Generalizing Multi-Context Systems for Reactive Stream Reasoning Applications[1]

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UNIVERSITÄT LEIPZIG

[1] Funded by the DFG (project FOR 1513)

Outline

Assisted Living (AL)

An Application for Artificial Intelligence

The Basic Idea

- Enhance an appartment with an AI which monitors the activities of daily living of the inhabitants.

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- Coordinate services by outside health care providers.

Assisted Living (AL)

An Application for Artificial Intelligence

The Basic Idea

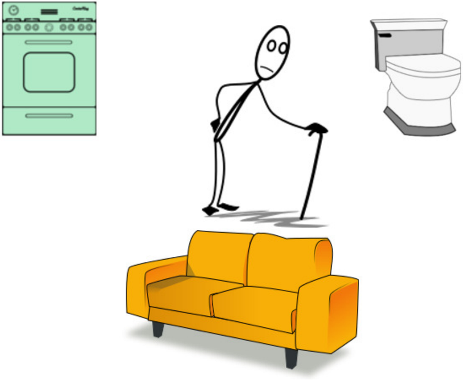
- Enhance an appartment with an AI which monitors the activities of daily living of the inhabitants.
- Coordinate services by outside health care providers.
- Provide supervision and assistance to ensure the inhabitants
  - health,
  - safety, and
  - well-being.

Assisted Living

An Example of AL in Action

Assisted Living

An Example of AL in Action



Assisted Living

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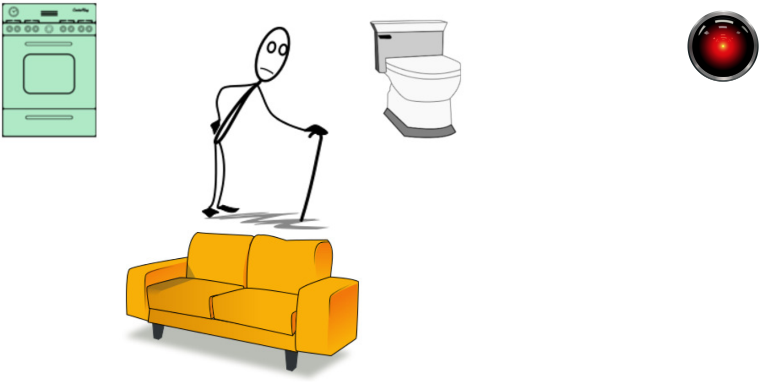

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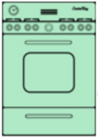

What shall the AI believe?

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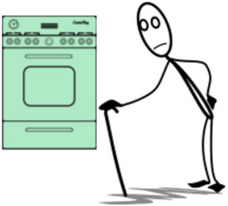

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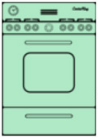

What shall the AI believe?

- The stove is active
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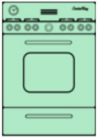

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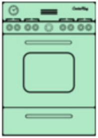

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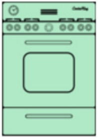

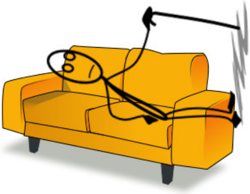

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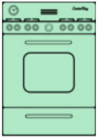

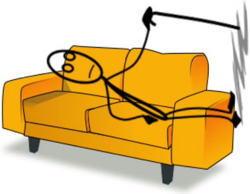

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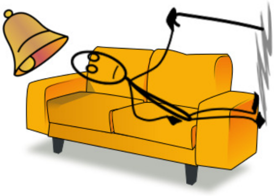

What shall the AI believe?

- The stove is active
- Bob is cooking
- Bob is on the toilet
- Bob is sleeping
- Unwanted situation - what to do now?
  - Wake up Bob
  - Disable the stove

Realization of this Vision

A first step and some considerations

AL-Environment

- Sensors
- Gadgets to communicate/(re)act
- Reasoning units

Realization of this Vision

A first step and some considerations

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Requirements

- Communication between the components
- Continuous evaluation of the situation
- Intelligent reasoning about intentions and beliefs

Realization of this Vision

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Existing Concepts

- (managed) Multi-Context Systems [1]

Realization of this Vision

A first step and some considerations

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Existing Concepts

- (managed) Multi-Context Systems [1]
- Stream Reasoning concepts
  - oclingo [2]
  - C-SPARQL [4]

(managed) Multi-Context Systems (mMCS)

