The Human-Robot Interaction Laboratory at Tufts

Research Overview 2013

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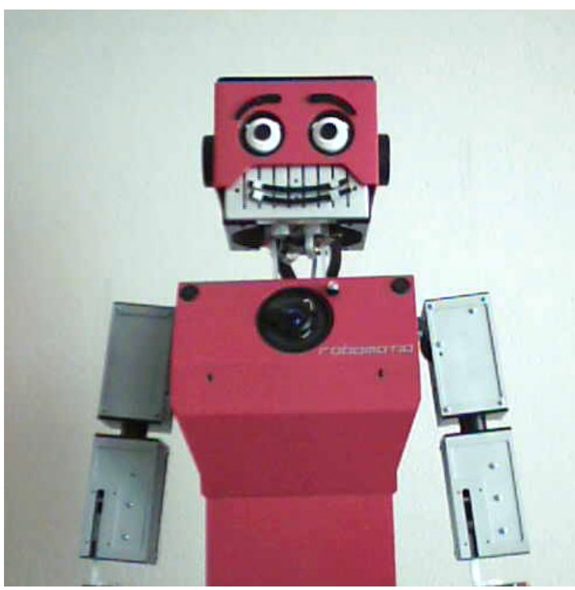

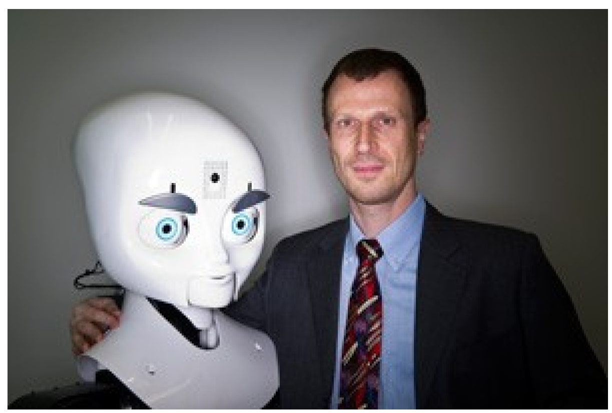

Matthias Scheutz, Director
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RESEARCH IN AI AND ROBOTICS

- **AI/robotics algorithms and architectures:**
  - situated natural language dialogues (including speech recognition, syntactic and semantic parsing, computational pragmatics, dialogue moves and user mental modeling)
  - one-shot learning (of navigation and manipulation actions, plan operators and rules, percepts, activities, etc.)
  - introspection, fault detection and recovery, dynamic adaptation and configuration of architectural components
  - ongoing work on the DIARC architecture and ADE middleware
- **Human-robot interaction (HRI):**
  - human subject experiments with scripted/teleoperated and autonomous robots to determine human attitudes about robots
  - various architectural HRI evaluation studies (on dynamic robot autonomy, the utility of affect, gender effects, joint attention, politeness, empathy, superhuman robot capabilities, etc.)

THE DIARC ARCHITECTURE USED AS A TOOL IN HRI

- Joint attention processes (e.g., establishing and maintaining joint attention, or breaking joint attention through “abnormal attention”)
- Human attitudes about robots (e.g., social facilitation and social inhibition to probe agency, or investigations of the effects of robotic voices, social presence, etc.)
- Human reactions to autonomous robots in cooperative tasks (e.g., to robot affect, robot autonomy, to local/remote HRI)
- Task-switching in human multi-tasking (e.g., fNIRs-based adaption of robot autonomy, effects of real vs virtual robots on multi-tasking performance)
- Philosophical and conceptual inquiry (e.g., what it is like to be an agent/have a red experience, or the effects of “ethical robots” on human decision-making)

THE DIARC ARCHITECTURE USED AS A MODEL IN HRI

- Spoken natural language and dialogue interactions (e.g., instructing and tasking in natural language, dialogue-based mixed initiative, robust NL interactions under time pressure)
- Introspection and self-awareness (e.g., detecting faults and failures, detecting capabilities, automatic adaptation of architectural components for improved automony)
- Planning, reasoning, and problem solving in open worlds (e.g., planning and reasoning with incomplete knowledge, determining optimal policies in open worlds)
- Knowledge-based learning (e.g., one-shot learning of new actions, new plan operators, and new perceivable objects)
- Mental models, simulation, and counterfactual reasoning (e.g., adverbial cues for inferring false beliefs, automatic inference from mental models, simulations of actions)

SIX DIVERSE EXAMPLES OF DIARC AT WORK

- Six examples of **natural dialogue-based HRI** with **DIARC** running on **five different ground and aerial robots** (**Videre**, **AR Drone**, **Segway**, **MDS**, **Pioneer, PR2**), in **indoor and outdoor** **single and multirobot interactions**
- *Example 1:* human-like **task-based dialogue interactions** and task performance as they occur in the search task
- *Example 2:* **multi-robot belief modeling and inference** with ground and aerial robots in indoor environments
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DIARC AT WORK
EXAMPLE 1

