Common Knowledge of Industrial Robots
Knowledge and Skill Representation for Industrial Robotics

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April 18, 2012

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EU by financing ROSETTA, SIARAS, RoSta

Overview

- Common Knowledge
- KIF (Knowledge Interchange Format, Genesereth 1990)
- KIF (Knowledge Integration Framework, Nugues et al. 2010)
- KIF (Knowledge Interchange Framework, ?)

Common knowledge

Joint knowledge
Common ground

Can a human and a robot have common knowledge?

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Can a human and a robot have common knowledge?

Seems very hard.

Let's try something simpler:

Can two robots have common knowledge?

Common knowledge

Suppose each student arrives for a class meeting knowing that the instructor will be late. That the instructor will be late is mutual knowledge, but each student might think only she knows the instructor will be late. However, if one of the students says openly "Jacek told me he will be late again," then each student knows that each student knows that the instructor will be late, each student knows that each student knows that each student knows that the instructor will be late, and so on, ad infinitum.

Common knowledge

A proposition A is *mutual knowledge* among a set of agents if each agent knows that A. Mutual knowledge by itself implies nothing about what, if any, knowledge anyone attributes to anyone else.

In the example, the announcement made the mutually known fact *common knowledge* among the students.

More examples

1. The Clumsy Waiter (SEP)
2. The Barbecue Party (SEP)
3. The Blue-Eyed People (Wikipedia)
4. Alice at the logicians convention (unknown source)
5. ...

Value of common knowledge

The fact that some piece of knowledge A is common knowledge makes it available at all levels of nesting.

We would like our robots to have this kind of capacity as well: to know that something is known and that other agents know it as well; to rely upon the knowledge being spread among all involved agents.

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It is not **WAIT** that makes the pancake.
Generally: *common sense* knowledge.

Common sense knowledge

Common knowledge *is not* common sense
nor vice versa

but

we need common sense knowledge to become common to succeed

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we need common sense knowledge to become common to succeed

so we need our robots to share common sense knowledge and be aware of this fact

Knowledge Interchange Format

Knowledge Interchange Format, 1990, Genesereth

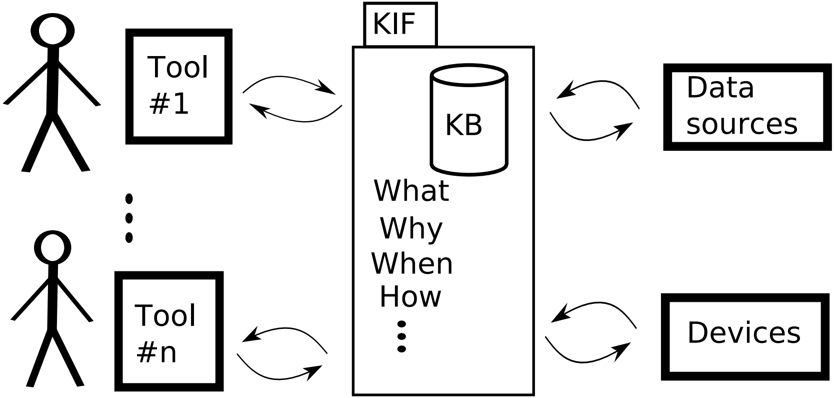
- Thought of as interlingua
- Based on (actually, a syntactic variant of) first order predicate logic
- Expected to be machine-readable
- Too complex, too early

Enabling Technology for Knowledge Sharing, 1991, Neches, Fikes, Finin, Gruber, Patil, Senator, Swartout

Knowledg


AI Magazine Volume 12 Number 3 (1991) (© AAAI)
Enabling Technology for Knowledge Sharing
Robert Neches, Richard Fikes, Tim Finin, Thomas Gruber, Ramesh Patil, Ted Senator, and William R. Swartout
À LA CARTE SYSTEMS MENU
KNOWLEDGE REPS (select one or more)
Rule-based 2 Mbytes
Logic-based 3 Mbytes
Frame-based 6 Mbytes
Hybrid 2 Mbytes
Analogic-based 10 Mbytes
Metalogic-based 17 Mbytes
ONTOLOGIES (select one or more)
Manufacturing 10 Mbytes
Electromechanical 8 Mbytes
Financial 5 Mbytes
Fluidics 4 Mbytes
Construction 6 Mbytes
REASONERS
Scheduler 5Mbytes
Classifier 4 Mbytes
Planner 7 Mbytes
Diagnoser 5 Mbytes
Evaluator 4 Mbytes

