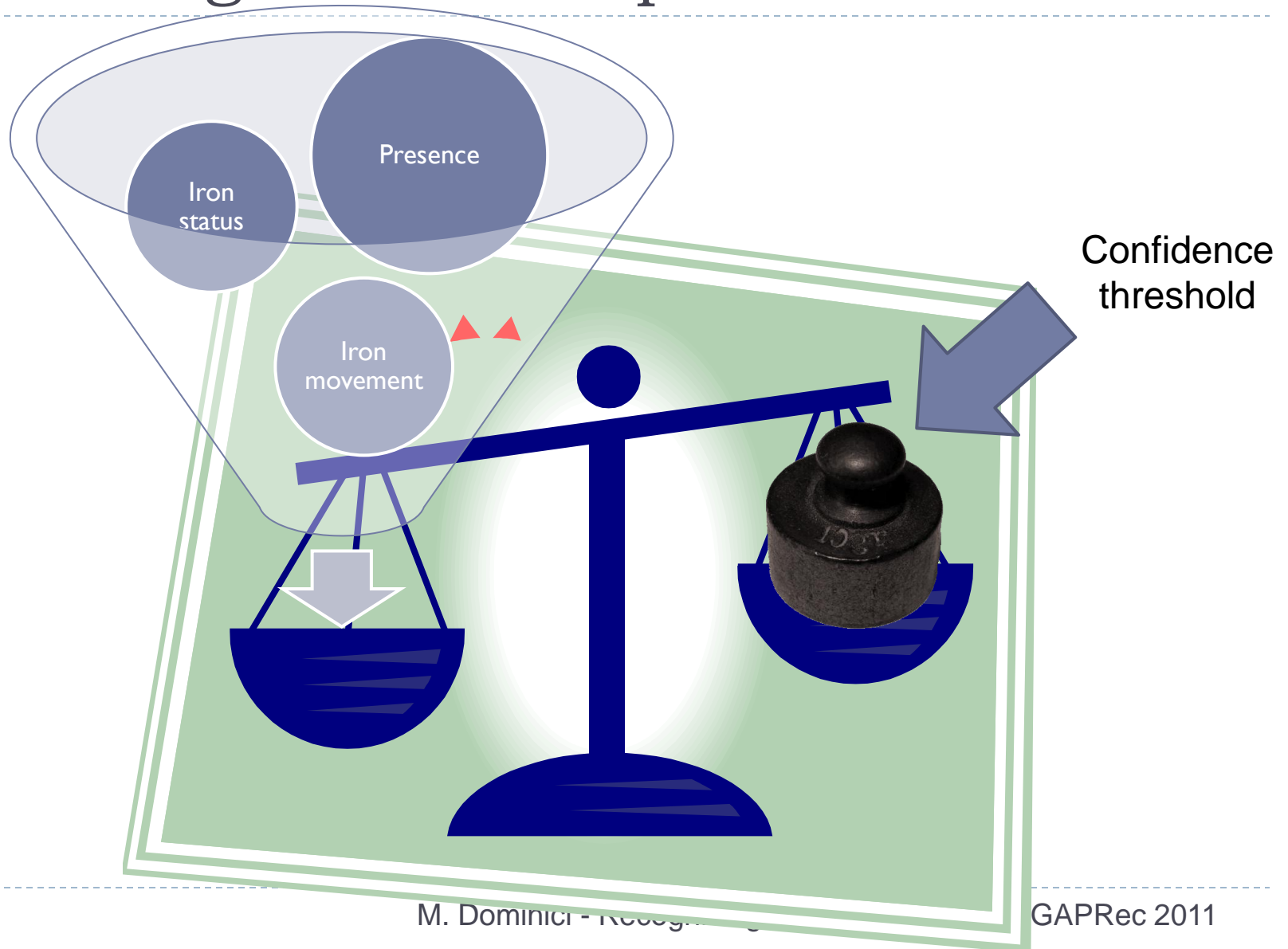
## Hidden Markov Model

*Kim et al.*

*"Human Activity Recognition and  
Pattern Discovery"*  
*IEEE Pervasive Computing, vol. 9,  
2010*



