Spoken Human Robot Interaction

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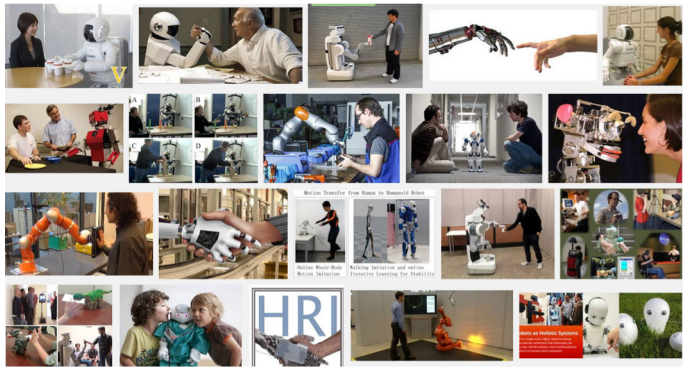
Robots and Humans



Robots and Humans

Service robots

Plan of this introduction

- Human Robot Interaction
  - Social Robots
  - Some examples
- Talking with robots
  - Command Interpretation
  - Dialog

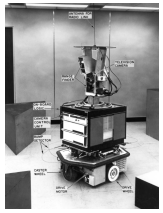
What is HRI?

"Human-robot interaction is the field of study dedicated to understanding, designing, and evaluating robotic systems for use by or with humans"

Dynamic Interaction (Goodrich, Schultz 2007, HRI)

Some temporal references

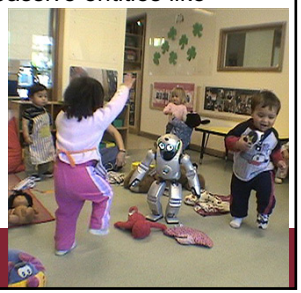
- 1992 – First IEEE Int. Symp. on Robot & Human Interactive Communication (RoMan)
- 1997 AAAI Hors d'oeuvres Anyone?
- 1999 IEEE RAS TC on Human-Robot Interaction & Coordination
- 2000 IEEE Humanoids
- 2006 ACM Int. Conf. Human-Robot Interaction
- 2006 RoboCup@Home
- 2009 Int. Conf. Social Robotics



HRI vs HCI

- Robots have (physical) bodies
- Robots act in the real world
- Robots are perceived as living entities
- Human-robot interaction is asymmetric (robots have not the same cognitive skills of humans)
- HRI is bidirectional (robots are not passive entities like computers!)

HRI is not a special case of HCI



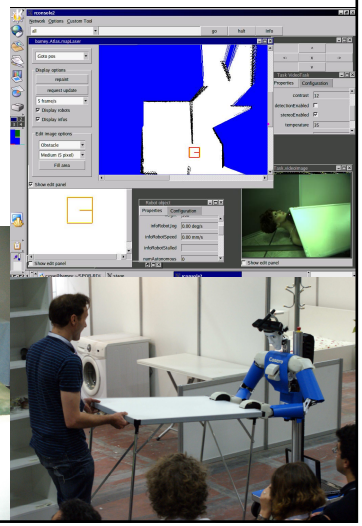
HRI: multidisciplinarity

HRI brings together a **variety of fields**, including:

- **engineering** (electrical, mechanical, industrial, and design),
- computer science (**human-computer interaction**, **artificial intelligence**, **robotics**, natural language understanding, and computer vision),
- **social sciences** (psychology, cognitive science, communications, anthropology, and human factors),
- **humanities** (ethics and philosophy).

HRI: settings

- Remote (Telepresence)
- Proximate (Co-location)
- Physical



Possible inputs (for the robot)

- Hand-held devices
- Speech
- Sound
- Touch

- Temperature
- Olfaction

People

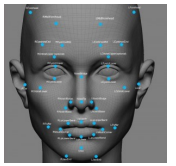
- Locomotion
- Gestures
- Race? Gender?