Knowledge Integration Framework



Knowledge Integration Framework

Semantic web lesson + Moore's law effects:

So far the paradigm of data (knowledge) storage was:
Organize your data according to the questions you intend to ask

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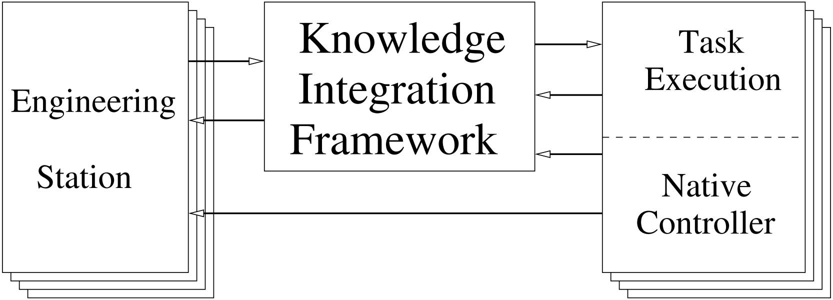
Organize your data according to the questions you intend to ask

The new paradigm is:
Store data,
then think about questions, think about algorithms to use, ...

Knowledge Integration Framework



Our interest area

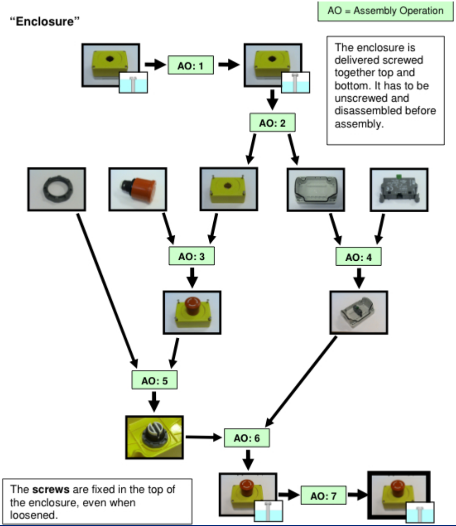
Knowledge-based industrial robotics and automation systems

A distinct domain than autonomous mobile robotics, mostly due to different focus of interest