# Occurring Situation Spaces

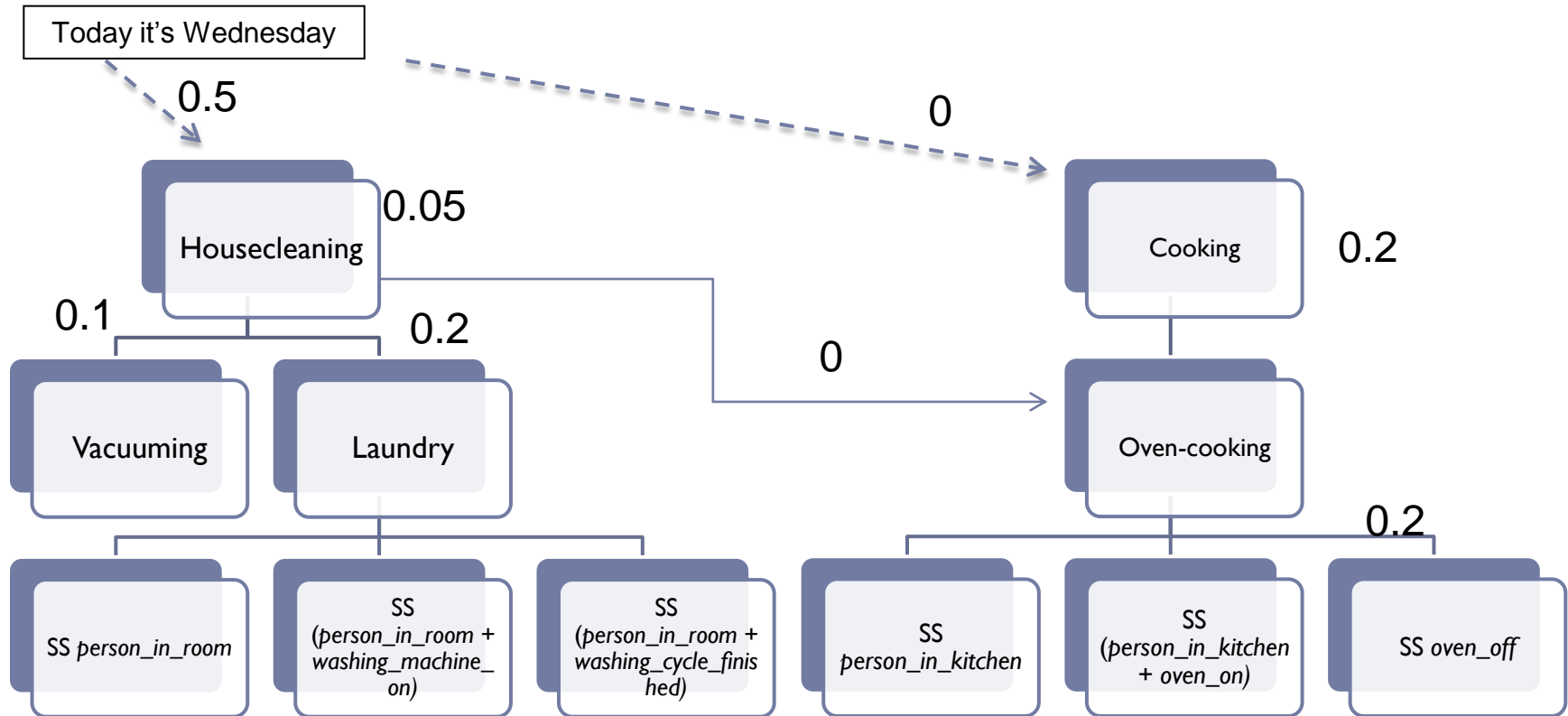


# Advantages of PHATT

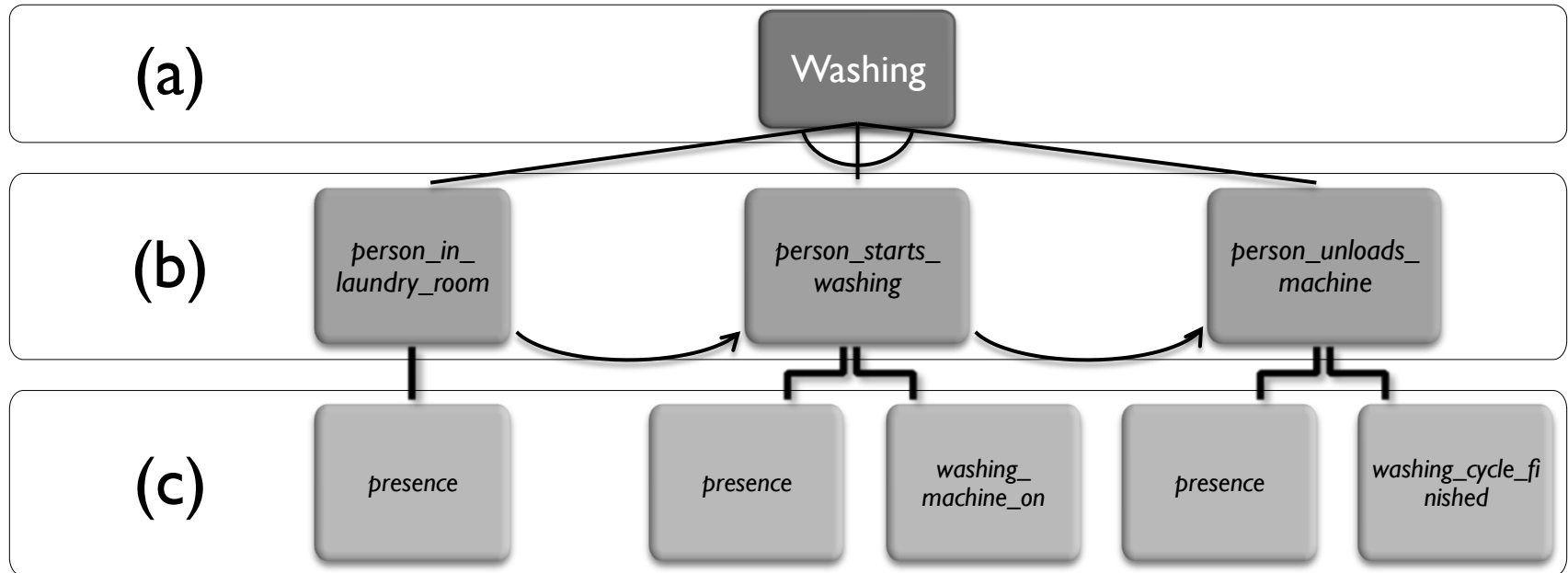
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- ▶ Combines the “explanation” capabilities with the intelligibility of HTN modeling
- ▶ Allows specifying probabilities of sets of tasks (*goals* and *methods*)
- ▶ Can be combined with machine learning techniques without relying on them