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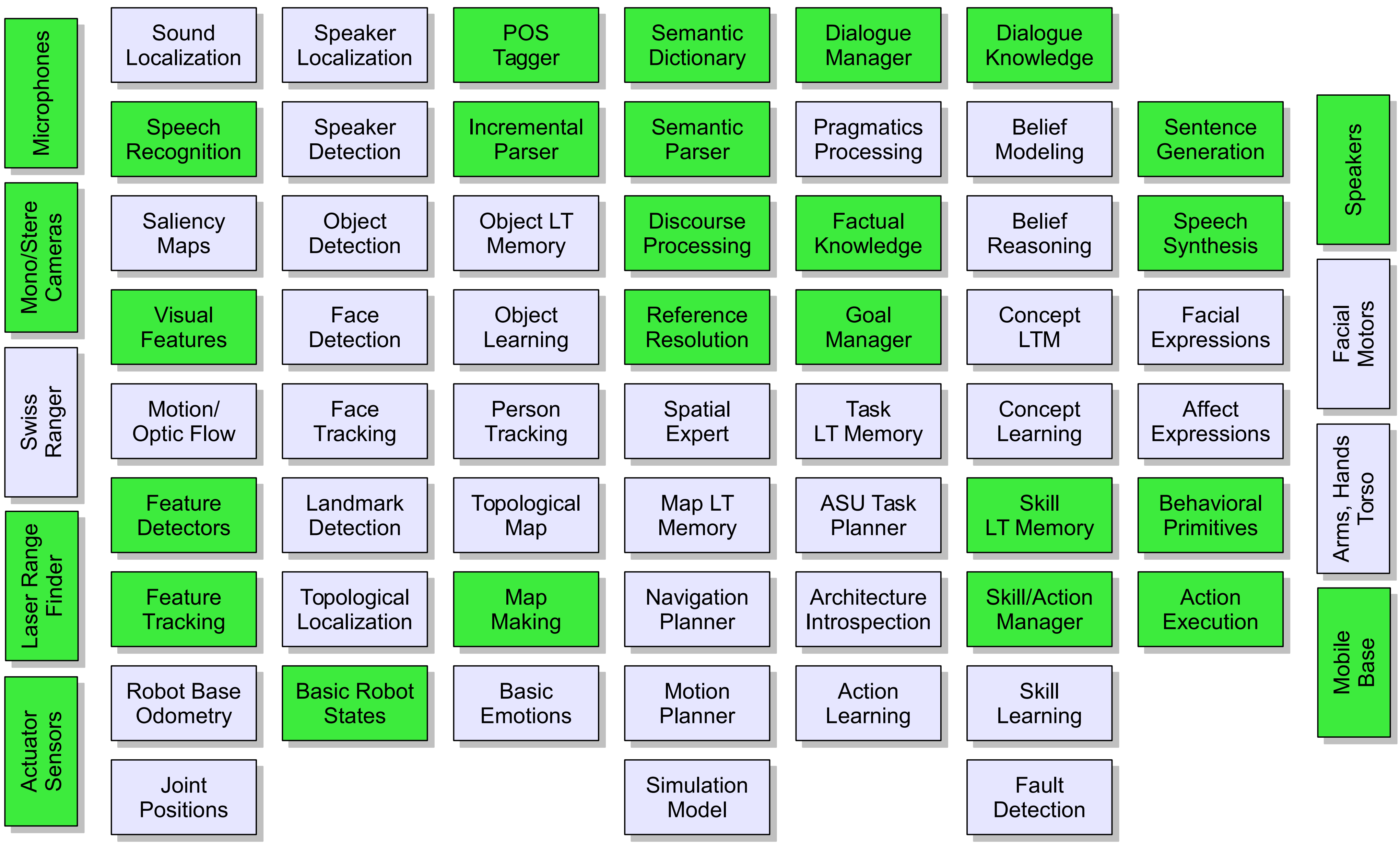
TASK-BASED NATURAL LANGUAGE DIALOGUE HRI



TASK-BASED NATURAL LANGUAGE DIALOGUE HRI

Robot has been going down one corridor and has stopped outside of a doorway.

H: Is there a hallway?
R: I see a hallway.
H: Okay, go down there.
R: Okay.

The robot drives down the hallway. As it is driving down it notices a doorway, which it reports to the team leader, also acknowledging its position.

R: Okay, I'm now in the hallway. There is a doorway on the left.
H: Good, go through that doorway.
R: Okay.

