Nathab: Policy management of pervasive computing services through natural language

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1 Overview

- Outline of project
- Description Logic
- Implementing policies in description logic

2 Motivation

The Pervasive Computing vision:

- Lots of devices, sensors, actuators, gadgets - in the home, car, workplace, street, clothes...
- Networked and accessible. Sending out events, and handling requests. Software services form the layer above:
  - Heating Service (manages all the temp sensors, thermostats, valves, vents etc.)
  - Location Service (RFID tags, motion sensors)

3 Research Questions

- Lots of current research in:
  - The devices themselves (hardware, comms...)
  - Middleware, infrastructure, platforms
  - Web Services, XML, DAML, Zero-Conf
  - Software Agents, Semantic Web, AI Planning
- In a world of pervasive computing, with a rich set of services, we want to make use of it all
- We'd like to configure and compose services

3.1 Programmer or User?

- Much of the research is software-centric:
  WSDL, DAML, Jini etc, allow programs to tie services together and configure their behaviour
- What about the users?
- Pervasive computing is supposed to be for everyday folk, i.e. non-technical With a heating service and location service, how will I actually get them to do what I want?
  - Switch off the heating when nobody is at home

3.1.1 Policies

- When users have pervasive computing, they can use it to tailor their environment:
  - When the house is empty for more than 30mins, turn the heating down
  - Before 7pm, if my mobile rings when I'm at home, re-direct the call to my landline instead
  - Email me when Ian is back in his office
  - Print short documents on the nearest printer
- These rules or preferences, we call policies

3.2 Bridging the User-System Gap

- Users, especially non-technical ones, prefer using speech, text and GUIs, not writing code
- To implement policies, we need to convert them into a formal representation, suitable for use by software that connects services
- Our project, Natural Habitat, seeks to explore how feasible this is...

3.3 The Questions

- Can we use the current state of the art to convert natural language descriptions of policies into formal descriptions of software usable by machines?
- How should we collect a natural language corpus of future technologies?
- What are the requirements of service middleware of NL policies?
- What should the dialogue interface look like between the user and the machine clarifying policies?