# Advanced aspects of PHATT

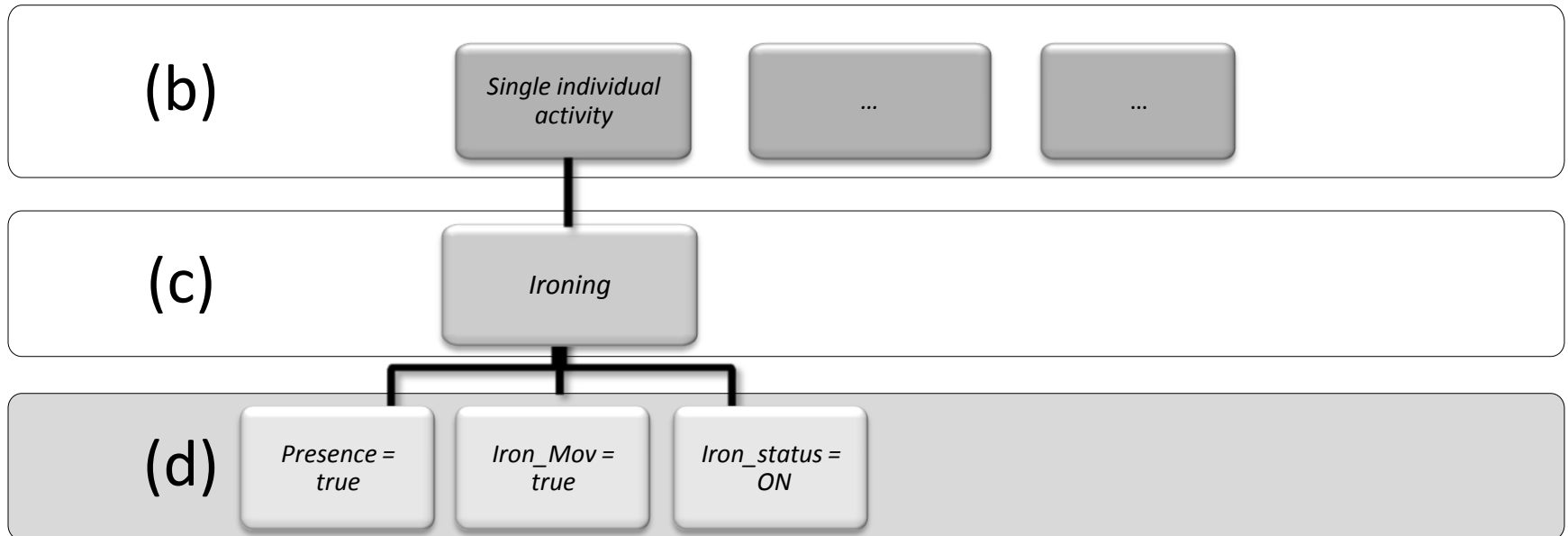


# Modeling



# Modeling

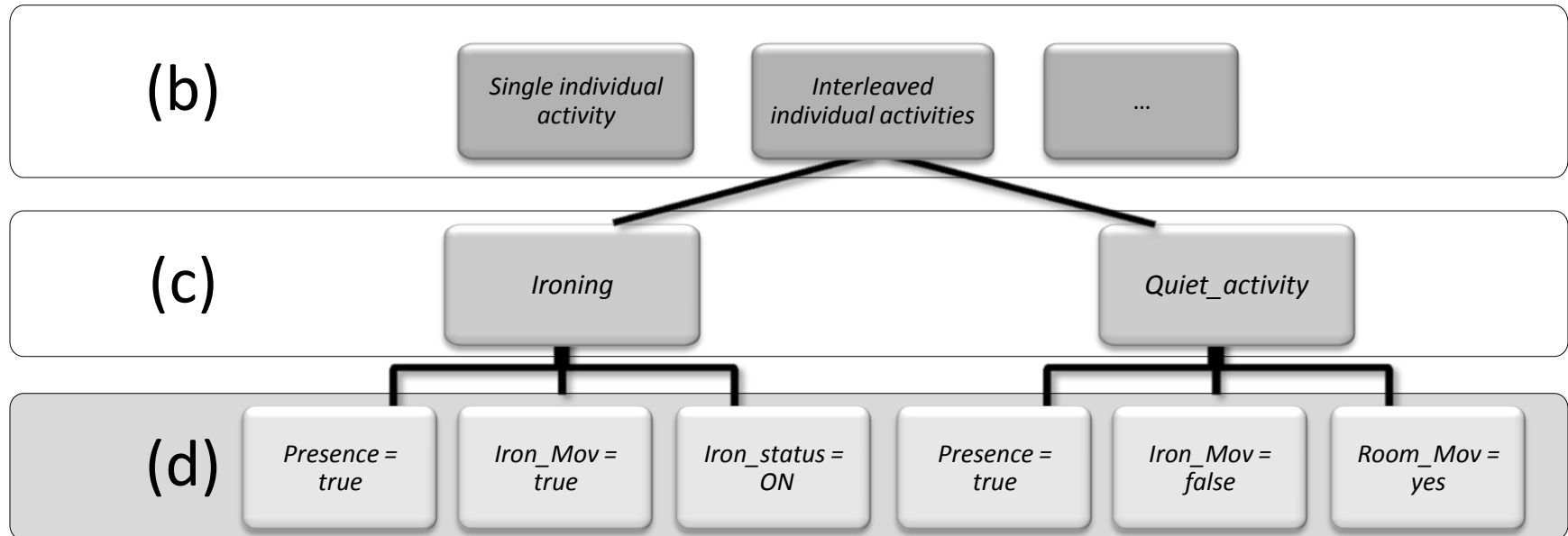
## Single individual activity (SIA)



