Human Robot Interaction

Session 3

Dr. Anaís Garrell

Recap

1. Interfaces and interaction modalities
2. User-centered design of social robots

Recap

1. Interfaces and interaction modalities
    a. Multi-modal means of interaction
    b. Gestures based interfaces
    c. Handheld Interfaces Speech/Vision
    d. Major issue in HRI
2. User-centered design of social robots

Recap

1. Interfaces and interaction modalities
2. User-centered design of social robots

Recap

1. Interfaces and interaction modalities
2. User-centered design of social robots
    a. Aesthetic Body
    b. Aesthetic Face
    c. Human-like body
    d. Body and Brain must Match

Today's Content

1. Social learning and skill acquisition via teaching and imitation
2. Robots in education, therapy and rehabilitation
3. Evaluation methods and methodologies for HRI research

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Learning Modes

Explicit Learning:
Reinforcement
Verbal instructions

Implicit Learning:
Observational learning
Imitation learning

Learning

Why should a robot learn?

Why do animals learn?

Learning

How can learning have evolved?

E. Wilson, *Sociobiology*, Belknap Harvard, 2000

Learning

How can learning have evolved?

- *Learning serves as a pacemaker for evolution,*

E. Wilson, *Sociobiology*, Belknap Harvard, 2000

Learning

How can learning have evolved?

- *Learning serves as a pacemaker for evolution,*
- *When exploratory behavior leads to a breakthrough for the survival of the species, the capacity for that kind of exploratory behavior and the imitation of this act is favored by* ***natural selection****.*

E. Wilson, *Sociobiology*, Belknap Harvard, 2000

Learning

When should a robot learn?

When and How much prior knowledge should be built- in?

Learning

Why would we spend time teaching a robot?

User-friendly platform → Adapted to our needs, wishes

What duration of training time is acceptable (speech engines....) ?

Learning

Why would we spend time teaching a robot?

User-friendly platform ⟶ Adapted to our needs, wishes

What duration of training time is acceptable (speech engines….) ?

What would motivate us to teach the robot?

Need rewards, dialogue, natural means of interactions, cute-friendly features, jokes?

Learning

Calinon, S. and Billard, A. (2007) **Incremental Learning of Gestures by Imitation in a Humanoid Robot**. in Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction (HRI).

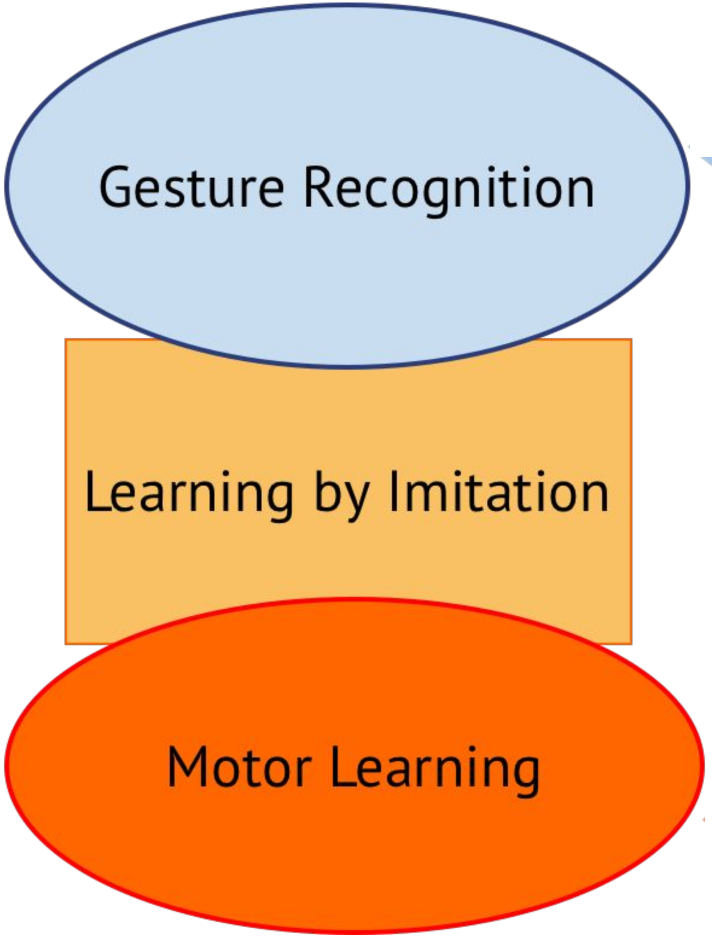
Learning

Gesture Recognition
How are actions perceived?
How is information parsed?

Imitation
Level of granularity: What is copied?
Should it copy the intention,
goal or dynamics of movement?

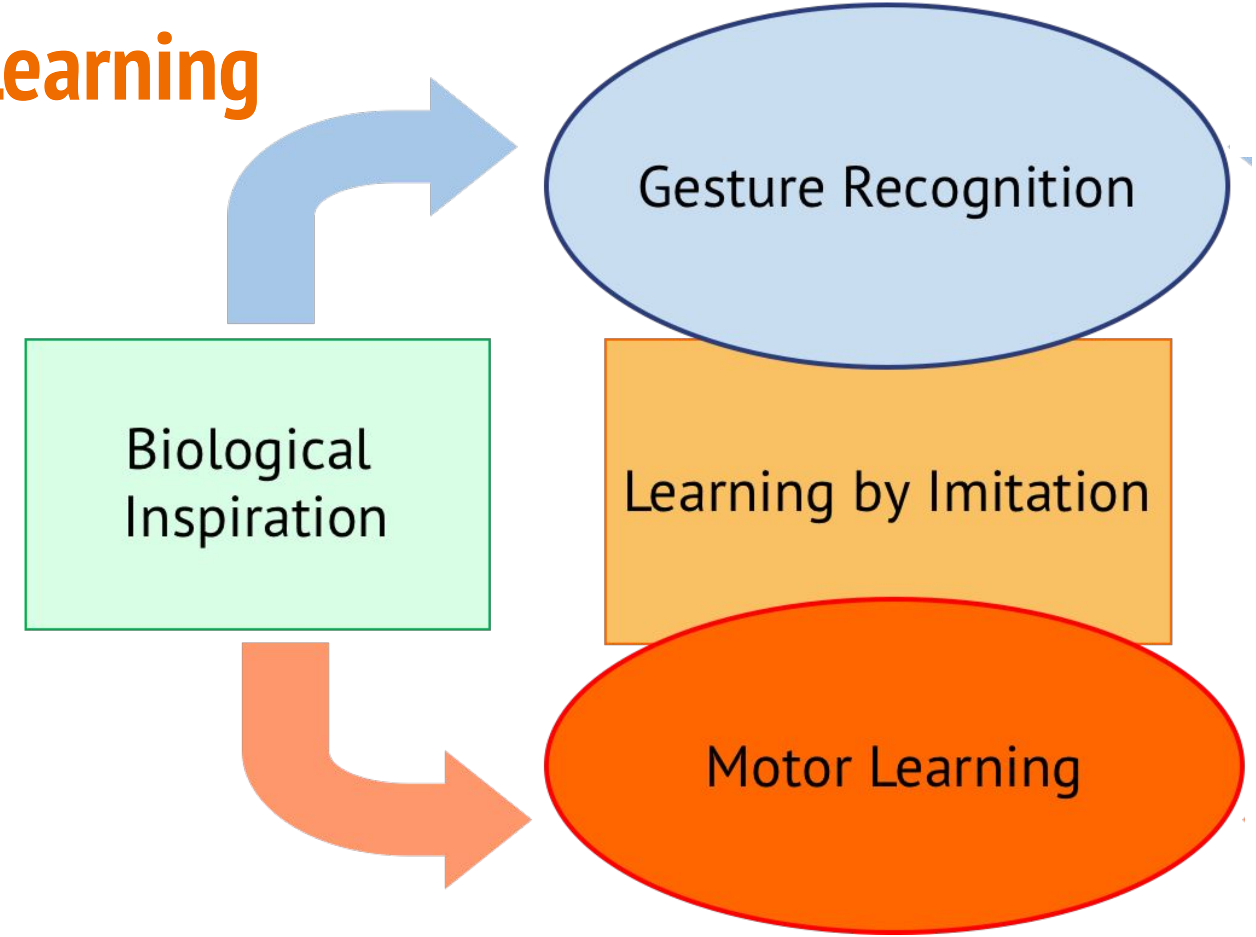
Motor Learning
How is information transferred
across multiple modalities?
Visuo-motor, Auditor-motor