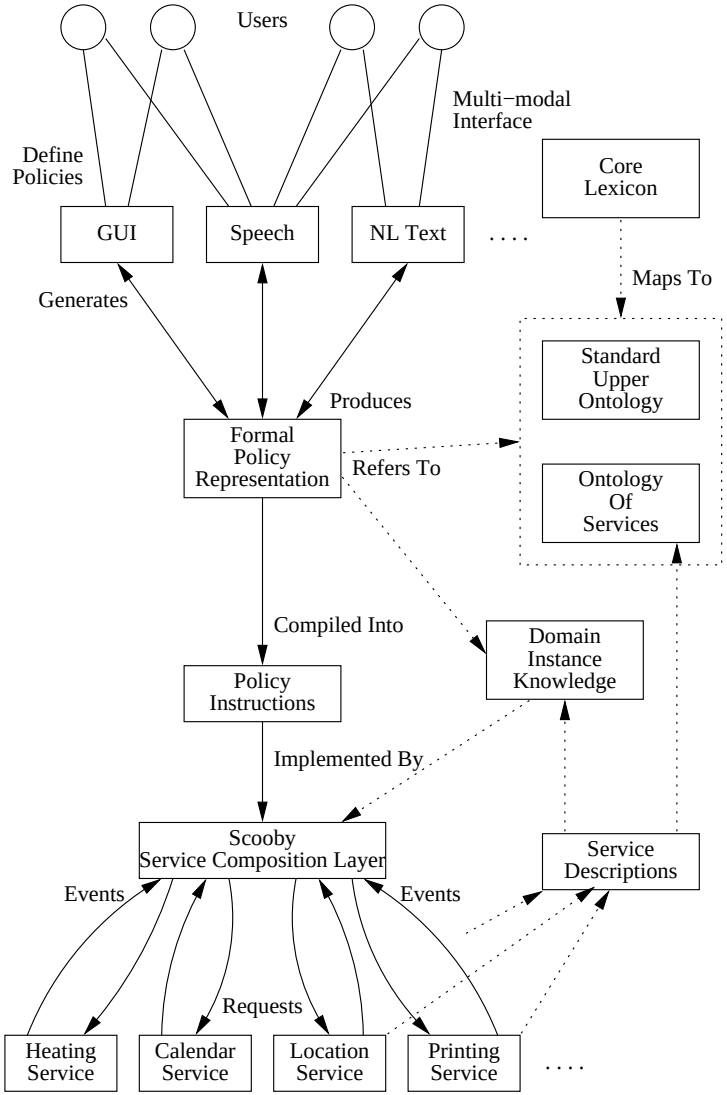
4 The Overall Architecture

Multi-disciplinary

- HCI
- NLP
- Network Services Ontologies

Avoiding

- AI, Goal-seeking etc.
- Automatic Service Composition



5 Policies in Description Logic

- NLP folk like a knowledge representation formalism
- Pervasive computing world is dynamic and open
- We need a way of explaining what is happening
- Description Logic seemed sensible (meets the above, and tools and theory available)...
- ...*but* no work in policy management used description logic that we could find.

5.1 What is Description Logic?

- Describes set membership in concepts and relations eg

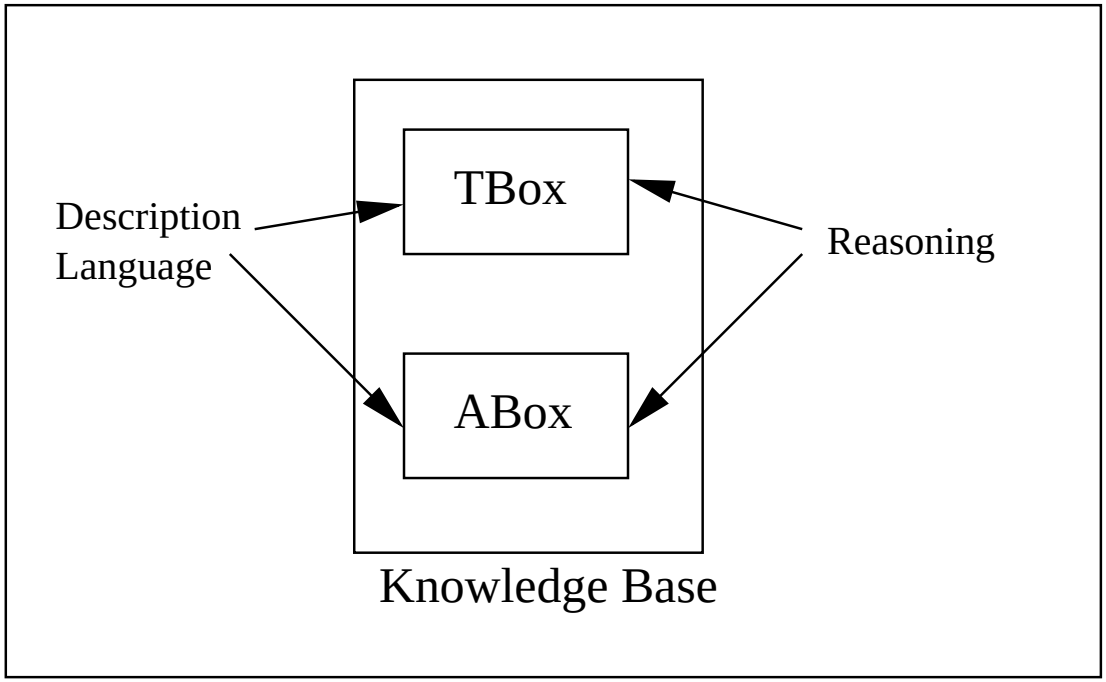
  $\text{Woman} \equiv \text{Person} \sqcap \text{Female}$

  $\text{Parent} \equiv \text{Person} \sqcap \exists\ \text{hasChild.Person}$

  $\text{Request} \sqsubseteq \text{Event}$

- Close relationship with predicate and other logics
- Used heavily in knowledge engineering