The robot enters the room through the doorway and notices several yellow blocks. Since these are task-relevant, it reports them to the team leader.

R: I'm now inside the room. There are yellow blocks in boxes.
H: Get a yellow block from a blue box.
R: Okay.

The robot verifies that there is a yellow block in a blue box, approaches the blue box, and gets the yellow block.

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Question requires perceptual action, followed by human instruction with deictic reference which is carried out

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Updates to the team leader; ongoing active perceptual monitoring generates additional updates on task-relevant landmarks

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More updates after completed actions and results from task-based attentional bias; spatial reference resolution and action generation

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click on image to play video

DIARC AT WORK
EXAMPLE 2

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MULTI-ROBOT BELIEF MODELING AND AUTOMATIC INFERENCE IN DIALOGUES

A human commander asks robot D about its goals and checks whether robot T has reached Nav point Alpha. Since T does not have that goal, it corrects the human's false belief and checks whether it should assume a new goal, which is then confirmed.

H: Drone, what are you doing?
D: Commander, I am not doing anything.
H: OK. Transport, are you at Alpha yet?
T: No, Commander. I do not have a goal to be at Alpha. Should I have one?
H: Yes, go to Alpha.
T: OK.
H: Drone, follow Transport.
D: OK.

Note that Robot D was listening in on H's conversation with T, hence it is able to infer where it is going given where T is going and can thus answer questions about its goals.

H: Drone, what are you doing?
D: Commander, I am following Transport.
H: OK. Drone, where are you going?
D: Commander, I am going to Alpha with Transport.
H: OK.

T informs H of its arrival at Alpha given that it believes that H intends to know that.

T: Commander, I am now at Alpha.

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Goal inquiry and updates, belief modeling and inference based on adverbial cues, and tasking in natural language

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Status inquiry, status updates and automatic goal location inference based on previous dialogues with the other robot

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Robot initiated status updates based on belief of what commander intends to know

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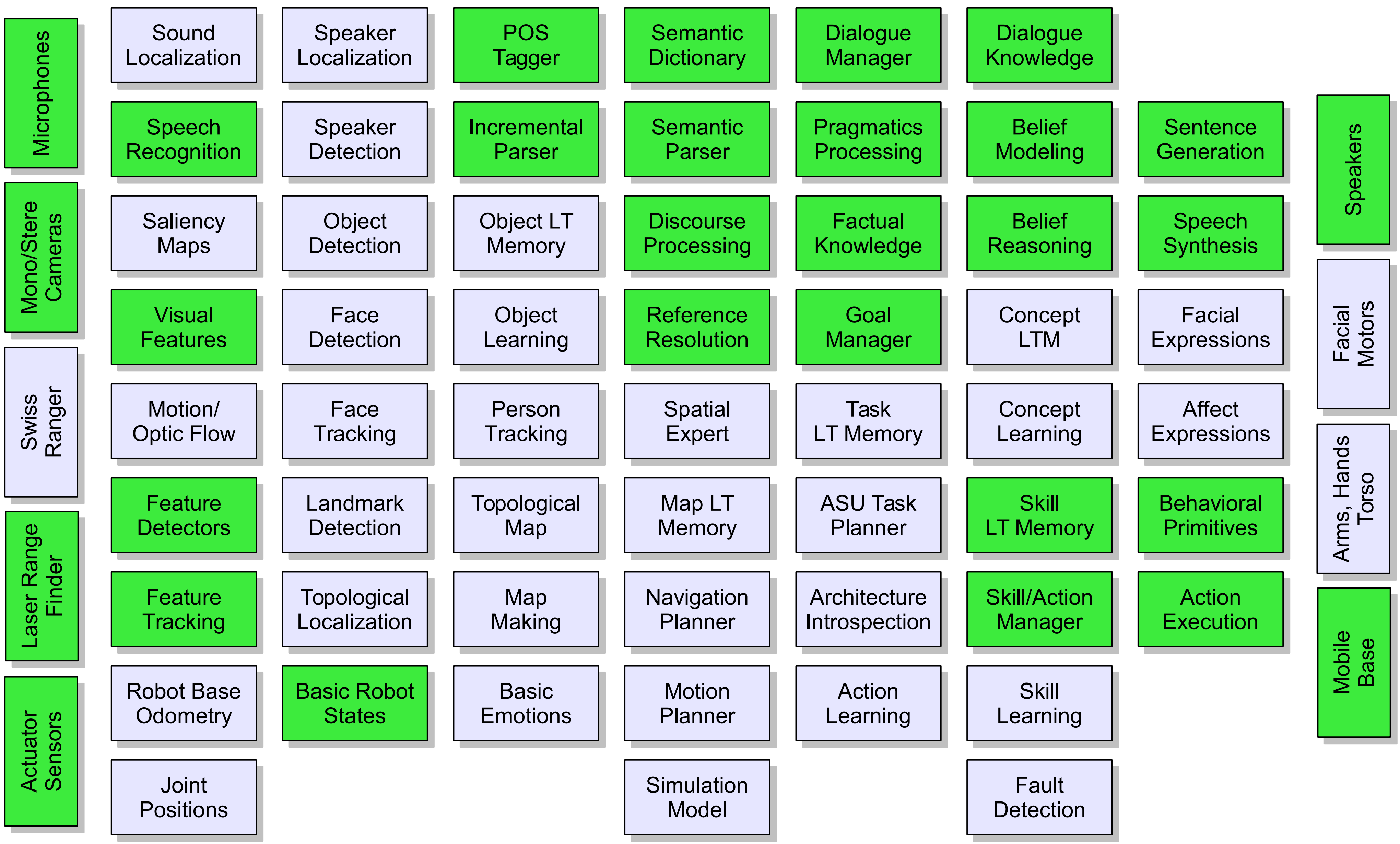

