Common Knowledge of Industrial Robots



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

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



Joint knowledge Common ground

Can a human and a robot have common knowledge?



Joint knowledge Common ground

Can a human and a robot have common knowledge?

Seems very hard.

Let's try something simpler:

Can two robots have 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 each student knows that each student the instructor will be late, and so on, ad infinitum.



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.

Common Knowledge of Industrial Robots



More examples

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



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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Spatula movements taking into account the dynamics of a half-baked dough. Pancake stove being put on and off at appropriate times. 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



Common sense knowledge

Common knowledge *is not* common sense nor vice versa

but

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









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



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

The new paradigm is:

Store data,

then think about questions, think about algorithms to use, ...





Common Knowledge of Industrial Robots



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

AO = Assembly Operation

"Enclosure"





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
- Al 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

Class Interactivy DBHOD Class Interactivy DBHOD Physical Color Physical Color Property Percent Property Scruct/Color Scruct/Politie Scruct/Color V Scruct/Politie Scruct/Scruct/Color V Scruct/Politie Scruct/Sc
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▼ ●ManipulationAndHandlingFunction
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 Convey Displace
Displace
▶ ● Feed
Chiert
Pan
Pare
Position
Turn
Secure
Store
ManufacturingFunction
OpticFunction
Processing
SensorFunction
Task

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

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