5.2 TBoxes and ABoxes



TBox Terminological descriptions of concepts - the ontology

ABox The assertions abut the world - what facts are known

Reasoning Satisfiability, Subsumption, Equivalence, Disjointedness

5.3 Print World - Domain-specific Mid-Level Ontology

Device	$\sqsubseteq$	Physical
ComputingObject	$\sqsubseteq$	Abstract
User	$\sqsubseteq$	Human
	$\sqcap$	$name$.String
DataType	$\sqsubseteq$	ComputingObject
String	$\sqsubseteq$	DataType
File	$\sqsubseteq$	ComputingObject
	$\sqcap$	$owner$.User
Event	$\sqsubseteq$	ComputingObject
Notification	$\sqsubseteq$	Event
Request	$\sqsubseteq$	Event
	$\sqcap$	$state$.StateValue
StateValue	$=$	{STOPPED, CANCELLED, COMPLETED}

5.4 Print World - Printing Service

$$
\begin{array}{lcl}
\text{Printer} & \sqsubseteq & \text{Device} \\
 & \sqcap & \mathit{name}.\text{String} \\
 & \sqcap & \mathit{owner}.\text{User} \\
 & \sqcap & \mathit{colour}.\text{ColourVal} \\
 & \sqcap & \mathit{status}.\text{StatusVal} \\
 & \sqcap & \mathit{duplicity}.\text{DuplexVal}
\end{array}
$$

$$
\begin{array}{lcl}
\text{Document} & \sqsubseteq & \text{File} \\
 & \sqcap & \mathit{security}.\text{SecureVal} \\
 & \sqcap & \mathit{colour}.\text{ColourVal}
\end{array}
$$

$$
\begin{array}{lcl}
\text{ColourVal} & = & \{ \text{COLOR}, \\
 & & \text{MONO} \} \\
\text{StatusVal} & = & \{ \text{BUSY, ONLINE}, \\
 & & \text{OFFLINE} \}
\end{array}
$$

$$
\begin{array}{lcl}
\text{DuplexVal} & = & \{ \text{SINGLE}, \\
 & & \text{DOUBLE} \} \\
\text{SecureVal} & = & \{ \text{OPEN}, \\
 & & \text{CONFIDENTIAL} \}
\end{array}
$$

$$
\begin{array}{lcl}
\text{Print} & \sqsubseteq & \text{Request} \\
 & \sqcap & \mathit{agent}.\text{User} \\
 & \sqcap & \mathit{patient}.\text{File} \\
 & \sqcap & \mathit{target}.\text{Printer}
\end{array}
$$

$$
\begin{array}{lcl}
\text{LJA} & \in & \text{Printer} \\
 & \sqcap & \mathit{colour}.\text{MONO} \\
 & \sqcap & \mathit{duplicity}.\text{SINGLE} \\
 & & \ldots
\end{array}
$$

5.5 Policy Examples

Policies either

- Change the description of the request
- or generate new requests/events

Action Trigger When a request or event matches a pre-condition, generate a new request/event eg when a print request goes to "ljx", email me.

$$\text{Print} \sqcap \text{target.name.}\text{“ljx”}$$
$$\Rightarrow \textit{new } y \in \text{Email} \sqcap \text{target.name.}\text{“ianw”}$$

Default When a request is incompletely specified, fill in relations eg when a print request has no target, send it to "ljx".

$$\text{Print} \sqcap \text{target}.\bot$$
$$\Rightarrow \text{target.name.}\text{“ljx”}$$