Head

- Gaze
- Facial Expressions

Possible inputs (vision)

– Face detection / tracking / recognition (including expressions)



– Person detection / tracking / recognition

Possible outputs (of the robot)

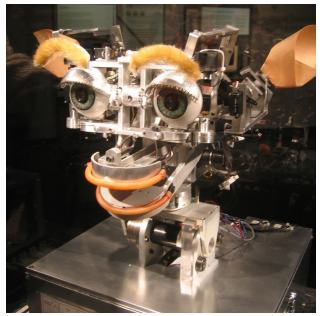
Body
- Position
- Speed

Head
- Turning
- Eye motion
- Facial expressions

Arms
- Grab/Hand objects
- Gestures
- Shake hands

- Speech
- Sound
- Lighting
- Smell

Possible outputs (of the robot)



HRI: application domains

ANY ROBOT !!!

Service Robotics and robots in our homes is one of the most compelling cases.

Social Robots

(e.g. Robots as dietary assistants)

"Intelligent" Robots

- at least: `not(stupid) robots`
- Gap between user expectations and robot functionality.
- Why?
  - limited capabilities of perception systems
  - difficulty of communicating with humans
  - ability to acquire, maintain and use knowledge

Our Approach: Symbiotic Autonomy

The concept

Enable a robot to get help from humans in the same fashion a person might be helped by another individual.

- Symbiotic autonomy[1] and symbiotic robotics[2]
- Exploit HRI to overcome the limitations of the robot

[1] *An effective personal mobile robot agent through symbiotic human-robot interaction*. Rosenthal, Biswas and Veloso.

[2] *Symbiotic robotic systems: Humans, robots, and smart environments*. Coradeschi and Saffiotti.

Are humans willing to help?

In the context of **Symbiotic Autonomy**

evaluate the **Collaboration Attitude** of humans

varying different factors:

- **Activity context**
- **Proxemics**
- **Gender**
- **Height**

Our approach: Small is beautiful

The concept

Acquire very detailed knowledge about the operational requirements through a continuous interaction

1. Environment (Semantic Map)
2. Tasks
3. User

Semantic Mapping

Herzberg & Nuchter, 2008

A semantic map for a mobile robot is a map that contains, in addition to spatial information about the environment, assignments of mapped features to entities of known classes.

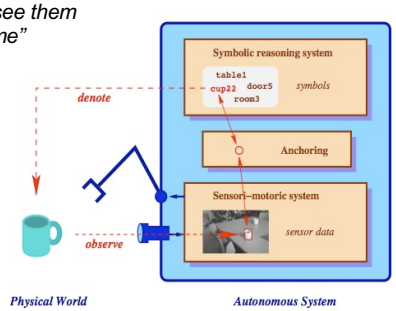
Semantic maps allow the robot to…

- …perform reasoning over environments, objects and properties
- …communicate with humans, understanding complex commands
- …perform complex tasks

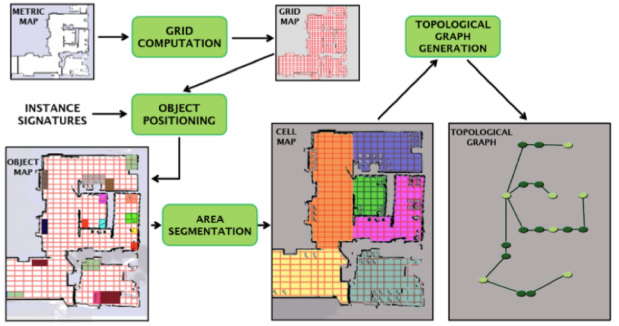
Symbol Grounding

"For things to exist there are two essential conditions, that a man should see them and be able to give them a name"
(*Saramago, 1995*)

- Symbol grounding (*Harnad*, 1990)
- Anchoring (*Saffiotti*, 1994)