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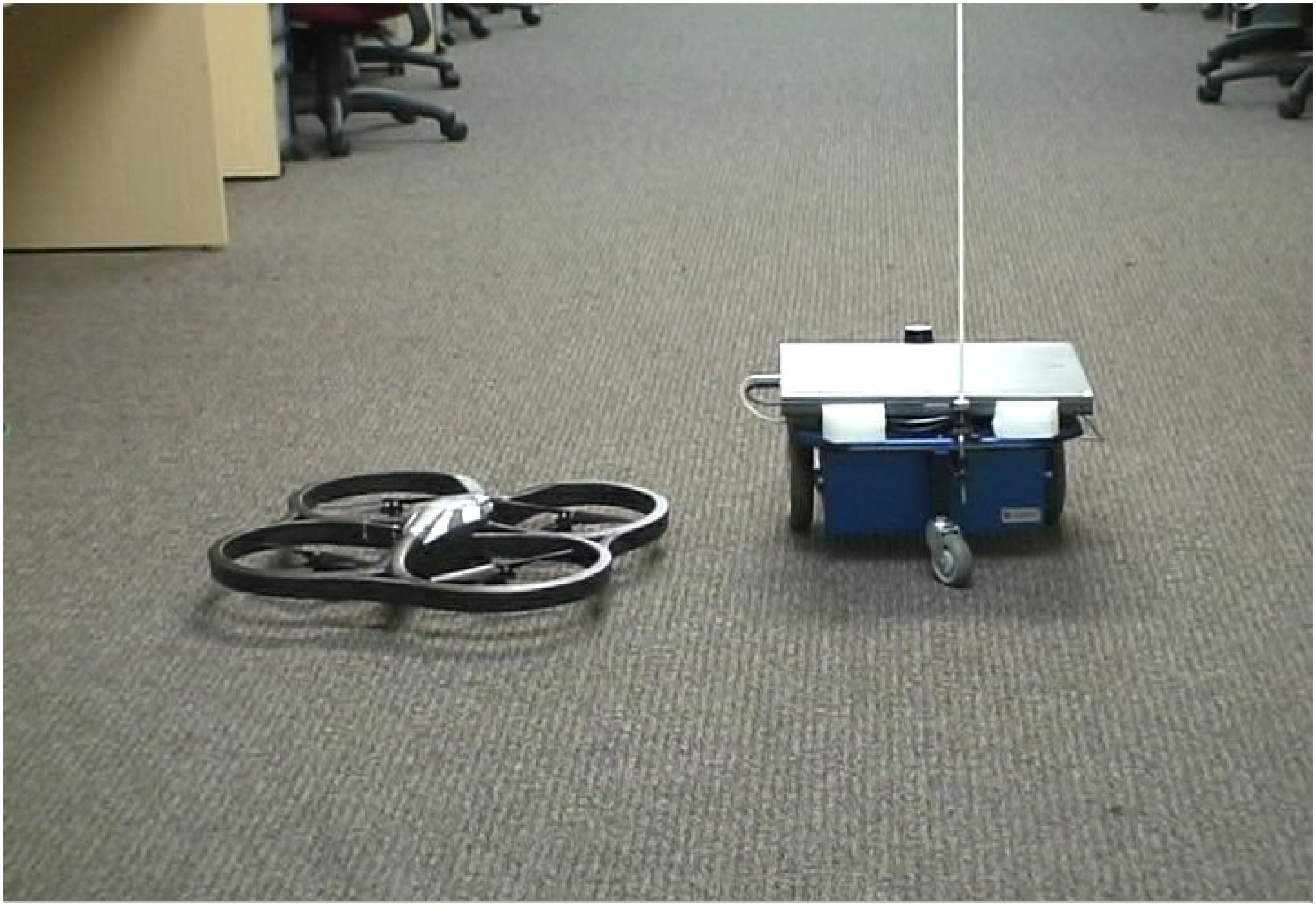

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DIARC AT WORK
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USING INTROSPECTION TO DISCOVER NEW FUNCTIONS

A robot is performing mission, when it gets a new order:

H: I have a new order for you. Go to Nav Point 4 and inspect all suspicious objects.