Definition

A managed Multi-Context System M is a collection $(C_1, \dots, C_n)$ of managed contexts where, for $1 \leq i \leq n$, each managed context C_i is a quintuple $C_i = (LS_i, kb_i, br_i, OP_i, mng_i)$ such that

- $LS_i = (\mathcal{BS}_{LS_i}, \mathcal{KB}_{LS_i}, \mathcal{ACC}_{LS_i})$ is a logic suite,
- $kb_i \in \mathcal{KB}_{LS_i}$ is a knowledge base,
- OP_i is a management base,
- br_i is a set of bridge rules for C_i, with the form

$$op_i \leftarrow (c_1 : p_1), \dots, (c_j : p_j), not(c_{j+1} : p_{j+1}), \dots, not(c_m : p_m).$$

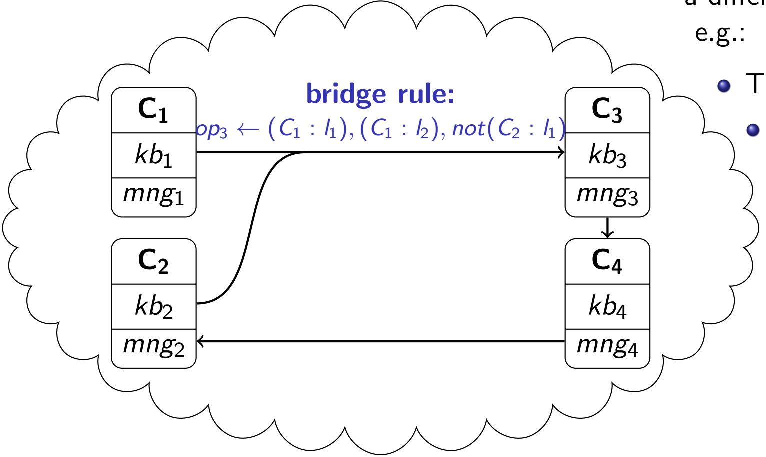
  such that $op_i \in F_{LS_i}^{OP_i}$ and for all $1 \leq k \leq m$ there exists a context $c_k \in (C_1, \dots, C_n)$ such that $p_k \in \ S \in \ \mathcal{BS}_{LS_{c_k}}$, and
- mng_i is a management function over LS_i and OP_i.

Definition

Let $M = (C_1, \ldots, C_n)$ be an mMCS. A belief state $S = (S_1, \ldots, S_n)$ is an equilibrium of M iff for every $1 \leq i \leq n$ there exists some $(kb'_i, ACC_{LS_i}) \in mng_i(app_i(S), kb_i)$ such that $S_i \in ACC_{LS_i}(kb'_i)$.

mMCS

Intuitive Concept



Each context may use a different formalism e.g.:

- Theorem Prover
- Datalog
- ASP
- SQL
- DL
- ...

Preference-based Iterative Managed Multi-Context Systems

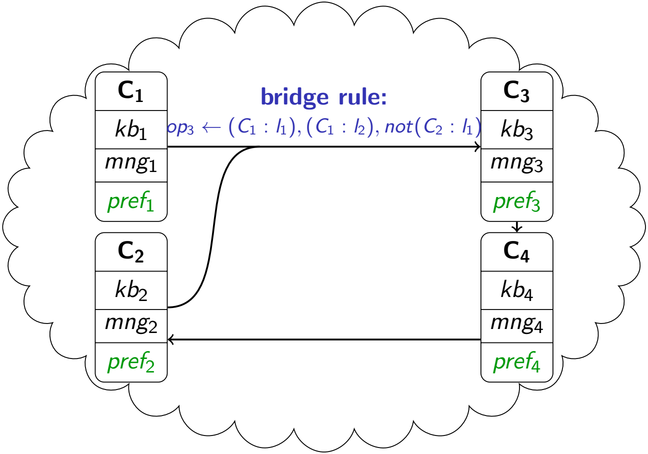
Basic Concepts

- Utilize iterative and stream reasoning approach from potassco [2, 3]
- Specialized contexts for different tasks

Context types

- Observing Contexts
- Reasoning Contexts
- Control Contexts
  - sliding windows
  - inconsistency handling policies
  - semantics and reasoning modes
  - determine actions
  - decide meta-reasoning aspects

Preference-based Iterative Managed Multi-Context Systems (pimMCS)