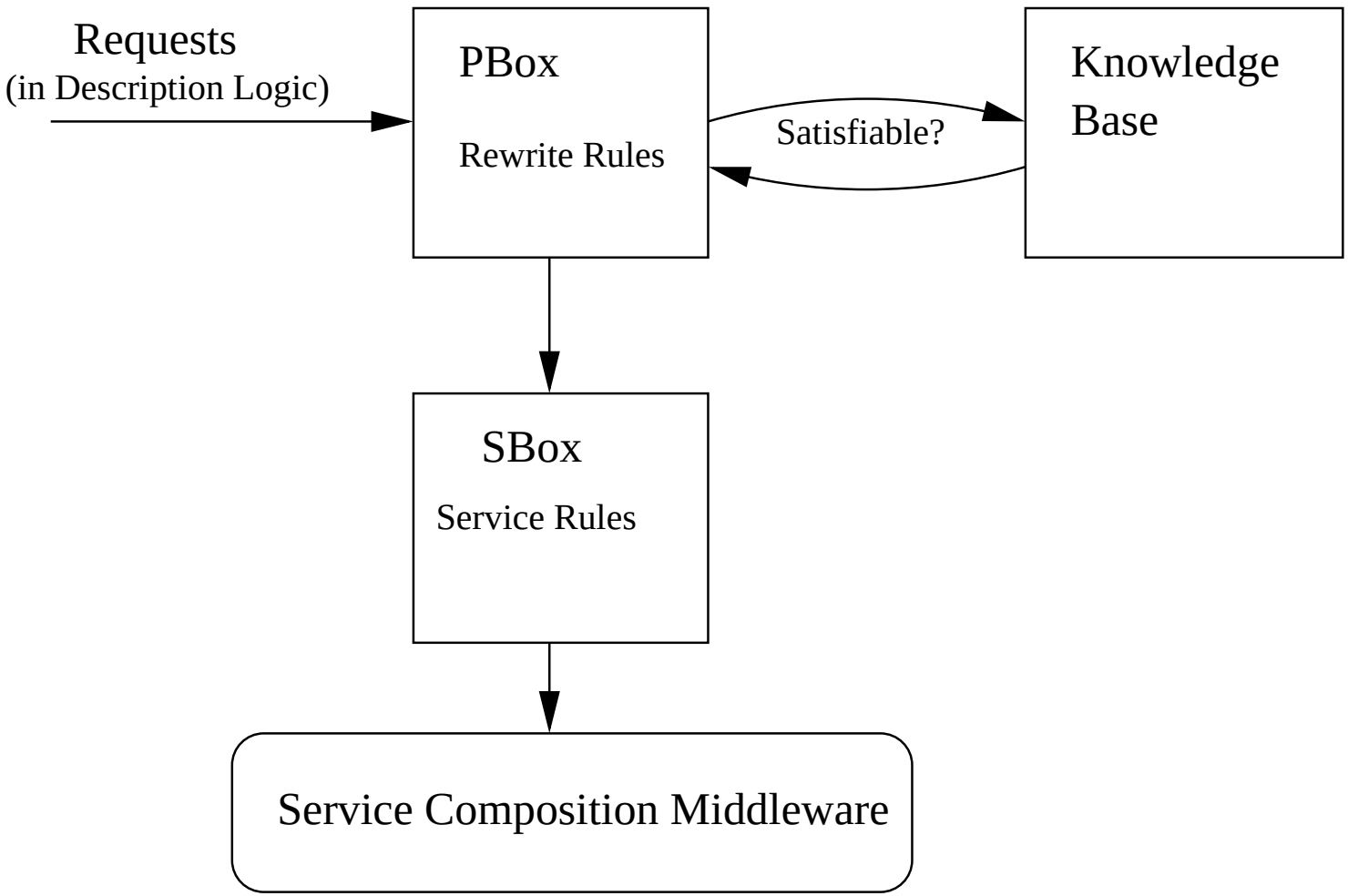
Alternate Targets If the world is in this state, rethink what to do with the request when the target of a print request is busy, send it to a non-busy printer.

$$\text{Print} \sqcap \text{target.busyness.}\text{“busy”}$$
$$\Rightarrow \text{target.busyness.}\text{“empty”}$$

Block Disallow some requests based on conditions, eg when a print request is from "Mark, stop it.

$$\text{Print} \sqcap \text{owner.}\text{“Mark”}$$
$$\Rightarrow \text{state.}\text{“stopped”}$$

5.6 The PBox: Rewriting Requests



5.7 (I can't get no) Satisfaction

- When a policy is fired, we treat the rewrite initially as an additional constraint on the request
- However, this can make the request non-satisfiable eg

  Print $\sqcap$ target.name."lja" $\sqcap$ target.busyness."busy"
  $\Rightarrow$ target.name."ljb"

  results in the request having two target names.
- Therefore before entering a policy, we check the satisfiability of the join of the pre and post-condition, to infer which facts are retracted

5.8 Constructing a Partial Ordering over Policies

- The order in which policies are applied to requests is obviously important.
- Description Logic allows the creation of a partial order over policies defining which policies are most specific, and which conflict.
- For policies P_1 and P_2, $P_1 \leq P_2$ if:
  1. The pre-condition of P_1 subsumes the pre-condition of P_2, if P_2 fires, then P_1 should be tested.
  2. If the pre-conditions of P_1 and P_2 are disjoint, then only the ancestors of the rules which fire should be tested.
  3. If a precedence between policies is imposed (below), test one then the other.