Learning



Gesture Recognition
Learning by Imitation
Motor Learning

Learning


Gesture Recognition
Biological Inspiration
Learning by Imitation
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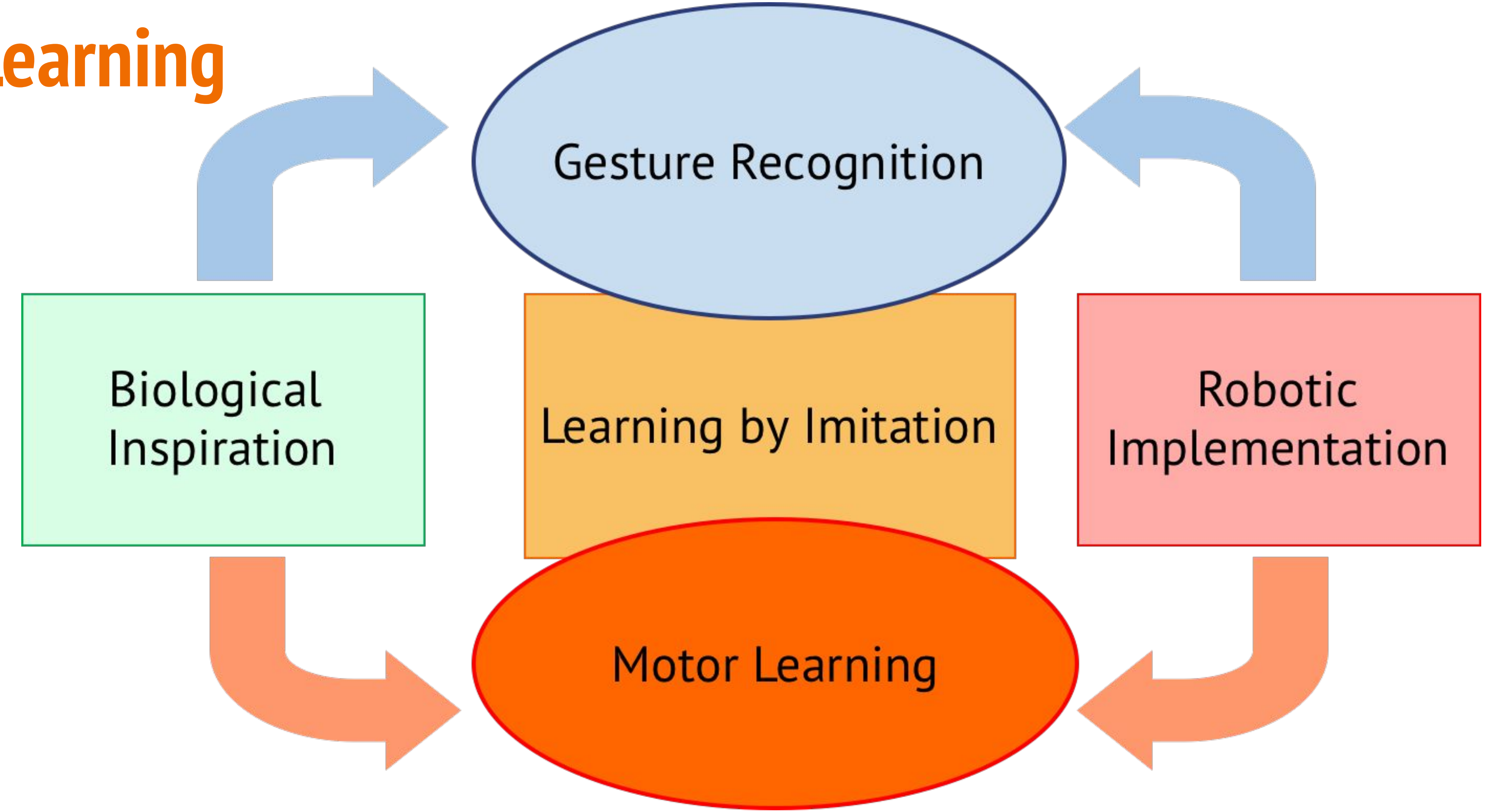
Learning


Gesture Recognition
Biological Inspiration
Learning by Imitation
Robotic Implementation
Motor Learning

Learning - Biological Inspiration

Prior to building any capability in robots, we might want to understand how the equivalent capability works in humans and other animals

Learning - Biological Inspiration

Biological Inspiration

Imitation Capabilities in Animals

Which species may exhibit imitation is still a main area of discussion and debate

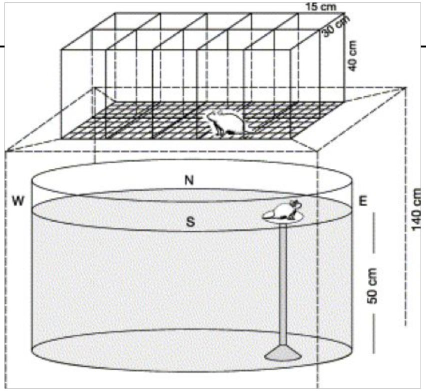
One differentiate “true” imitation from copying (flocking, schooling, following), stimulus enhancement, contagion or emulation