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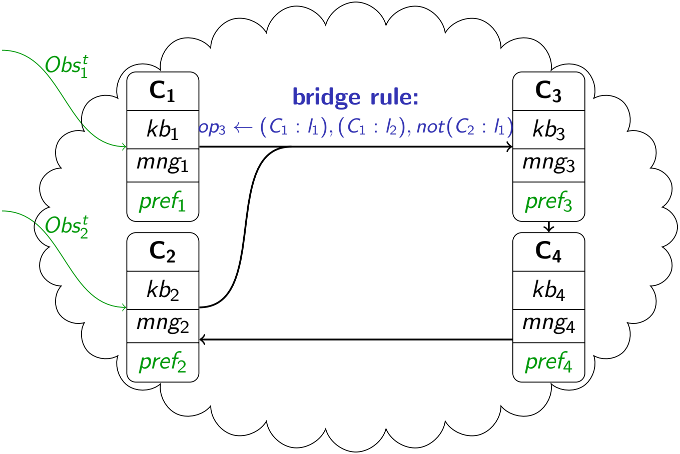

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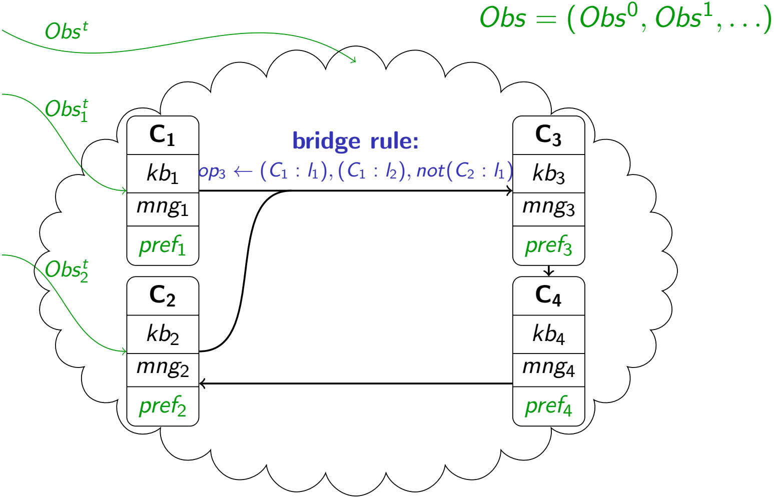

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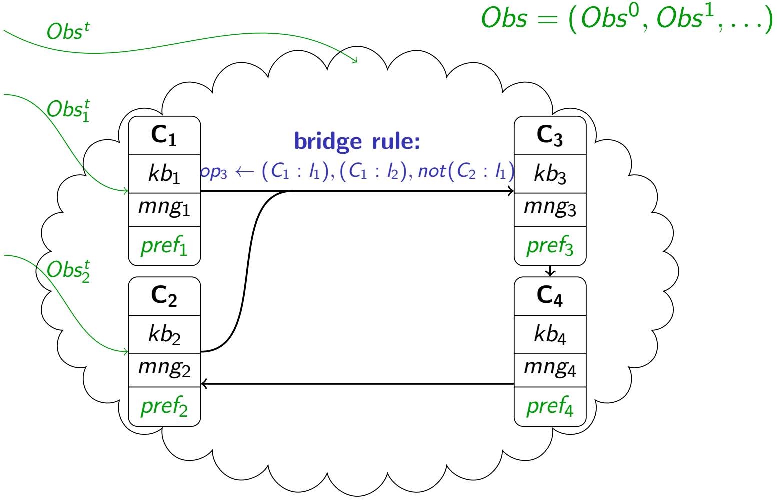
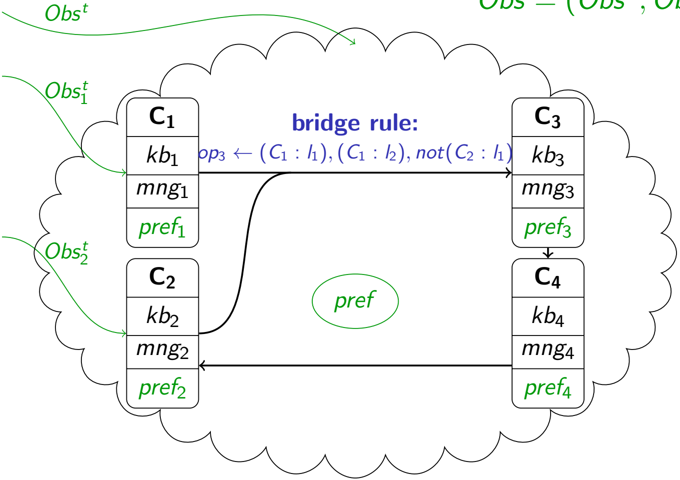