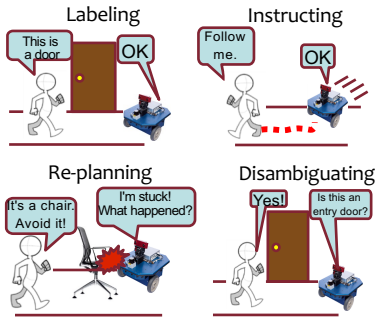


Cell Map and Topological Graph Generation



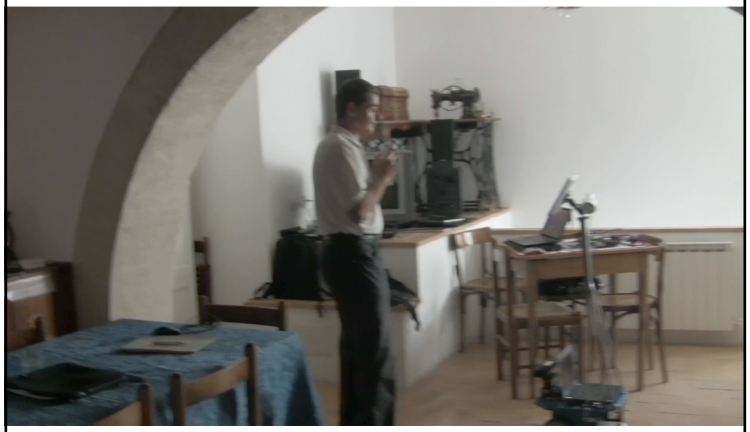
Human Augmented Methods

- Human-in-the-loop
- Human-Robot uni-modal or multi-modal interaction
- Integration with perception
- Clarification dialogues



Diosi *et al.*, Zender *et al.*, Kruijff *et al.*, Nieto-Granda *et al.*, Pronobis and Jensfelt, Randelli *et al.*

Basic Knowledge Acquisition (home)



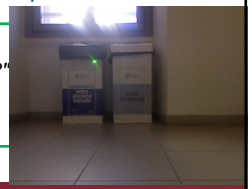
Example dialogs

Knowledge from the map for disambiguation

User: *"Go to the socket.".*
Robot: *"There are many sockets. Which one do you mean?"*
User: *"The one close to the emergency door."*
Robot: *"OK. I am going to the socket close to the emergency door."*

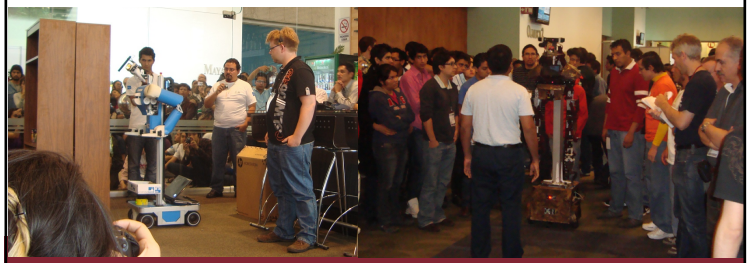
Knowledge from the map combined with perception

User: *"Throw the paper in the garbage bin.".*
Robot: *"There are many garbage bins. Which one?"*
User: *"The blue one."*
Robot: *"OK. I am going to the blue garbage bin."*



RoboCup@Home

- Development of Domestic Service Robots
  - Complex Integrated Systems
  - Large variety of tasks
  - Human-Robot Interaction



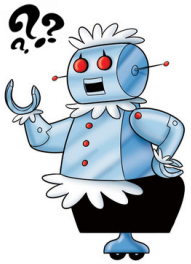
HRI and semantic map

Take the screwdriver on platform 1 …

Human Robot Interaction
within
RoboCup@Work scenarios

Learning Tasks from the User

- Robots face difficulties not envisioned by their developers at programming time
- Tasks specialized and adapted to the needs of specific users and environments



1. Learning parametric task descriptions that are defined as a combination of primitive actions
2. Learning primitive actions (e.g. handover)

Teaching parametric tasks

Bring @object to @location

Spoken Human-Robot Interaction

- Design robotic systems that exhibit a natural and effective interaction with users
  - spoken language
  - guiding touch
  - gestures
  - gaze
  - visual demonstration

- Natural Language is a ***natural*** way of communicating

Not really convinced…

- Why don't we use a dedicated UI?
  - Touch
  - Artificial Language
  - Gestures
- Because an artificial UI requires training and NL is the most efficient and natural way of communicating
  - Elder
  - Kids
  - Lazy people

Challenges in Spoken Human Robot Interaction

- The input signal (sound) is highly noisy (unless very constrained)
- Natural Language is inherently ambiguous
  - Natural Language (English or Italian are highly ambiguous)
    - Syntactic: Jordan could write more profound essays – "more" what?
    - Semantic: *Prostitutes appeal to the Pope* (real life headline) - appeal may mean both "to be liked by someone" and "to seriously request for help"
- Natural Language Interpretation is highly dependent on context