The robot immediately attempts to simulate the goal and determines that it cannot complete it because the "examine objects" perception action fails (due to the fact that the robot does not have a camera and therefore no vision processing component instantiated). It reports the problem to the human operator:

R: I cannot achieve the goals because I do not have a way to examine objects.
H: Okay, come back and I will get you a camera.
R: Okay.

The robot postpones the goals from the order and returns to the base where human operator installs a camera. The camera causes a vision processing component to be started automatically, which, in turn, allows the robot to notice that it can now examine objects and continue the postponed task.

R: I am now able to examine objects, resuming postponed goals.

The robot then moves goes to Nav Point 4 and starts looking for suspicious objects. It detects a suspicious unattended object, reports it to the operator and starts inspection.

R: I found an unattended crate, moving to investigate.

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Tasking in natural language

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Simulation
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uncovers that the task cannot
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Automatic detection of new sensory device and auto-configuration of processing components, reflection on functional capabilities

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Continuation of previously postponed goal, target detection and automatic notification of operator

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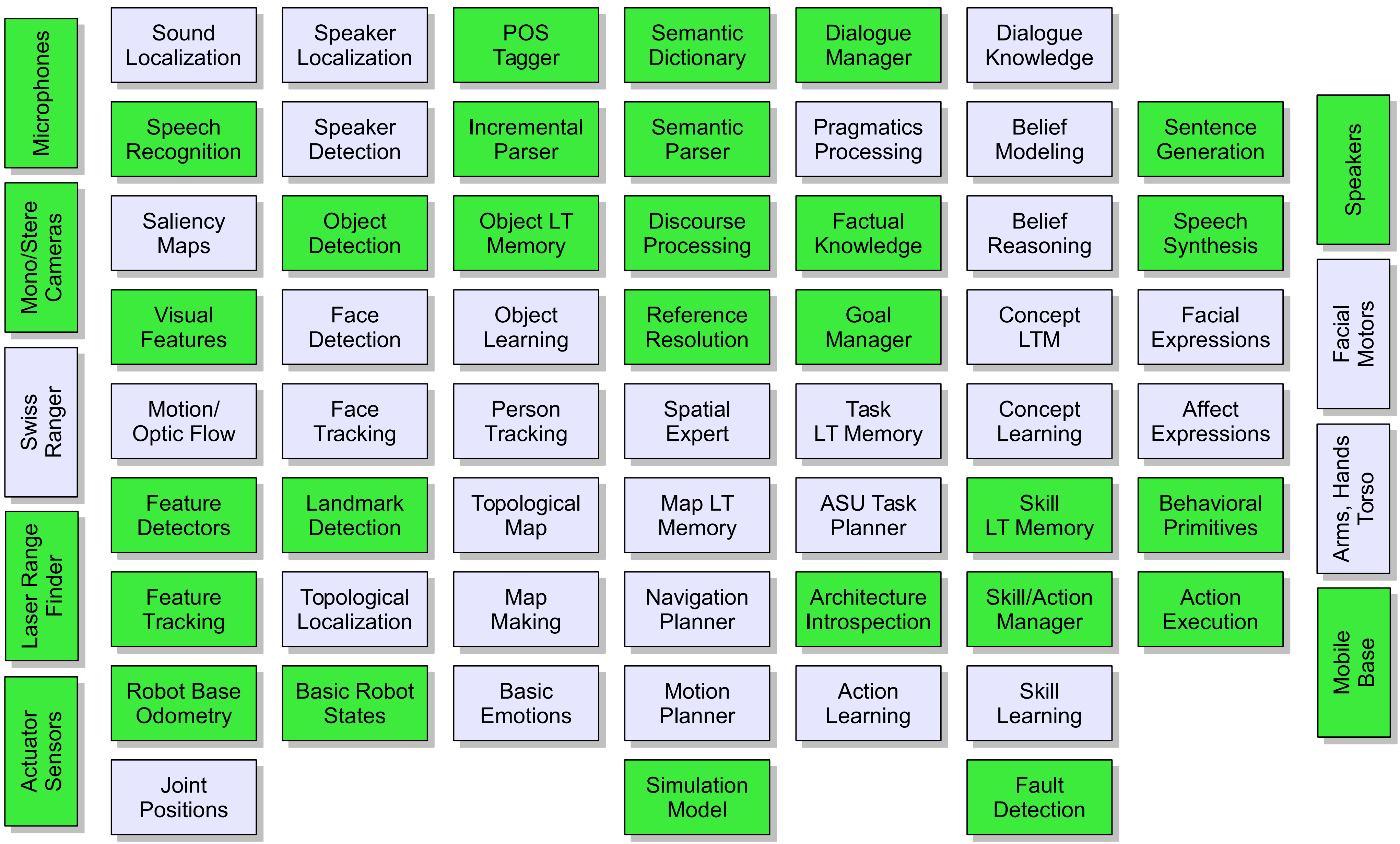