Learning - Biological Inspiration

Biological Inspiration

Imitation Capabilities in Animals

- Copying and Mimicry: Rats, Monkeys
- Observe companion actor **rats** performing different spatial tasks differing according to the experimental requirements. After the observational training, surgical ablation to block any further learning



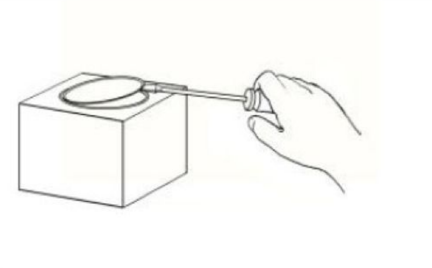
- Legio et al, *Brain Res. Protocols, 2003*
- Heyes, *Trends in Cog. Sciences*, 2001

Learning - Biological Inspiration

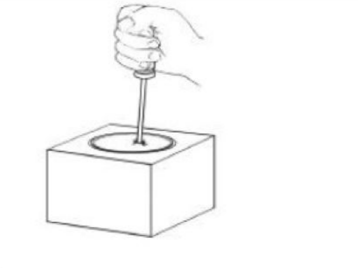
Biological Inspiration

Imitation Capabilities in Monkeys

Subjects who saw the Lever demonstrations tended to use a levering movement to pop open the lid whereas subjects who viewed Poke, as well as the controls, did not display this behavior at all.



Lever technique: use the tool to pop open the lid



Poke technique: use the tool to poke through the lid

- Whiten et al, *Journal of Comparative Psychology, 1996*

Learning - Biological Inspiration

Biological Inspiration

Imitation Capabilities in Animals

- "True" imitation: Ability to learn new actions not part of the usual repertoire
- The appanage of humans only, and possibly great apes

- Whiten & Ham, *Advances in the Study of Behaviour, 1992*
- Savage & Rumbaugh, *Child Devel, 1993*

Learning - Biological Inspiration

Biological Inspiration

Imitation Capabilities in Animals

- Complex Imitation capabilities in Dolphins & Parrots. Large repertoire of imitation capabilities, demonstrating flexibility and generalization in different contexts.

- Moore, *Behaviour, 1999.*
- Herman, *Imitation in Animals & Artifacts, MIT Press, 2002*

Learning - Biological Inspiration

Biological Inspiration

Developmental Stages of Imitation

- Innate Facial Imitation (newborns → 3 months)
  Tongue and lips protrusion, mouth-opening, head movements, cheek and brow motion, eye blinking
- Delayed imitation up to 24 hours

→ Imitation is mediated by a stored representation

Meltzoff & Moore, *Early Development and Parenting, 1997*
Meltzoff & Moore, *Developmental Psychology, 1989*

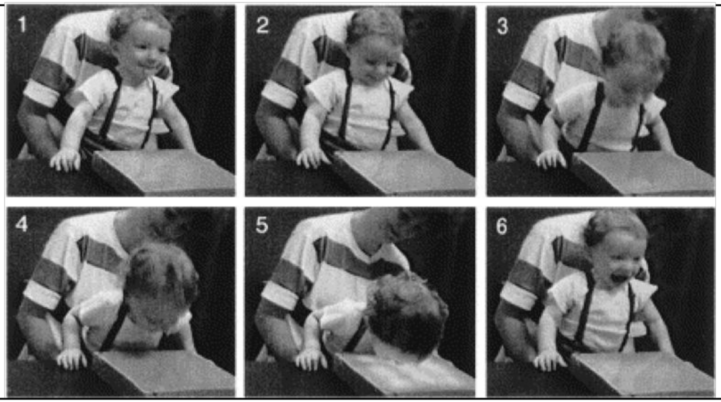
Learning - Biological Inspiration

Biological Inspiration

Developmental Stages of Imitation

- Deferred and delayed imitation - 18 month (Piaget), 9-12 months (Meltzoff)
- Deferred imitation of novel behavior

67% of the infants who saw the display reproduced the act after the week's delay, as compared to 0% of the control infants who had not seen the novel display.



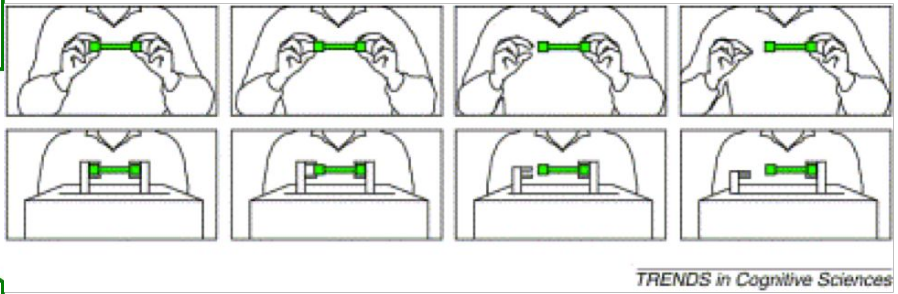
- Piaget, *Play, Dreams and Imitation in Infancy, 1962 ;*
- Meltzoff, *Body and the self, 1995*

Learning - Biological Inspiration

Biological Inspiration

Goals and Intentions

- 18-months infants
- Differentiate between human and machine demonstration
  → Attribute intentions only to the human
- Learn from unsuccessful examples



- Meltzoff, *Dev. Psychol.* ***31***, *1995.*

Learning - Biological Inspiration

Biological Inspiration

Imitation in adults

- Reaches highest level of complexity
- Is present in all activities:

Social influence in establishing group norms; *collective frame of reference*, transmission of phoebias

Learning - Biological Inspiration

Advantages: When is Imitation useful?

- It is a powerful means of transferring skills
- It speeds up the learning process by showing possible solutions or conversely by showing bad solutions