5.9 Conflict Resolution

- Users may choose conflicting policies. Can we detect conflicts? (Current state of play)
  1. If the pre-conditions of P_1 and P_2 are do not subsume and are not disjoint, then the policies require precedence ordering and may conflict.
  2. If the post-conditions of P_1 and P_2 involve separate conditions, then they don't conflict
- Resolve through
  - Querying the user (through the multi-modal interface) for disambiguation and precedence
  - Using heuristics to generate an ordering, eg security is more important than anything else

5.10 Problems in conflict resolution

- If a high precedence policy rewrites and increases the generality of the request, lower precedence policies may fire. Is this acceptable?

5.11 Automatic Conflict Detection: An Example

- The initial policy is to print documents on lja

  1. Print $\sqcap$ target.$\perp$ $\Rightarrow$ target.name.“lja”

Print ^ target._
 −> target.name."lja"

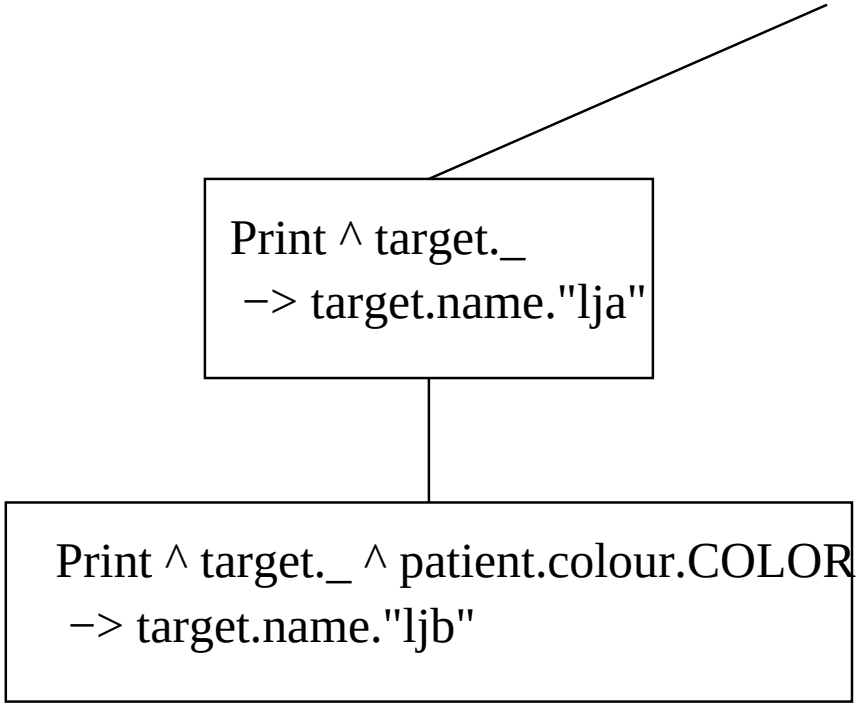
5.11.1 Disambiguation

- The next policy is to print colour documents on ljb

  2. Print $\sqcap$ patient.colour.COLOR $\Rightarrow$ target.name."ljb"

- However, this is neither subsumed/subsumes 1. nor is disjoint
- The user must disambiuate or define an arbitrary ordering.
- Disambiguation chosen

  2'. Print $\sqcap$ target.$\perp$ $\sqcap$ patient.colour.COLOR $\Rightarrow$ target.name."ljb"