$R(Obs) = Kb^0, Eq^0, Kb^1, Eq^1, \ldots$

Preference-based Iterative Managed Multi-Context Systems (pimMCS)

$Obs = (Obs^0, Obs^1, \ldots)$



$R(Obs) = Kb^0, Eq^0, Kb^1, Eq^1, \ldots$

- If there is no global equilibrium, no actions between contexts
- Computation of one global equilibrium is expensive [1]

Some flaws of pimMCS

- If there is no global equilibrium, no actions between contexts
- Computation of one global equilibrium is expensive [1]

⇒ fast reaction to events is highly unlikely

Reactive Bridge Rules

Concept Idea

- Use bridge rules on local belief sets instead of global equilibria
- All contexts have input streams
- Manipulate the input stream of other contexts

Comparison to pimMCS

- Contexts do not have to wait for the global equilibria
- No agreement neccessary
- Communication in case of emergencies is more immediate
- Inconsistency handling needs to be done via stream handling

Reactive Bridge Rules

Definition

A Reactive Bridge Rule (RBR) r for a context C_i of a collection of n contexts is a rule of the form

$$t, j : h \leftarrow b_1, \ldots, b_k, not\ b_{k+1}, \ldots, not\ b_m$$

where

- $t \in \{b, c\}$ specifies whether the literals need to be evaluated bravely or cautiously,
- $j \leq n$ specifies which context will be provided with additional information,
- h is information which may be added to the input stream of C_j, and
- for $l \leq m$, b_l is a literal.

Reactive Bridge Rules

Definition

Let r be an RBR of a context C_i, $ACC_{LS_i} \in \mathcal{ACC}_{LS_i}$ be a selected semantics, and $S = \{S_1, \ldots, S_j\}$ be the belief sets of C_i at step t, such that $S = ACC_{LS_i}(kb_i^t)$, where kb_i^t is the knowledge base of context C_i at step t.

- If r is a cautious RBR, it is satisfied if $\forall_{B \in S}(b^+(r) \subseteq B \land b^-(r) \cap B = \emptyset)$.
- If r is a brave RBR, it is satisfied if $\exists_{B \in S}(b^+(r) \subseteq B \land b^-(r) \cap B = \emptyset)$.

If a rule r is satisfied, then h will be added to the input stream of the context C_j at step $t + 1$.

Conclusion & Future Work

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We have introduced

- pimMCS to compute equilibria on stream based MCS
- RBRs to modify input streams of other contexts

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In addition there is

- a combination of pimMCS and RBRs
  - reactive managed Multi-Context Systems (rmMCS)
  - computes runs with equilibria like pimMCS
  - free capacities used for additional belief sets
  - RBRs may fire during the computation of the equilibria

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Further Work

- Restrictions to Contexts
- Side effects of rmMCS
- Instantiation
- Implementation
- Reactive "extensions" for one-shot formalisms

Thank you!

The pictures used in this talk are taken from [5, 6]

References I

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[6] Wikipedia.
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[Online, accessed 19-September-2013].

Appendix

Preference-based Iterative Managed Multi-Context Systems

Definition

Let M be a managed MCS with contexts $C = (C_1, \ldots, C_n)$ ($C_1, \ldots, C_k$ are observer contexts), where $C_i \in C$ is a quintuple $C_i = (LS_i, kb_i, br_i, OP_i, mng_i, pref_i)$. Let $Obs = (Obs^0, Obs^1, \ldots)$ be a sequence of observations, that is, for $j \geq 0$, $Obs^j = (Obs_i^j)_{i \leq k}$, where Obs_i^j is the new (sensor) information for context i at step j, which is formalized as sets of formulas.

A run R of M induced by Obs is a sequence

$$R = Kb^0, Eq^0, Kb^1, Eq^1, \ldots$$

where

Preference-based Iterative Managed Multi-Context Systems

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A run R of M induced by Obs is a sequence

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where

- $Kb^0 = (Kb_i^0)_{i \leq n}$ is the collection of initial knowledge bases, Eq^0 an equilibrium of Kb^0,
- for $j \geq 1$ and $i \leq n$, Kb_i^j is the knowledge base of context C_i produced by the context's management function for the computation of Eq^{j-1}, and $Kb^j = (Kb_i^j)_{i \leq n}$,
- for $j \geq 1$, Eq^j is an equilibrium for the knowledge bases

$$(Kb_0^j \cup Obs_0^j, \ldots, Kb_k^j \cup Obs_k^j, Kb_{k+1}^j, \ldots, Kb_n^j).$$

$(C, Obs, pref)$ is called a preference-based iterative managed Multi-Context System.