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LEARNING NEW ACTIONS AND PLAN OPERATORS FROM NL DIALOGUES

The robot is driving down the hallway as part of its task when a human operators asks it about it current goals.

H: What are your orders?
R: I have been ordered to listen for instructions, to go to the end of the hallway, and try to look for a red box.

The robot enters the next room with an open door, searches the room and exits without finding a red box. The robot then drives by a closed door. While it recognizes the door, it does not know what to do with it, hence it cannot search the room. At this point, the human operator provides a new knowledge item to the robot, from which the robot automatically extracts a rule/plan operator which it then can apply right away.

H: To go into a room when you are at a closed door, push it one meter.
R: Understood.

When the robot then encounters the next room with a closed door, it now quickly generates a new plan based on the new operator, which causes it to push the door open. It enters the room, starts to search it, and finds and report a red box which it would have otherwise missed.

R: There is a red box in Room 1.

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Goal query and automatic generation of natural language reports of current goals

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Explicit instruction of new rule/plan operator

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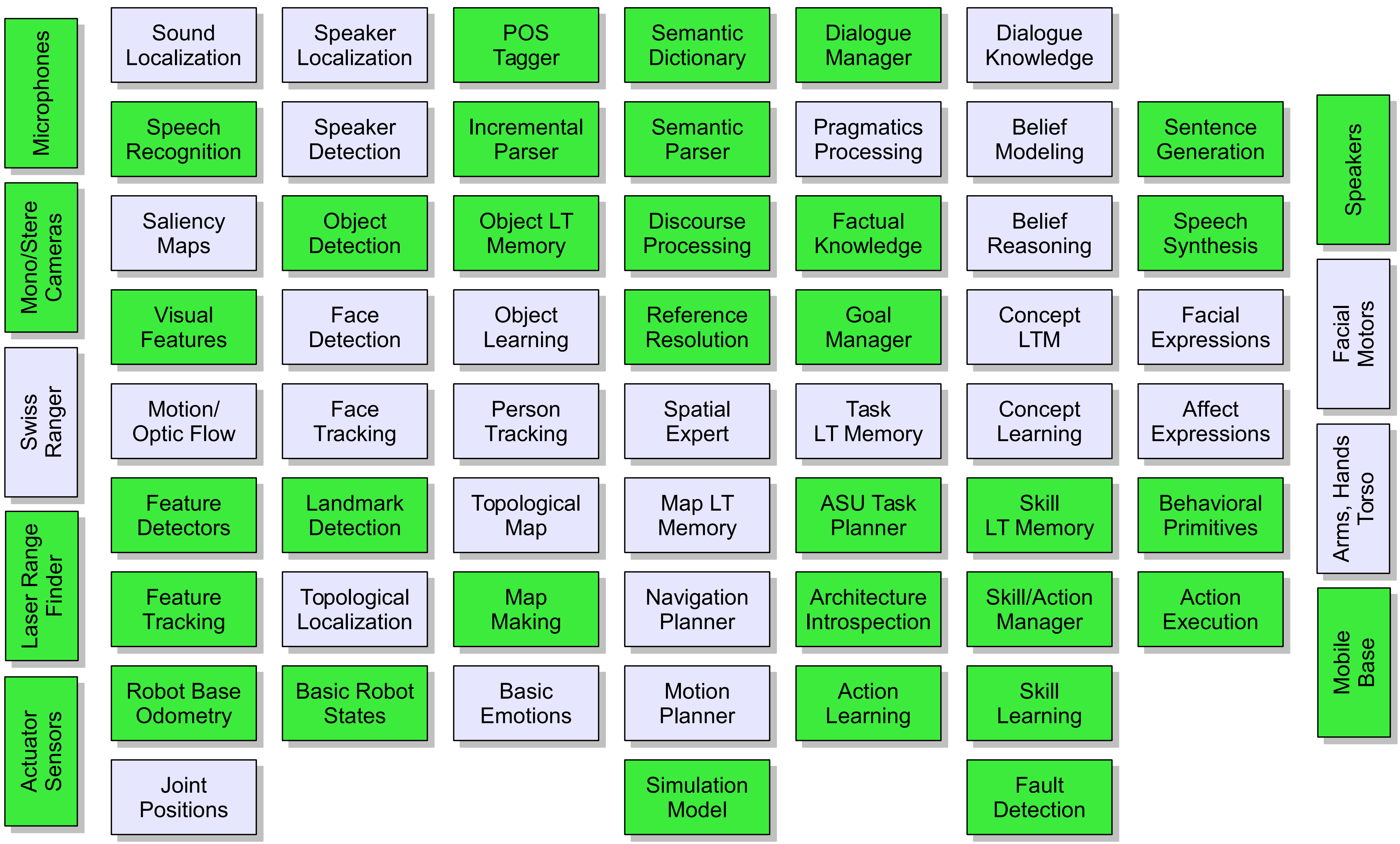
Operator update based on discovered target item