Learning - Biological Inspiration

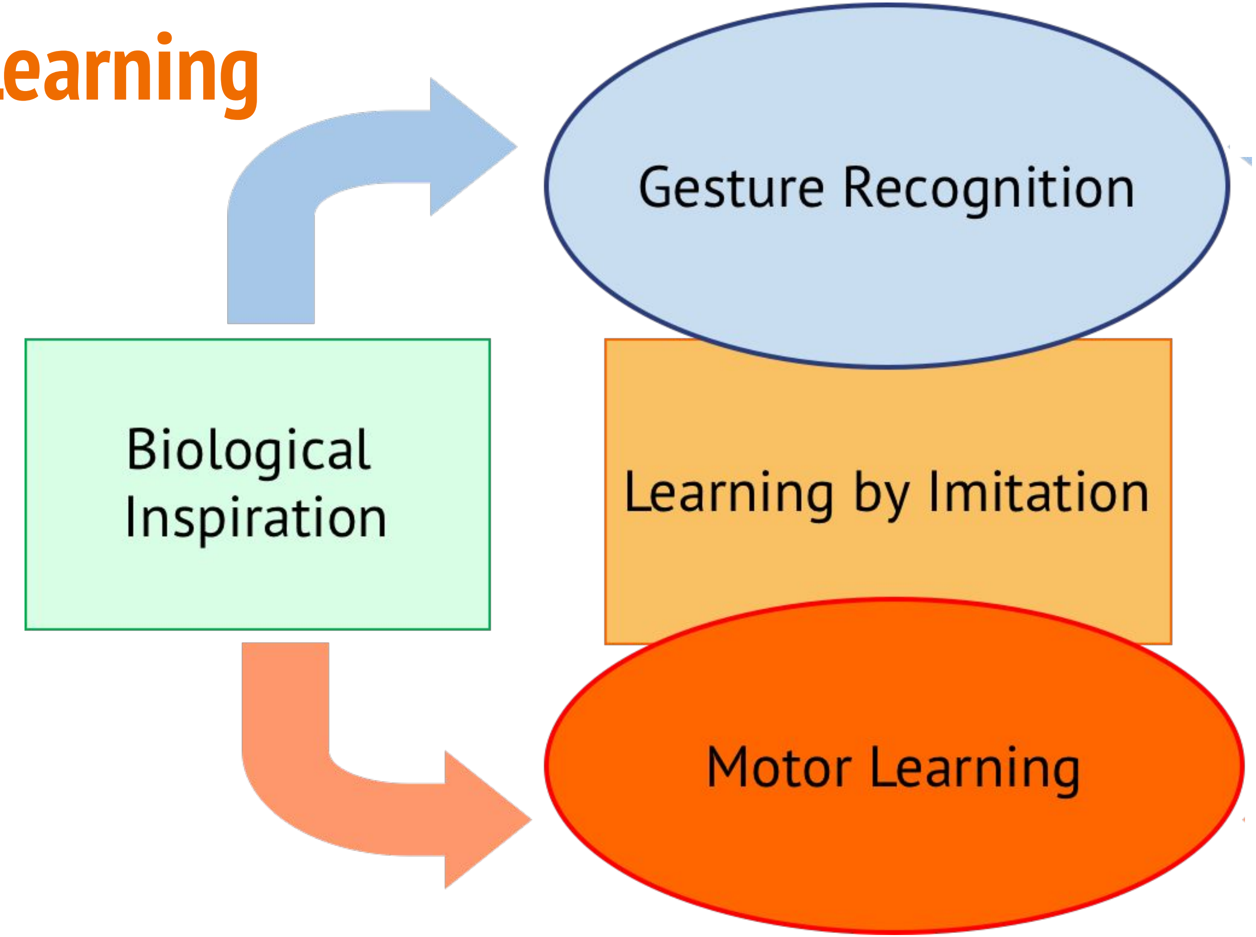
Disadvantages:

When is Imitation not useful?

Not appropriate: When a good solution for the teacher is not a possible solution for the learner

Disadvantageous: When it induces you in error - bad teacher (e.g. phobia of spiders)

Learning


Gesture Recognition
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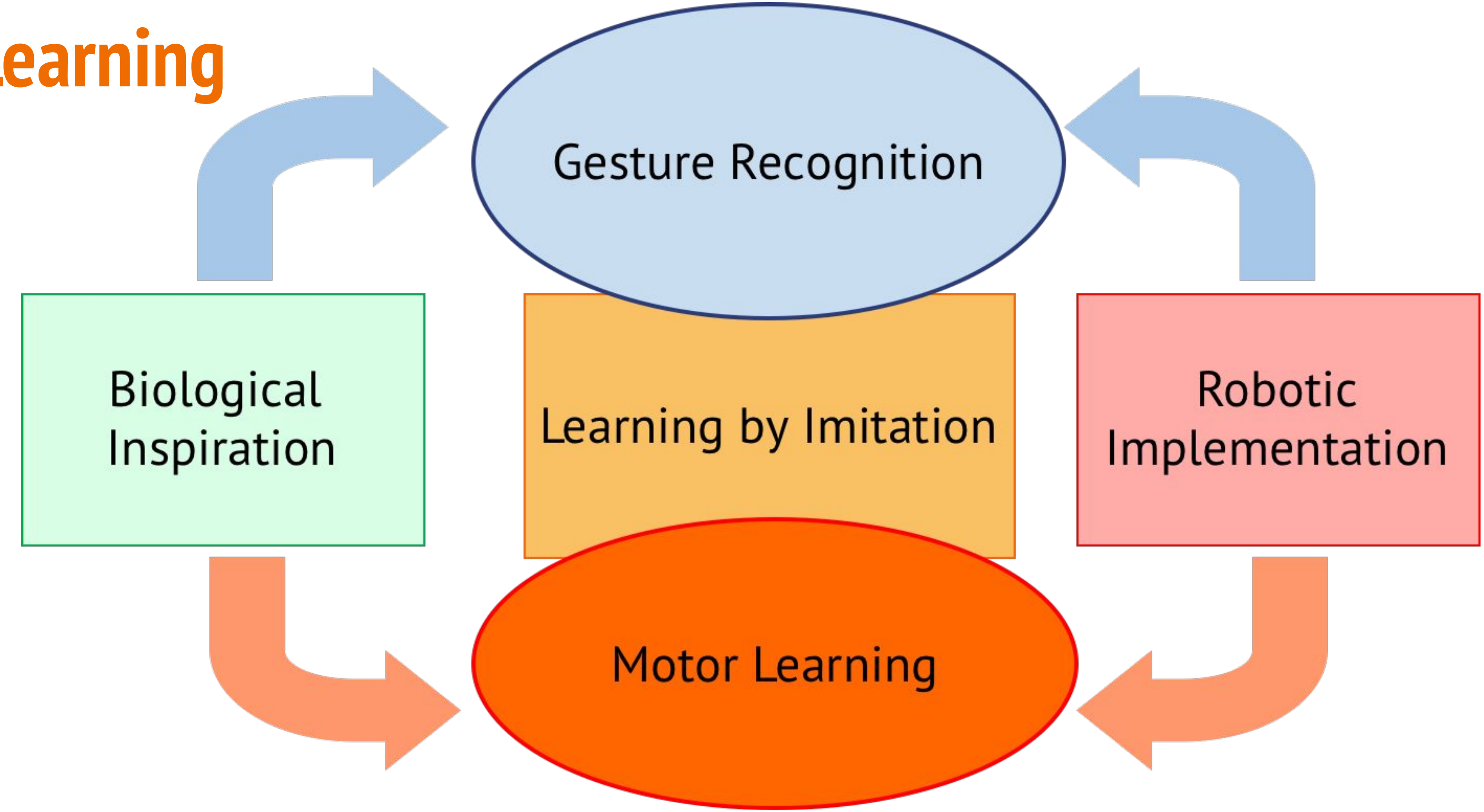
Learning by Imitation
Motor Learning