(b): Method of PHATT - (c): Situation Spaces  
(d): Context Attributes

# Modeling

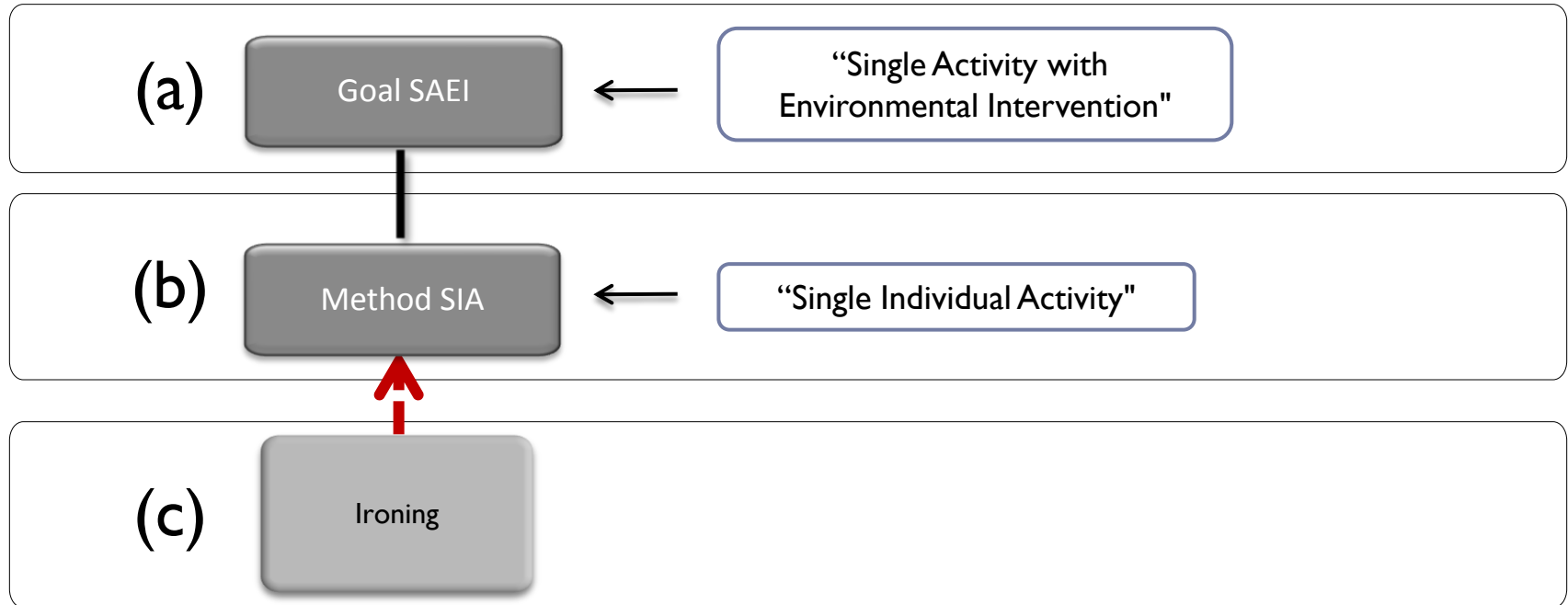
## Interleaved individual activities (IIA)