R: There is a red box in Room 1.

LEARNING NEW ACTIONS AND PLAN OPERATORS FROM NL DIALOGUES



LEARNING NEW ACTIONS AND PLAN OPERATORS FROM NL DIALOGUES

click on image to play video

DIARC AT WORK
EXAMPLE 5

- Six examples of **natural dialogue-based HRI** with **DIARC** running on **five different ground and aerial robots** (**Videre**, **AR Drone**, **Segway**, **MDS**, **Pioneer, PR2**), in **indoor and outdoor single and multirobot interactions**
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PERCEPTUAL LEARNING AND DIALOGUE-BASED PRAGMATIC INFERENCE

A robot is driving through a building when its human commander contacts it.

H: Cindy, Commander Z really needs a medical kit.
H: There should be one in the room you are in.
R: Okay.
R: Understood. Commander Z really needs a medical kit.

The robot repeats the gist of the information and infers that this information might be a hidden request, thus asking to confirm whether it was indeed a implicit order.

R: Should I get one for him?
H: Yes.
H: He is in the room with the green door.

The robot first acknowledges the information about the room and then confirms that it understood the order by repeating the gist of it.

R: Okay.
R: I'll get one for him.

As the robot is forming its plan, it notices that it does not know what a medical kit looks like, hence it asks (and based on the description it is able to proceed).

R: What does it look like?
R: It is a white box with a red cross on it.
R: Okay.

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Implicit goal specification leading to open-world quantified goal inferred from NL expression and request confirmation through content repetition

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Explicit goal question based on inference about implicitly specified goal and additional specifications of relevant facts

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Goal confirmation and assurance through repetition inferred from pragmatic principles

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Perceptual learning based on natural language descriptions and action simulations