Learning



Gesture Recognition
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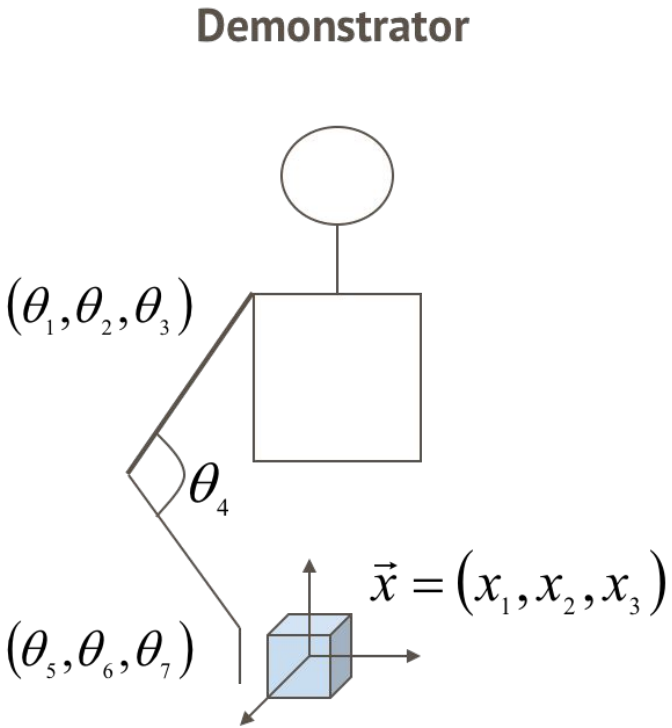
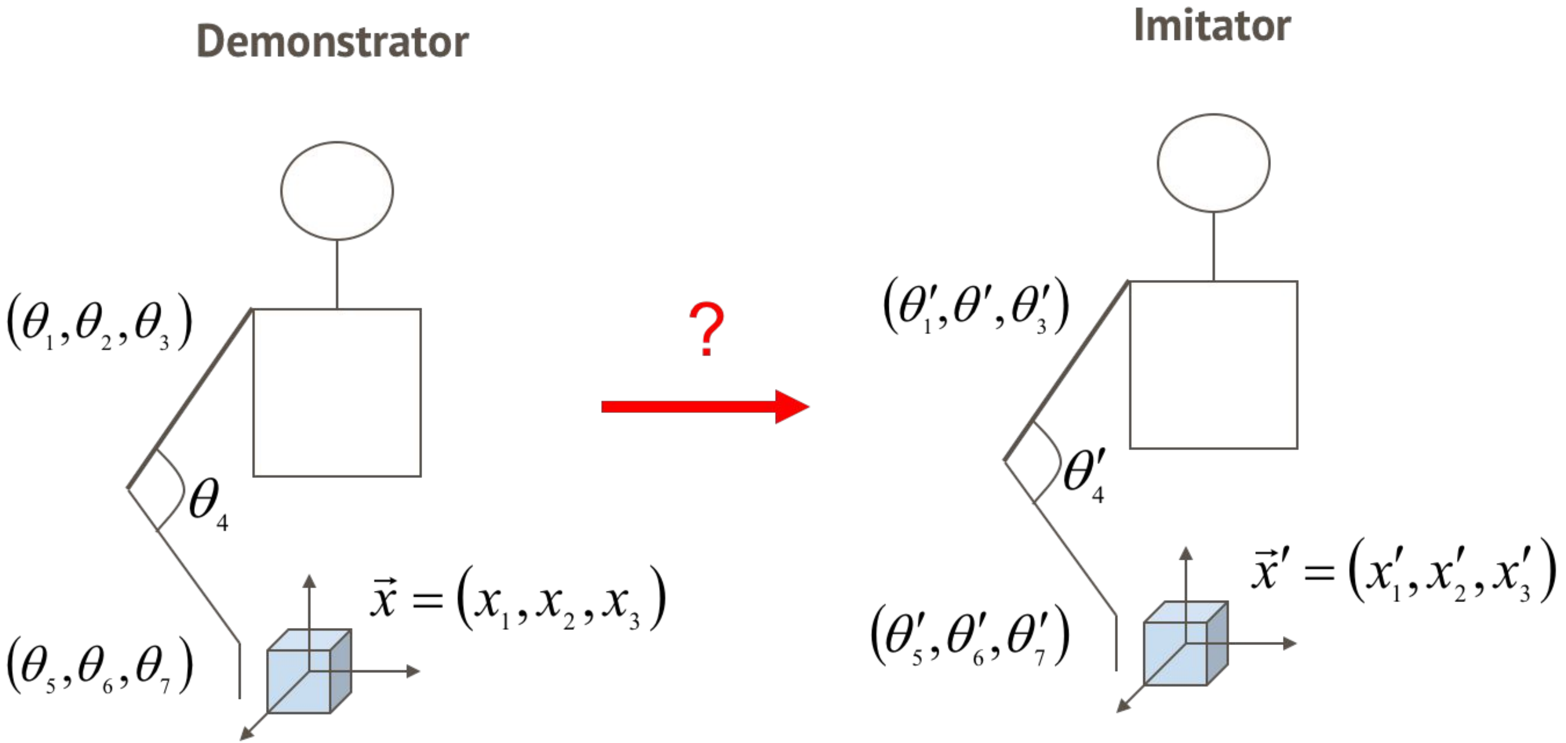
The Transfer Problem

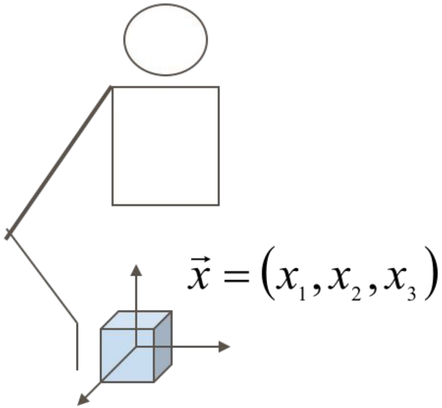


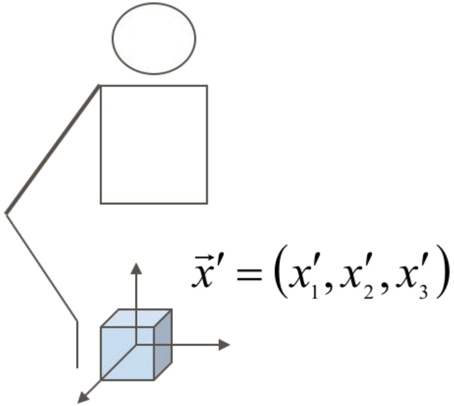
The Transfer Problem



The Transfer Problem

$\vec{x} = \vec{x}'$ **Same Object, same target location**





The Transfer Problem

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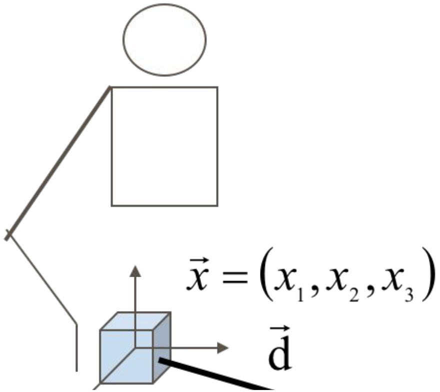
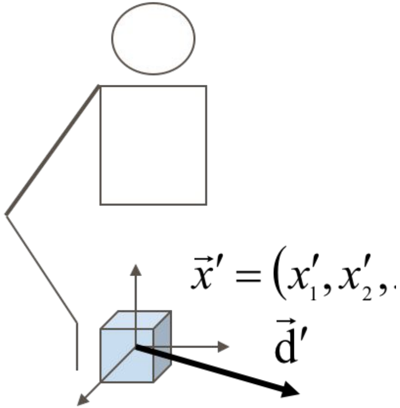
$\vec{\mathrm{d}} = \vec{\mathrm{d}}'$ **Same direction of motion**