(b): Method of PHATT - (c): Situation Spaces  
(d): Context Attributes

# Execution

## Single Individual Activity

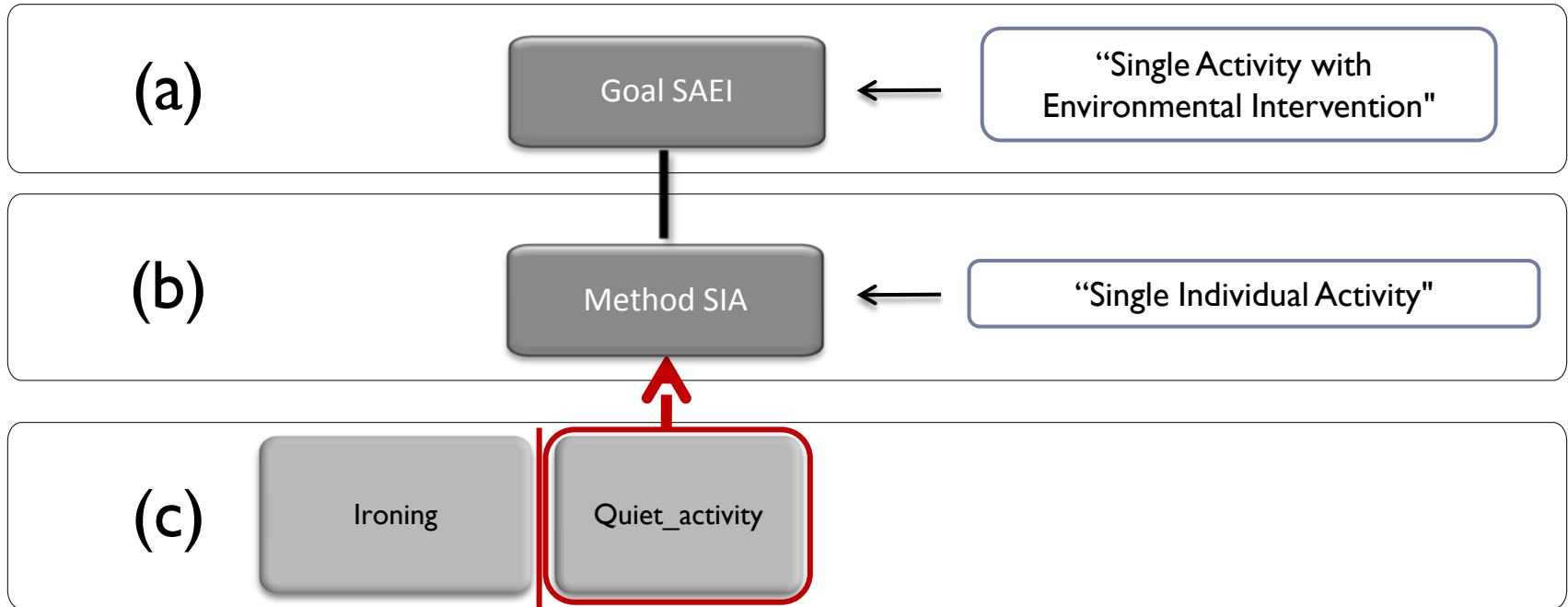


(a): Goals - (b): Methods - (c): Input to PHATT