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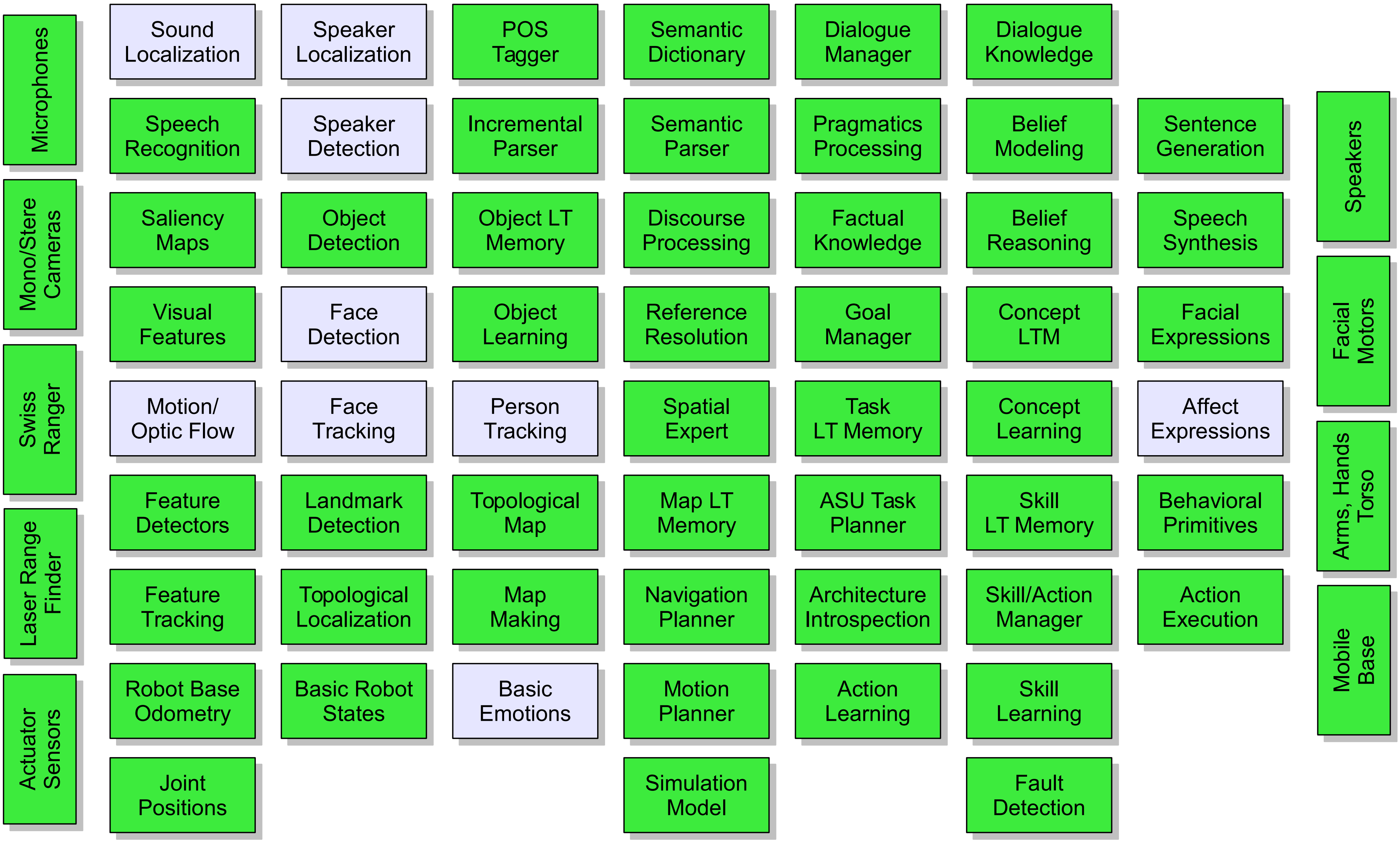

PERCEPTUAL LEARNING AND DIALOGUE-BASED PRAGMATIC INFERENCE

click on image to play video

ONE-SHOT ACTIVITY LEARNING AND MULTI-ROBOT TRANSFER

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ONE-SHOT ACTIVITY LEARNING

The robot is asked to perform a task it does not know how to perform, which it notices.

H: Aandy, please pick up the medkit.
A: I do not know how I pick the medkit up.
H: Let me show you.
A: Okay.

The instruction begins using a simple dialogue paired with visual demonstrations that allow the robot to resolve indexicals like "this" as well as positions.

H: Put your hand above the medkit with your palm down like this.
A: Okay.
H: Close your hand.
A: Okay.
H: Lift your hand.
A: Okay.

During the instructions, the robot pays attention to each step and records it.

H: And that's how you pick it up.
A: Okay.

The robot has learned the activity and is immediately able to perform it when asked.

H: Now you try.
A: Okay.

ONE-SHOT ACTIVITY LEARNING

- Microphones
- Mono/Stere Cameras
- Swiss Ranger
- Laser Range Finder
- Actuator Sensors

Sound Localization	Speaker Localization	POS Tagger	Semantic Dictionary	Dialogue Manager	Dialogue Knowledge	
Speech Recognition	Speaker Detection	Incremental Parser	Semantic Parser	Pragmatics Processing	Belief Modeling	Sentence Generation
Saliency Maps	Object Detection	Object LT Memory	Discourse Processing	Factual Knowledge	Belief Reasoning	Speech Synthesis
Visual Features	Face Detection	Object Learning	Reference Resolution	Goal Manager	Concept LTM	Facial Expressions
Motion/ Optic Flow	Face Tracking	Person Tracking	Spatial Expert	Task LT Memory	Concept Learning	Affect Expressions
Feature Detectors	Landmark Detection	Topological Map	Map LT Memory	ASU Task Planner	Skill LT Memory	Behavioral Primitives
Feature Tracking	Topological Localization	Map Making	Navigation Planner	Architecture Introspection	Skill/Action Manager	Action Execution
Robot Base Odometry	Basic Robot States	Basic Emotions	Motion Planner	Action Learning	Skill Learning	
Joint Positions			Simulation Model		Fault Detection	

- Speakers
- Facial Motors
- Arms, Hands Torso
- Mobile Base

ONE-SHOT ACTIVITY LEARNING

click on image to play video

ACKNOWLEDGMENTS

- Faculty collaborators: Kathleen Eberhard (U of Notre Dame), Sandra Kuebler (IU), Chitta Baral and Subbarao Kambhampati (ASU), Michael Zillich and Markus Vincze (TU Wien)
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- Papers available online at http://hrilab.tufts.edu/publications/