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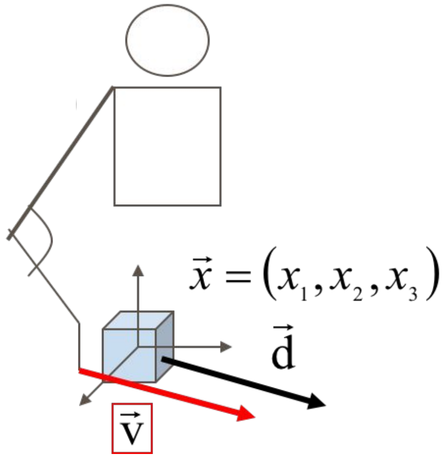

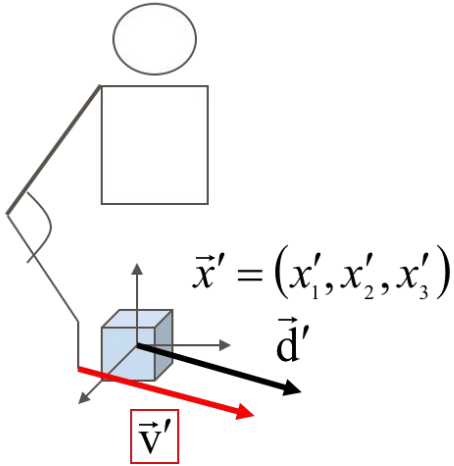

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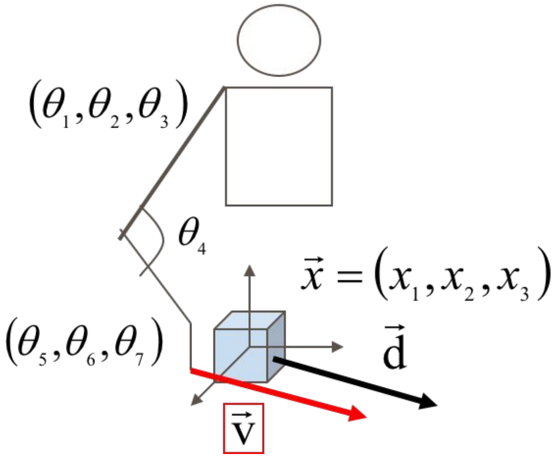
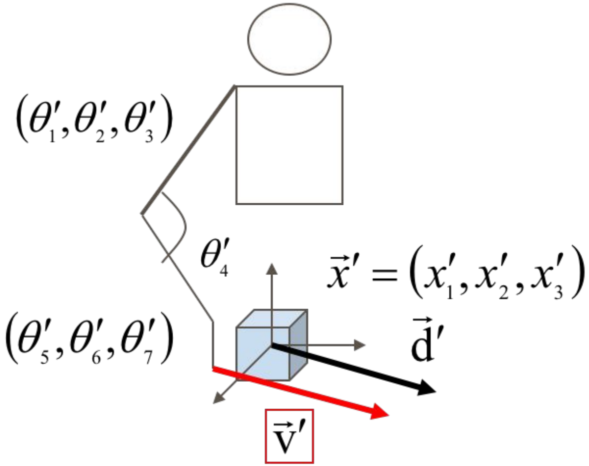
$\vec{\theta} = \vec{\theta}'$ **Same posture**





Learning: Robotic Implementation

Following – an imitation mechanism

- While following the teacher, the learner robot learns to associate a word with a meaning in terms of sensory inputs

http://calinon.ch/paper4007.htm

- Billard et al, ESANN'1997,
- Billard & Dautenhahn, *Robotics & Autonomous Systems 1998*,
- Billard & Hayes, 99,00

Robotic Implementation

Learning: Robotic Implementation

Following – an imitation mechanism

- Teaching path in a Maze
  Demiris & Hayes, 1994, 1996;

- Teaching how to climb a hill
  Dautenhahn, *Robotics & Autonomous Systems*, 1995

- Teaching a path in the environment
  Billard & Hayes, *Adaptive Behavior, 1999*
  Moga, Gaussier, Applied Artificial Intelligence, 2000
  Kaiser et al, *Robotics & Autonomous Systems, 2002*
  Nicolescu & Mataric, *AGENTS' 2003*

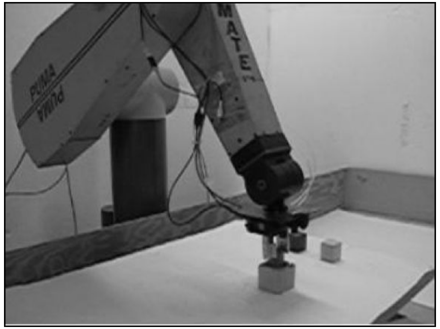
- Teaching a vocabulary
  Billard 1997, 1998, 1999
  Vogt & Steels, *ECAL, 1999*

Robotic Implementation

Learning: Robotic Implementation

One-Shot Learning Methods

- Segmentation of demonstration into primitives
- Classification of gestures into predefined states (e.g. grasp, collision)
- Built-in controller for producing sequences of states



- Kuniyoshi et al. IEEE Trans. on Robotics and Automation,1994.
- Dillmann et al, Robotics & Autonomous Systems, 2001.
- Ritter et al, Rev Neuroscience, 2003
- Aleotti et al, Robotics & Autonomous Systems, 2004.

Robotic Implementation

Learning: Robotic Implementation

One-Shot Learning Methods

Explicit teaching/learning:
-Reasoning about tasks
-Verbal instructions

Gesture Recognition:
For each sensor a context-dependent model based on background knowledge is provided: '*opening the refrigerator door*', '*extracting the bottle*' and '*closing the door*'

Task Reproduction:
Store action sequences in a tree-like structure of macro-operators

Robotic Implementation

R. Dillmann, Robotics & Autonomous Systems 47:2-3, 109-116 2004

Learning: Robotic Implementation

Robot Programming by Demonstration: Grasping

Because of the large range of possible shapes, generalizing pre-programmed grasps to new and general objects is a rather hard task:

- Orientation of the hand
- Positioning of the fingers (correspondence problem!)