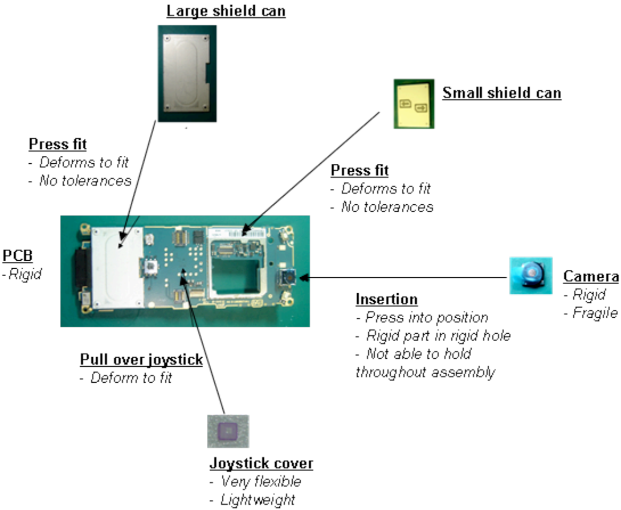
The unifying concept: **robot skill**

Domain of interest: Assembly

Typical assembly process



Another assembly process



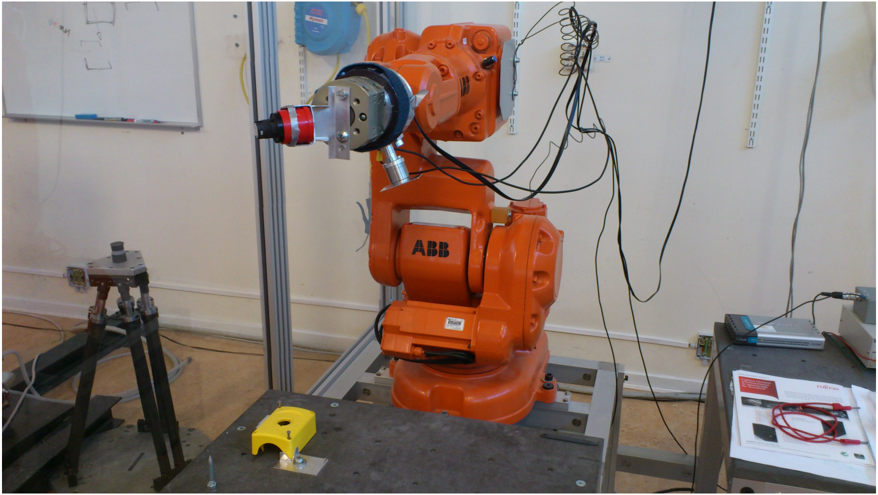
Hard problems

- flipping a pancake using a spatula
- snap-fit insertion
- shield can placement

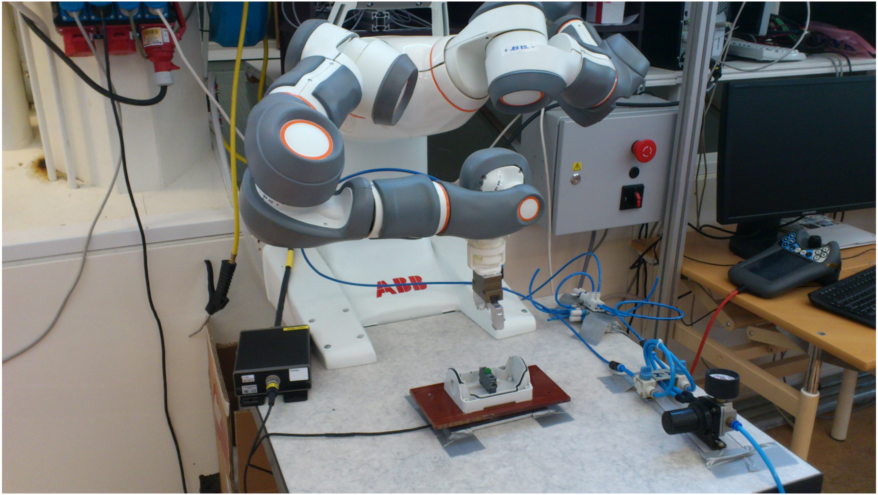
More generally:

- sensor feedback
- force control
- variations of hardware resources
- small change of tolerances affects the whole process

Our target robots: IRb-140



Our target robots: FRIDA



Our assumptions

- hybrid, layered architecture
- AI planning still not sufficient (Beetz 2011)
- semantic web technology - revival of logic (thanks to Moore's law), but also more understanding of computability issues (DL et co.)
- KnowRob, RoboEarth, GeRT (Generalizing Robot manipulation Tasks), ...

Vocabulary

- Activities:
  - Motions
    continuous space-time activity of a robot finishing on some observable condition (detectable by sensors)
  - Actions
    every other continuous-time activity but a motion, e.g. image processing or path-planning
- Skills
  Discretely interconnected set of activities (FSM, with states possessing appropriate structure), may span several levels of complexity (compound skills vs. primitive skills)
- Tasks
  Abstracted skills, providing information about the goal, but not the means; e.g. the assembly graph for the stop-button case

Conventions: skill ontology

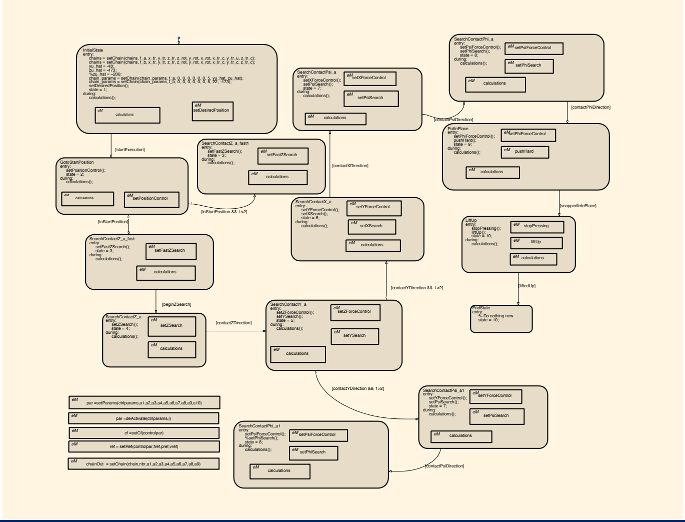
Origins (EU-funded since 2006):