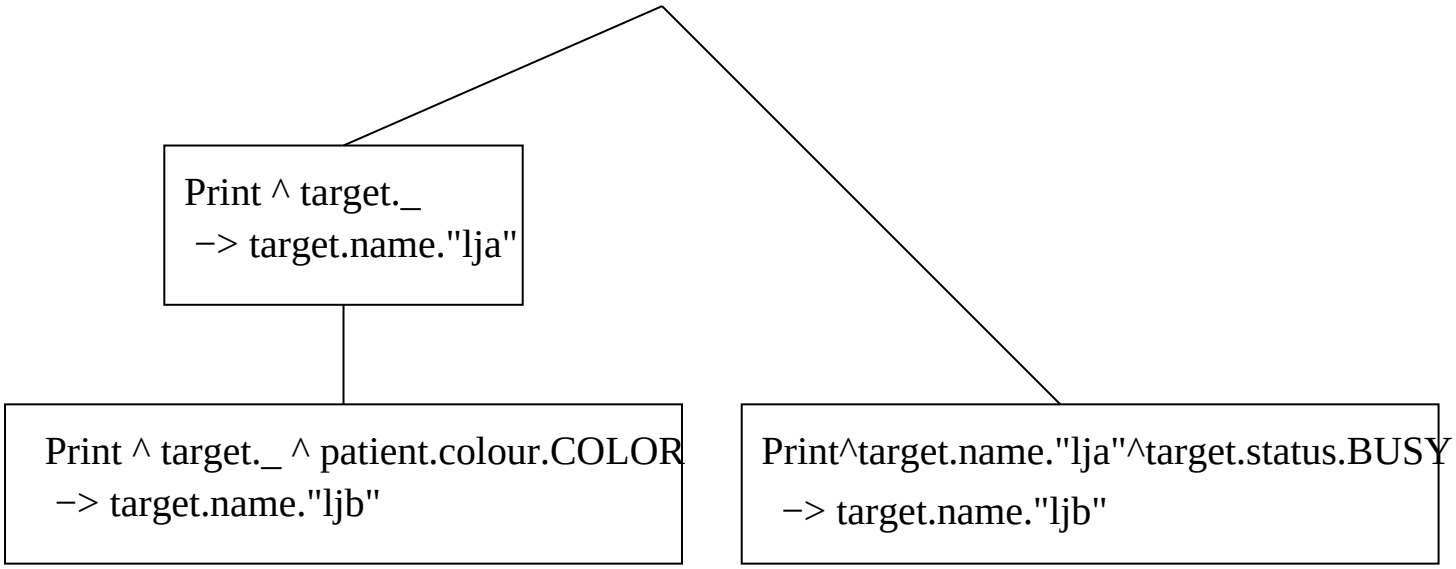

Print ^ target._
−> target.name."lja"
Print ^ target._ ^ patient.colour.COLOR
−> target.name."ljb"

5.11.2 Disjointedness

- The next policy is to print documents targetted for lja on ljb if lja is busy

  3. Print $\sqcap$ target.name."lja"$\sqcap$ target.status.BUSY $\Rightarrow$ target.name."ljb"

- This is disjoint from the policies 1 and 2' since there is a specified target.