Tactile forces, stable object contact

Robotic Implementation

Other related works are, e.g.:

- Kuniyoshiet al, ICRA, 1994
- Aleottiet al, *Robotics & Autonomous Systems, 47:2-3, 153-167,* 2004
- Zhang & Roessler, *Robotics & Autonomous Systems*47:2-3, 117-127, 2004

Learning: Robotic Implementation

Robot

Demon

Because of t
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rather hard t

- Orienta
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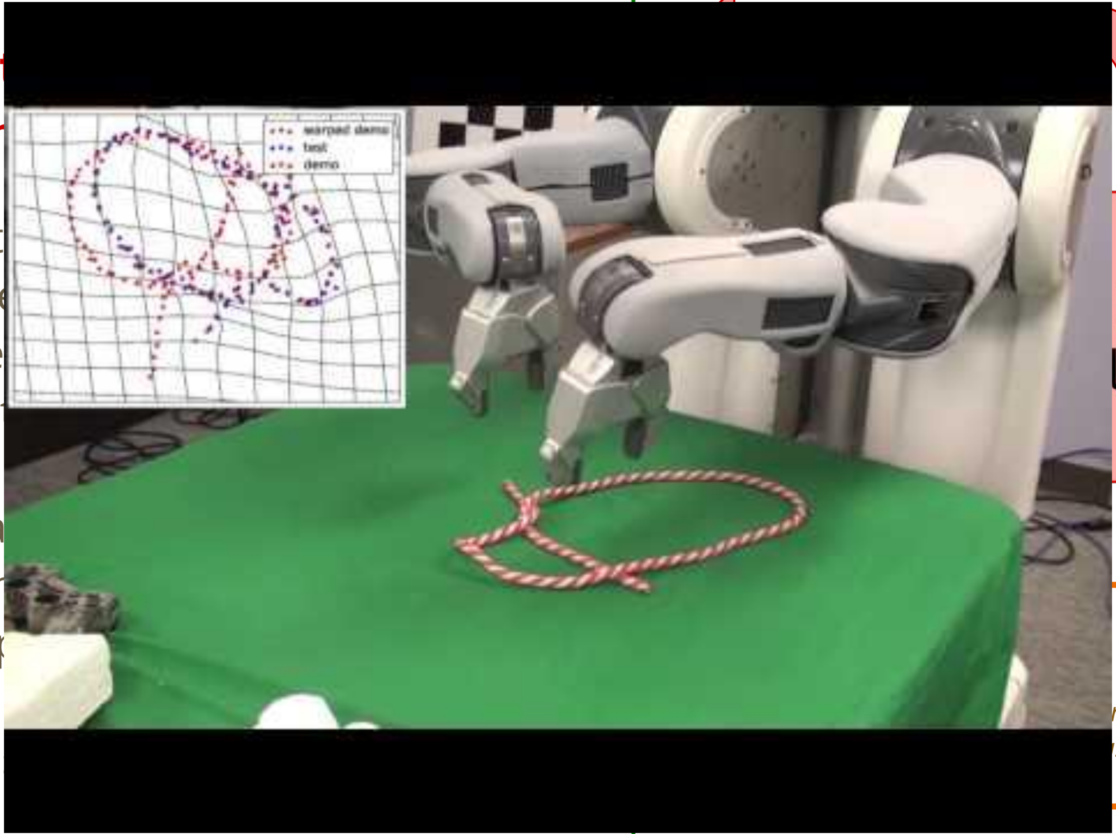
  (corresp

Tactile force

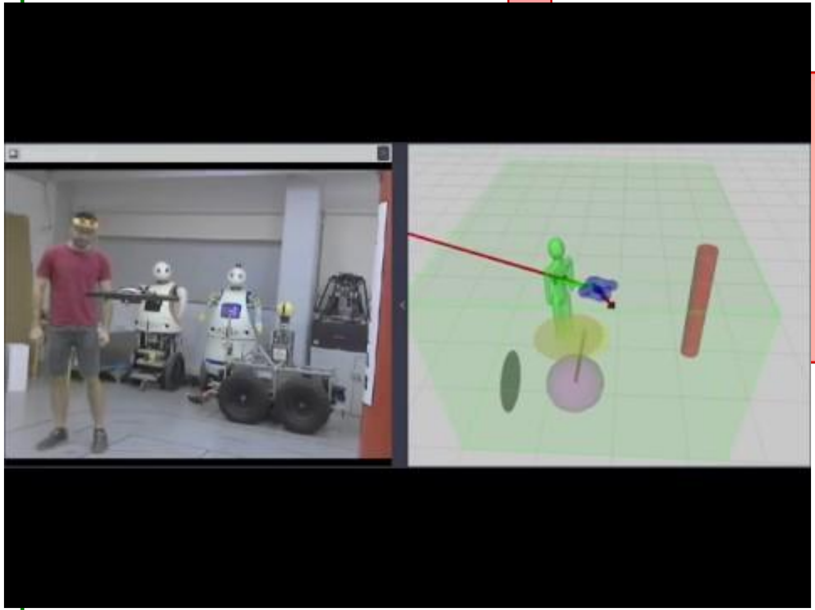


Robotic
lementation

ms, 47:2-3, 153-167, 2004
*s Systems*47:2-3, 117-127,

Teaching a drone to fly and accompany a person

Learning: Robotic Implementation



Learning: Robotic Implementation

Other type of learnings:

- Incremental learning.
- Reinforcement learning.
- Dynamic Adaptation.
- Learning of Dynamical Systems.

Robotic Implementation

Summary

Learning new tasks relies on various means of teaching the robots.

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- The robot must however rely on generic skills of its own to adapt the demonstration to its own body and to the context

Summary

Learning new tasks relies on various means of teaching the robots.