Interpreting commands

Goal performance evaluation in command understanding

- open the blinds
- get me the mug
- robot please find my glasses

Outcome HURIC data set

Interpreting commands – increasing complexity

could you please find the remote controller of the television and bring it to the kitchen

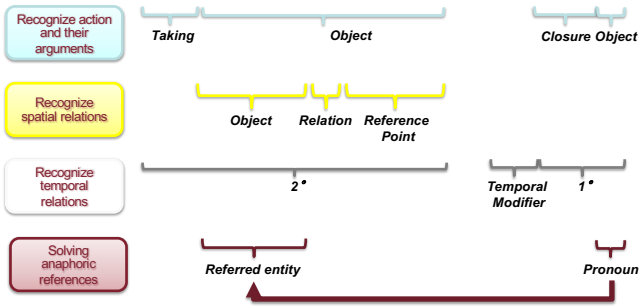
```
LOCATING(phenomenon:"the remote controller of the television")#
BRINGING(theme:"it",goal:"to the kitchen")
```

go to the bathroom, take the soap, and bring it to the side-table

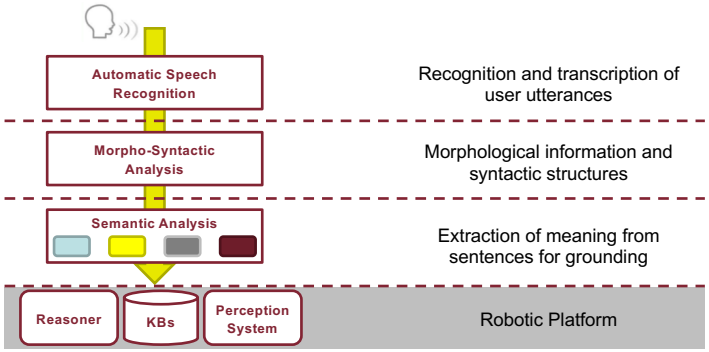
```
MOTION(goal:"to the bathroom")#TAKING(theme:"the
soap")#BRINGING(theme:"it",goal:"to the side-table")
```


Interpreting commands

"take the bottle on the table but first open it"



SLU for interpreting commands: typical pipeline



SLU for interpreting commands: approaches

Grammar-based	Data-driven
Hand-crafted grammar development	Learning from data
Parsing	Statistical models rather than grammars
Limited coverage (structure+lexicon)	Generalization (structure+lexicon)
High performance on specific domains	Over/Under-fitting risk

Grammar-based vs. data-driven

- **S4R[1]** (Speaky 4 Robots)
  - Grammar-based
  - Language is domain-specific
  - Interpretation is application-dependent
- **LU4R[2]** (adaptive spoken Language Understanding 4 Robots)
  - Data-driven
  - Language is domain-driven
  - Interpretation is context-sensitive

S4R: *Speaky For Robots*

A tool for generating spoken command interpretation

- Based on
  - **Hand-crafted grammar**
    - reflecting domain-specific linguistic phenomena
  - **Frame Semantics [Fillmore, 1985]**
    - psycho-linguistic theory about the lexicon
    - semantic frames (e.g. *Motion*, *Taking*, …) correspond to situation evoked by the lexicon
    - each frame involves different semantic arguments (e.g. GOAL, THEME)
  - **Microsoft Speech Recognition API**
- SLU performed in a single step (ASR, Morpho-syntactic, Semantic)
- Controlled language

```
S      -> Verb, Object
Verb   -> "take" | "grab" | …
Object -> "bottle" | "glass" | …
…
```

Emanuele Bastianelli, Daniele Nardi, Luigia Carlucci Aiello, Fabrizio Giacomelli, Nicolamaria Manes, "Speaky for robots: the development of vocal interfaces for robotic applications", *In Applied Intelligence*, vol. 44, no. 1, pp. 43-66, 2016.