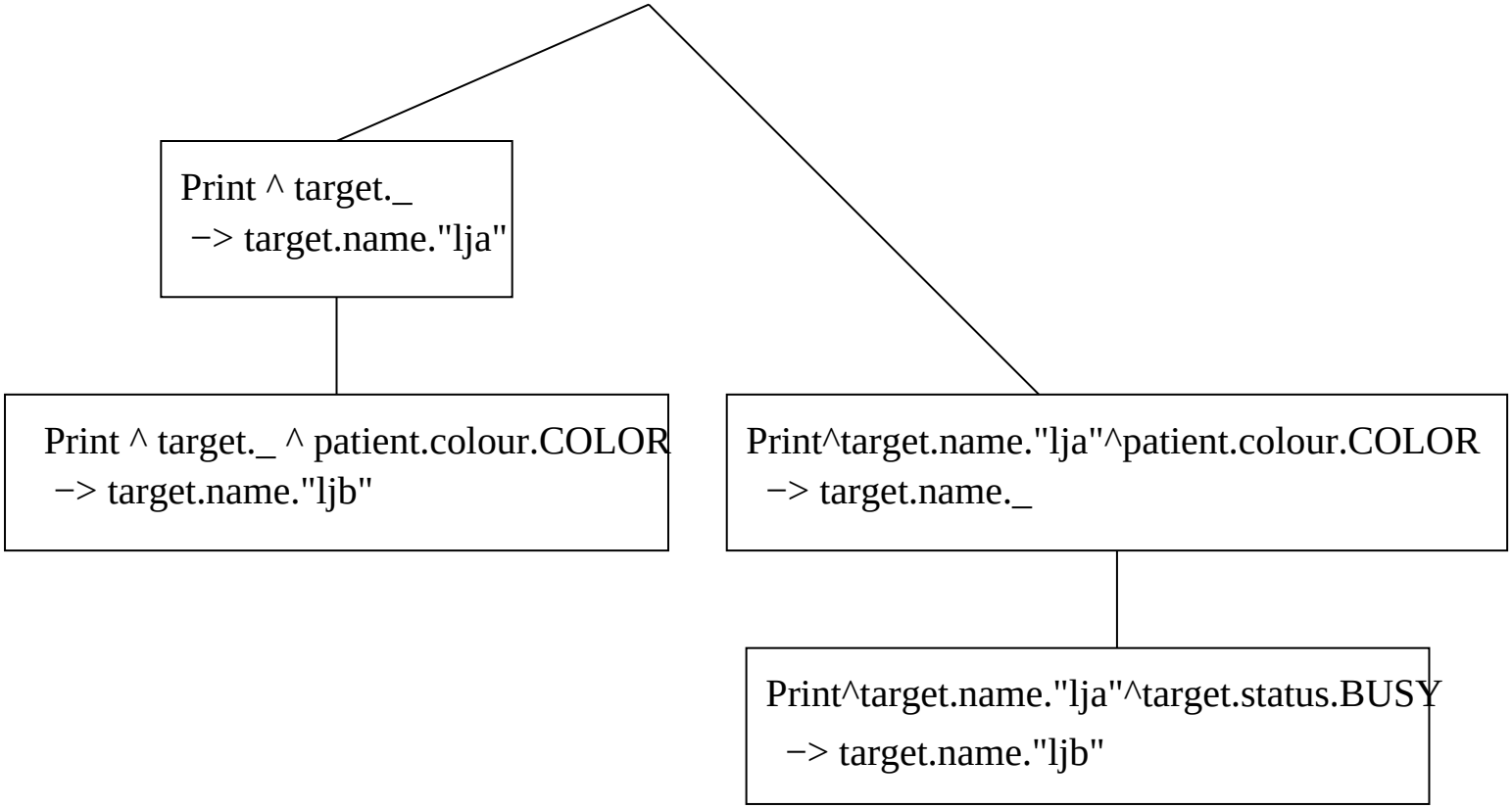

Print ^ target._
−> target.name."lja"
Print ^ target._ ^ patient.colour.COLOR
−> target.name."ljb"
Print^target.name."lja"^target.status.BUSY
−> target.name."ljb"

5.11.3 Arbitrary Precedence

- *Don't print colour documents on lja*

  4. Print $\sqcap$ target.name."lja"$\sqcap$ patient.colour.COLOR $\Rightarrow$ target.name.$\perp$

- This is neither disjoint not subsumed/subsumes policy 3.
- User chooses to give 3. a higher precedence


Print ^ target._
−> target.name."lja"
Print ^ target._ ^ patient.colour.COLOR
−> target.name."ljb"
Print^target.name."lja"^patient.colour.COLOR
−> target.name._
Print^target.name."lja"^target.status.BUSY
−> target.name."ljb"

5.12 Executing Policies

- A request starts at the bottom of the constructed lattice and each policy which matches the pre-condition has the rewrites applied.
- When all the relevant policies have been executed, the necessary sets of possible targets, patients etc are inferred.
- The service rule is then fired if possible, using (arbitrary?) choices to fill the relevant slots.

5.13 (I *still* can't get no) Satisfaction

- Policy rewrites may make requests unsatisfiable
- eg requiring the document to be printed in my office on a colour printer, when I have no colour printer in my office.
- After each policy rewrite, test the request for satisfiability against the ABox.
- If non-satisfiable, flag it to the user, since it may indicate a real-world problem in policies.

5.14 Current State

- Print policy corpus collected
- Natural Language implementation underway
- Thought designs and rapid prototyping to get to this point on policy implementation
- Middleware layer services (sms, email, etc) implemented (twice) over elvin and rmi (Jon Robinson).

6 Conclusion

- Description Logic is a promising mechanism for dealing with policy management of the pervasive computing environment
- Application to other policy management areas possible