# Execution

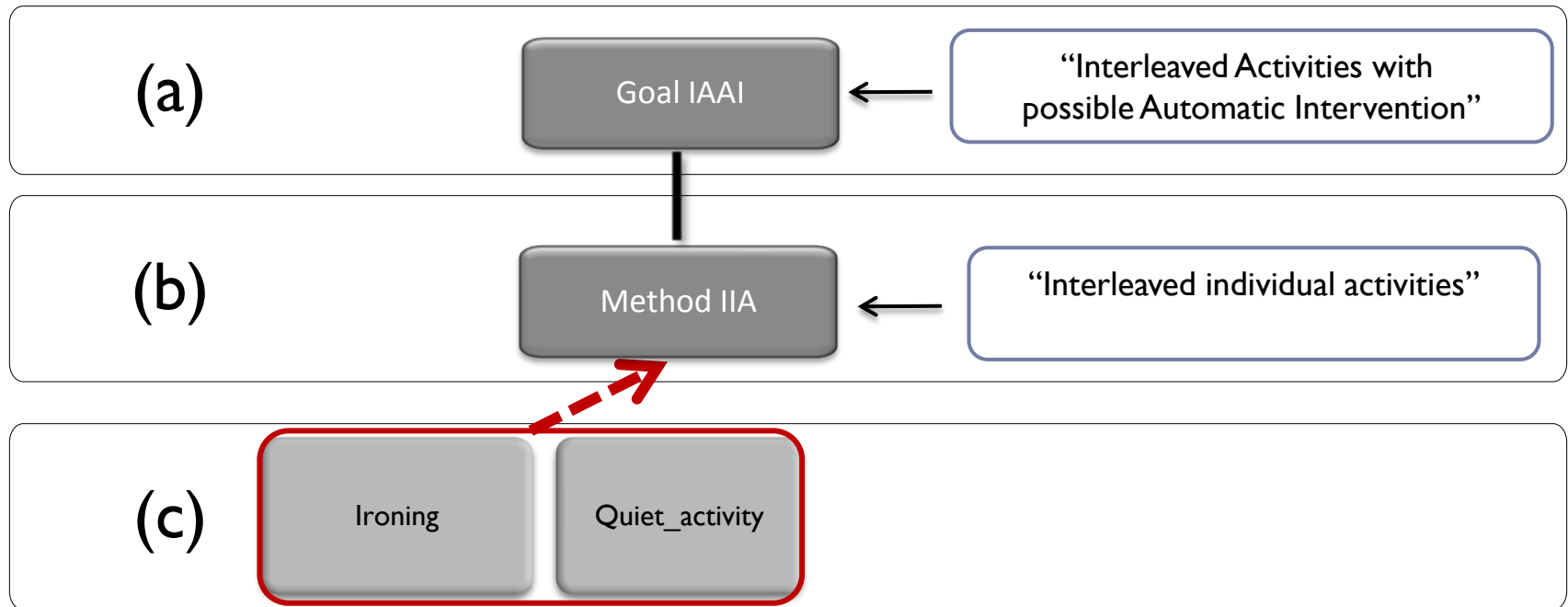
## Choice 1: Single Individual Activity



(a): Goals - (b): Methods - (c): Input to PHATT

# Execution

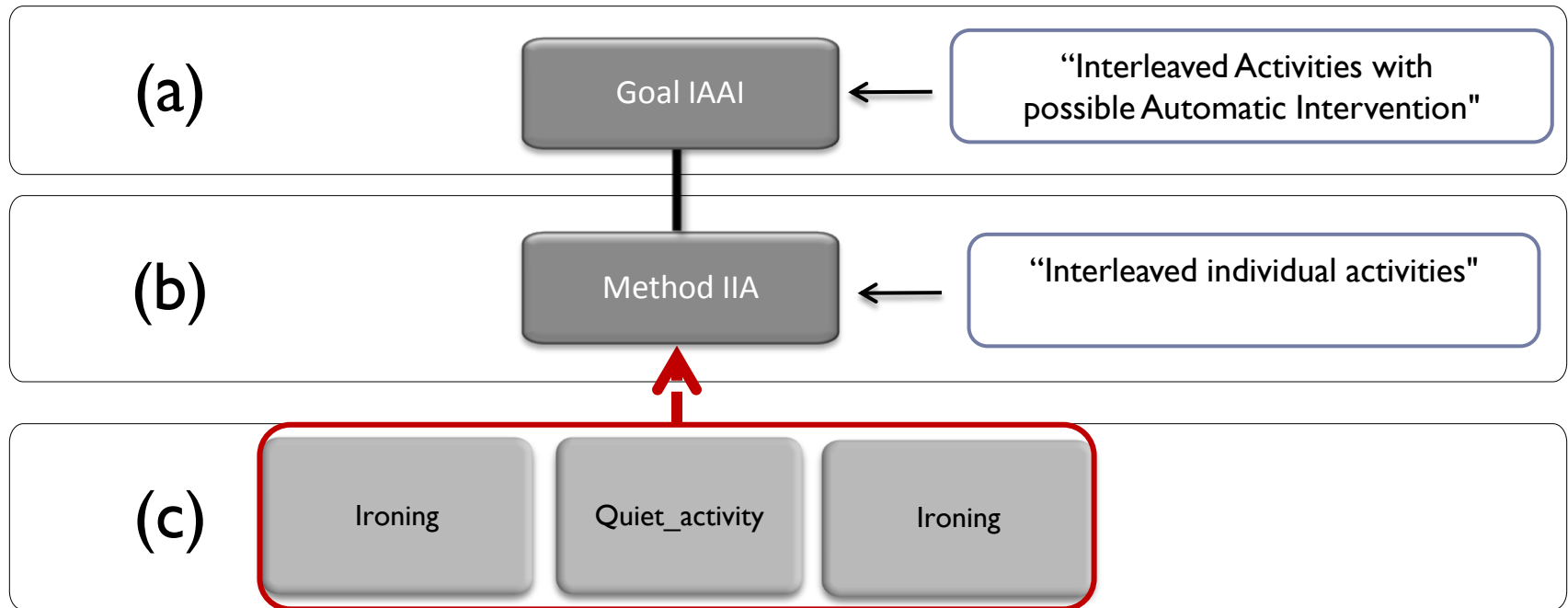
## Choice 2: Interleaved individual activities (IIA)