LU4R: *adaptive spoken Language Understanding chain For Robots*

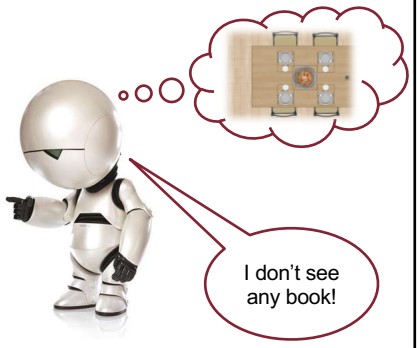
A Spoken Language understanding tool for robotic commands

- Based on
  - **Frame Semantics [Fillmore, 1985]**
    - psycho-linguistic theory about the lexicon
    - semantic frames (e.g. *Motion*, *Taking*, …) correspond to situation evoked by the lexicon
    - each frame involves different semantic arguments (e.g. GOAL, THEME)
- ..and relies on
  - **A cascade of data-driven processors**
  - **Perceptual evidence**
    - Interpretation depends on the environment (e.g. semantic map)

Bastianelli, E., Croce, D., Vanzo, A., Basili, R., Nardi, D.: **A discriminative approach to grounded spoken language understanding in interactive robotics**. In: *Proceedings of the Twenty-Fifth International Joint Conference on Artificial Intelligence*, IJCAI 2016, New York, USA (July, 9–15 2016)

Connection with perception

"bring me the book"



Proposed approach: dialogic interactions

- Improve by interacting with the user
  - The user instructs the robot to fill the gaps
- Interactions require a Spoken Dialogue System (SDS)

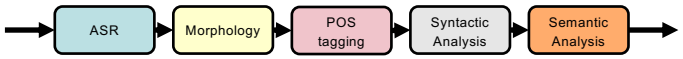
```
User: bring me the book
Robot: I don't see any book. Where is the book?
User: follow me
Robot: Okay, I'm following you!
            [The robot starts following the user]
User: okay stop
                    [The robot stops following]
User: now turn left
      [The robot turns left and the user points the book]
User: this is the book
...
```


Command Interpretation vs. Spoken Dialog Systems

- **Command interpretation**
  - Communication is an atomic processing of sentences
  - Each sentence is independent
  - Linguistic/Physical context irrelevant
  - The SLU process is enough to carry out the task
- **Dialogic interactions**
  - Communication is a sequence of turns (sentences)
  - Each sentence depends (at least) on the previous one
  - The dialogue state influences the flow
  - Implies: dialogue manager, SLU, dialogue state tracking, natural language generation, …

Plan of the lectures

- Command Interpretation
  - ASR (1)
  - Morpho-syntactic analysis (1,2)
    - Morphology
    - POS tagging
    - Syntactic Parsing
  - Semantic Analysis (3)



- Dialogue Management (4)
  - Rule-based
  - Statistical DM

Summary of introduction

- ***HRI is a critical feature for (service) robots***
- ***Speech is a powerful HR interaction channel***
- ***Spoken HRI is a an ideal framework to address the integration of symbolic and numerical reasoning***

Options in the curriculum to go deeper

Course Natural Language Processing

Course Elective in AI Section on Human Robot Interaction

References (read at least one)

E. Bastianelli, D. Croce, A. Vanzo, R. Basili, D. Nardi, "A Discriminative Approach to Grounded Spoken Language Understanding in Interactive Robotics", *In Proceedings of IJCAI 2016, New York, NY, USA, 9-15 July 2016*, pp. 2747-2753, 2016.
https://www.ijcai.org/Proceedings/16/Papers/390.pdf

G. Gemignani, R. Capobianco, E. Bastianelli, D. Bloisi, L. Iocchi, D. Nardi, "Living with Robots: Interactive Environmental Knowledge Acquisition", *In Robotics and Autonomous Systems*, vol. 78, pp. 1-16, 2016.
http://www.dis.uniroma1.it/~gemignani/documents/papers/15-ras.pdf

G. Gemignani, E. Bastianelli, D. Nardi, "Teaching Robots Parametrized Executable Plans Through Spoken Interaction", *Proceedings of AAMAS 2015*, pp. 851-859, 2015.
http://www.dis.uniroma1.it/~gemignani/documents/papers/15-aamas.pdf