- SIARAS (assembly, sensing)
- RoSta (manufacturing)
- Rosetta (assembly)

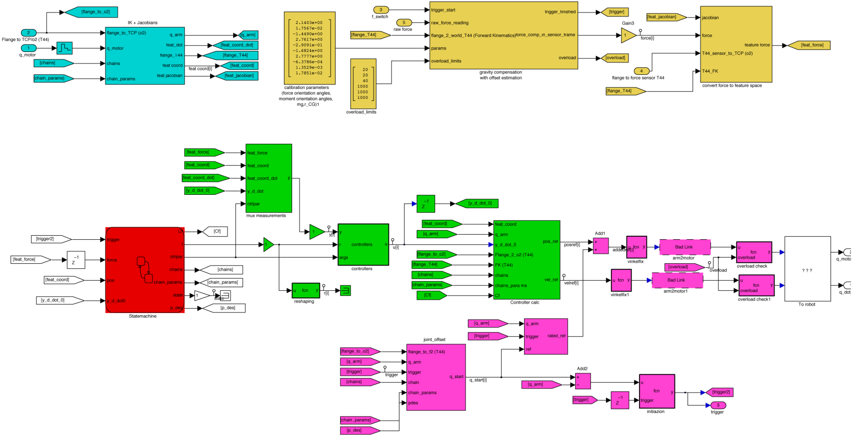
Ongoing modularization:

- qudt (quantities, units, dimensions, types) ontology
- OWL-S
- state transition formalisms of various kinds
- project-specific knowledge

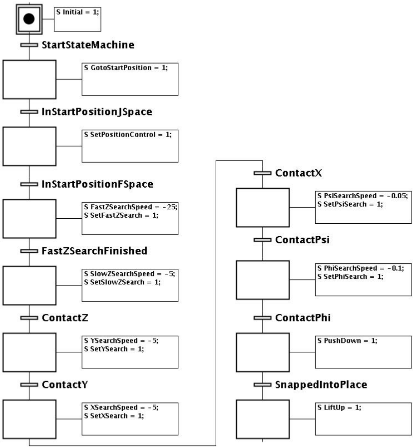
An example skill: snap-fit



Snap-fit on iRB-140 hardware



Knowledge about snap-fit



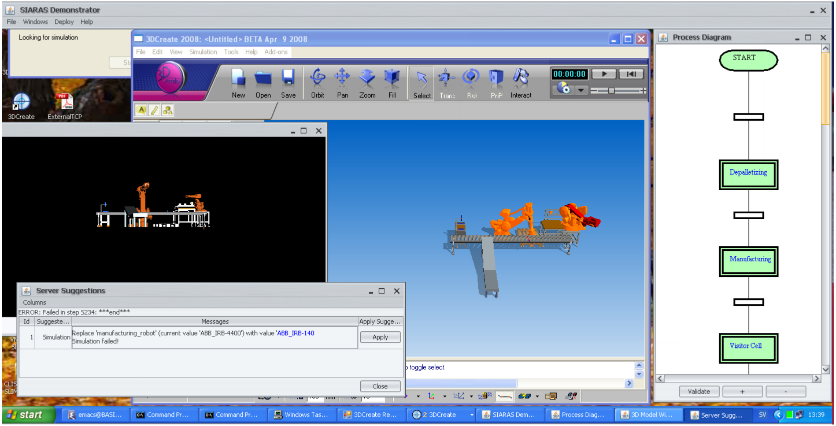
Each step is a state, associated with:

- a concrete robot controller (iTaSC, instantaneous Task Specification using Constraints),
- RAPID program,
- Simulink code,
- Python code,
- mathML formulae,
- ...

Reasoners

- consistency checks of various sorts
- simulation tools
- domain-specific knowledge sources (a la blackboard architecture): interesting issues related to consistency, subsumption, quality of results, resource consumption, ...
- geometric reasoning, kinematics of robots
- constraints solver(s)
- parameter learning
- error detection

Simulation-based reasoning



Conclusions

- An interesting and complex domain
- Disparate kinds of knowledge needed
- Procedural attachment is necessary
- Management of knowledge is not trivial
- Focus on interaction with various kinds of users

Goal: common knowledge available in Knowledge Interchange Framework

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Thank you.

Geometric reasoner