(a): Goals - (b): Methods - (c): Input to PHATT

# Execution

## Interleaved individual activities (IIA)



(a): Goals - (b): Methods - (c): Input to PHATT

# Exploitation (2)

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In a different scenario where different rooms are involved, e.g., the kitchen...

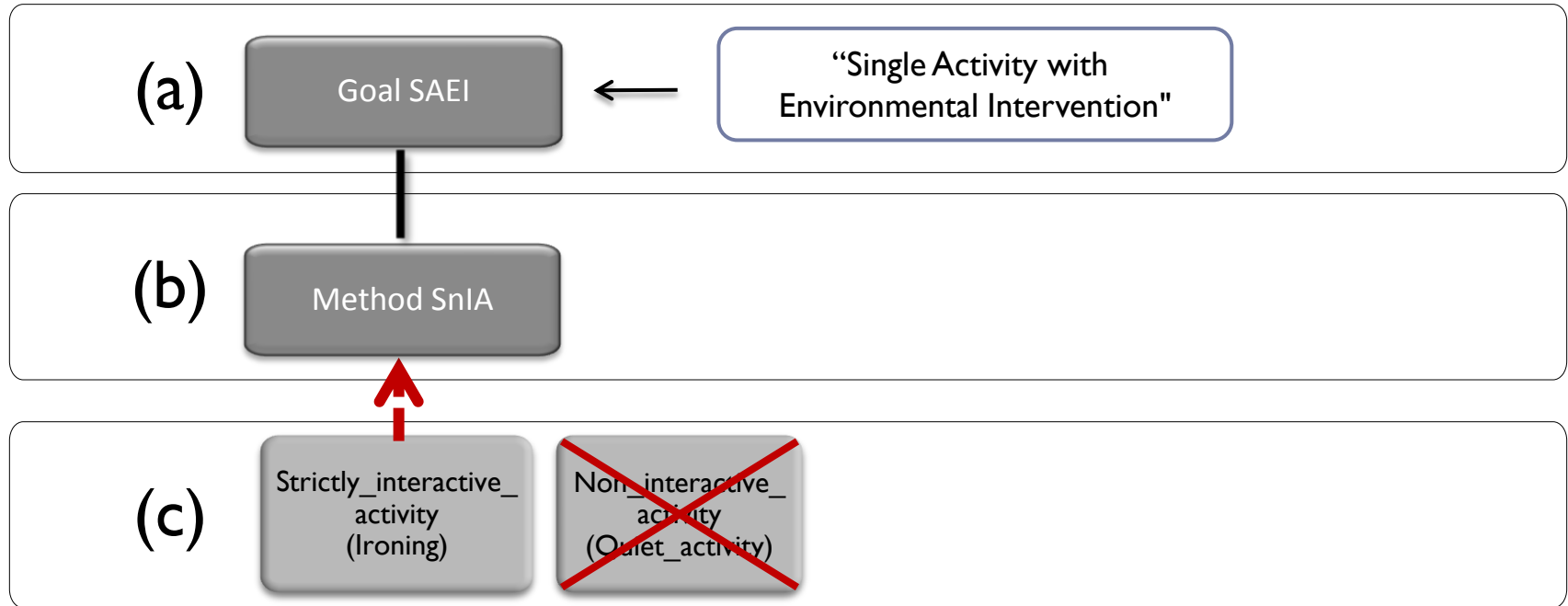
## Kitchen heater

**Knows:** *Interleaved Activities with possible Automatic Intervention*

**Does:** Stay on (comfort temperature)

# Execution

Action for its own sake



(a): Dynamic activity - (b): Methods - (c): Input to PHATT

# Exploitation

---

## Iron

**Knows:** *Interleaved Activities with possible Automatic Intervention*

**Does:** Reduce temperature when not in use

**Knows:** *Single Activity with Environmental Intervention*

**Does:** Turn off when not in use

# Interleaved group activities

(a)

Interleaved  
group activities

(b)

Method 1

Method 2

Method 3

(c)

*Group watching  
TV  
&  
Kitchen Activity*

*Group watching  
TV*

# Exploitation

---

## Kitchen light

**Knows:** *Interleaved group activities INVOLVING  
SS Kitchen Activity*

**Does:** Turn off when CA *Presence* is false

## Kitchen heater

**Knows:** *Interleaved group activity INVOLVING  
SS Kitchen Activity*

**Does:** Stay on (comfort temperature)

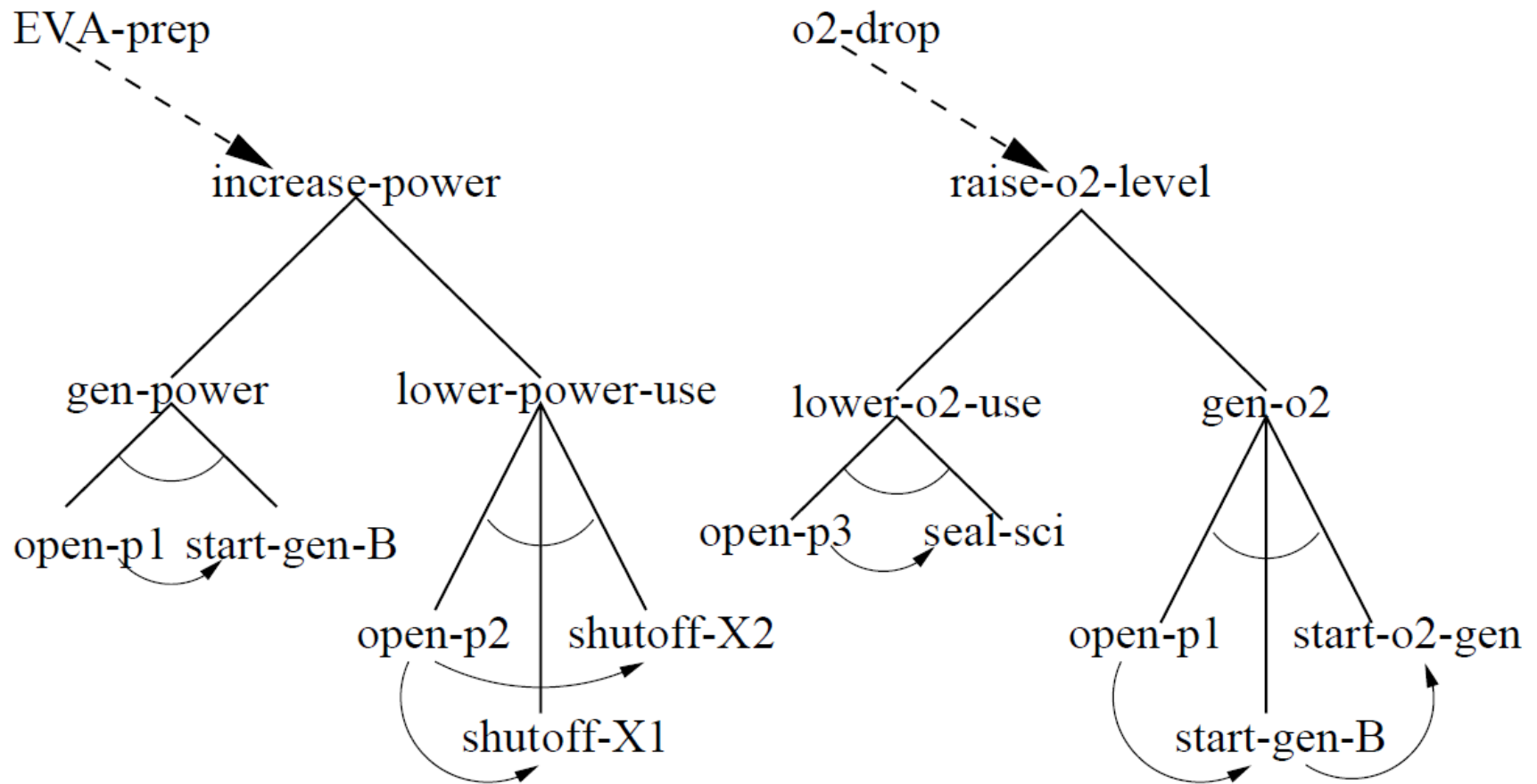
## TV

**Knows:** *Interleaved group activity INVOLVING  
SS Watching TV*

**Does:** Stay on



# OR/AND tree



# Model of plan execution