- Imitation learning is useful in so far that it gives <u>hints</u> as to the optimal solution

- The robot must however rely on generic skills of its own to adapt the demonstration to its own body and to the context

- Learning of complex skills is overall relatively slow and must proceed incrementally

Today's Content

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2. Robots in education, therapy and rehabilitation
3. Evaluation methods and methodologies for HRI research

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1. Social learning and skill acquisition via teaching and imitation
2. Robots in education, therapy and rehabilitation
    a. Therapy
    b. Education
3. Evaluation methods and methodologies for HRI research

Robots is education, therapy and rehabilitation

Current real-life applications of HRI are in Education, Therapeutic and Rehabilitation

These applications rely often on toy-like robots that are small, and, as such convey a sense of security and cuteness

Robots is Therapy

- Use for the disabled (autistic children, paraplegics, etc)
- Use for the elderly

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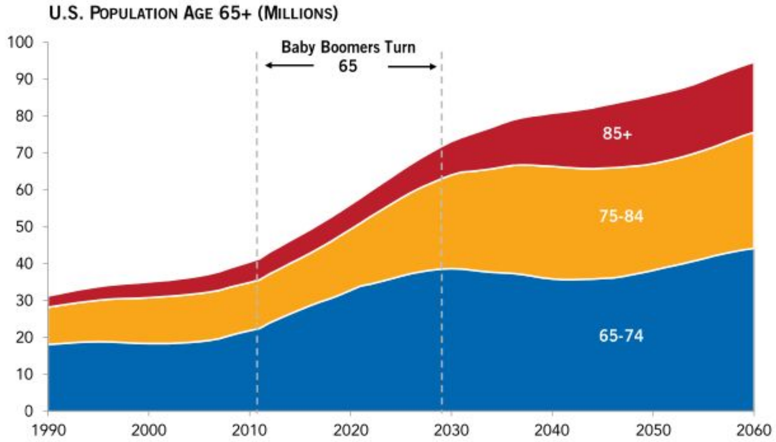

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- Sick child or elderly person in a home → loneliness of the sick
    - a toy robot replaces a domestic animals in environments where those cannot be accepted (allergies)

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  - petting the toy robot will improve the patient's mood, fulfill its need to care and be cared for and enhance interaction and communication across patients (a mediator)

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  - a robot allows to follow the patient’s development in longitudinal studies

Robots is Therapy

<u>Paro, the Seal Robot (AIST, Japan)</u>

- 8 actuators; 2 for upper and lower eyelids,
- 1 for rotation of eyes, 2 for the neck,
- 1 for each front fin, and 1 for two rear fins.
- Paro weights about 2.8 kg.

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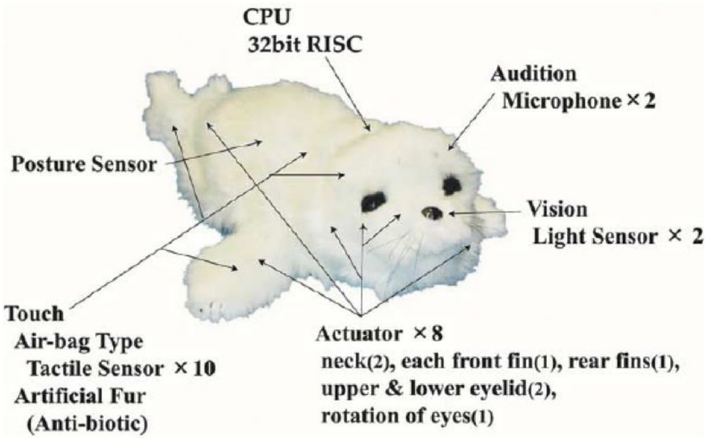

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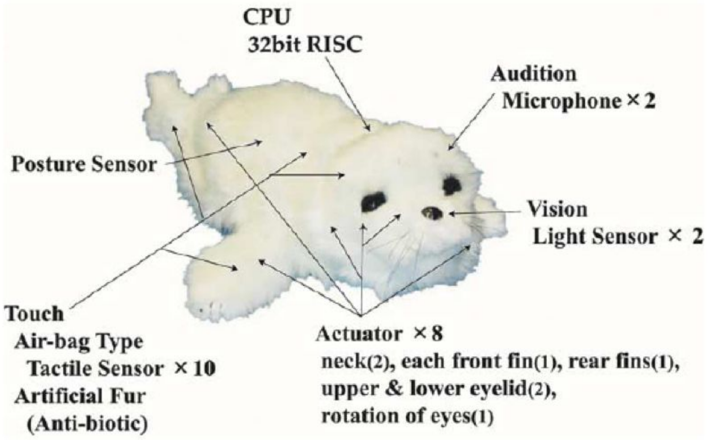


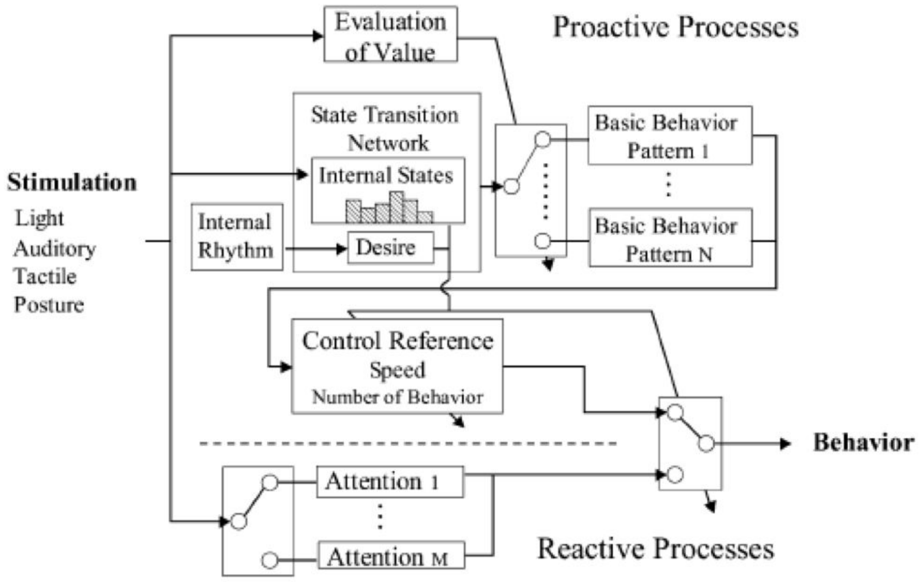
Robots is Therapy

- Paro has internal states that correspond to emotions.

- Each state activity changes as a function of the interactions and otherwise decays with time.

- Interaction changes the internal states of Paro and, thus, the user creates the character of Paro.

- Reinforcement learning: positive for stroking, negative for beating.



Robots is Therapy

Tests: 2-15 years old children hospitalized; Paro robot was presented 3 time a day over the course of 11 days

Wada, K.; Shibata, T.; Saito, T.; Tanie, K, **Effects of robot-assisted activity for elderly people and nurses at a day service center**, Proceedings of the IEEE, Volume 92, Issue 11, Nov. 2004 Page(s):1780 – 1788.

Robots is Therapy

Tests: 2-15 years old children hospitalized; Paro robot was presented 3 time a day over the course of 11 days

Results:
The children's moods improved on interaction with Paro, encouraging the children to communicate with each other and caregivers.

In one striking instance, a young autistic patient recovered his appetite and his speech abilities during the weeks when Paro was at the hospital.

In another case, a hospitalized child patient who felt pain when she moved her body, arms, and legs and could not move from her bed. When Paro was given to her, she smiled and was willing to stroke Paro.
Paro had a rehabilitative function as well as a mental effect.

Wada, K.; Shibata, T.; Saito, T.; Tanie, K, **Effects of robot-assisted activity for elderly people and nurses at a day service center**, Proceedings of the IEEE, Volume 92, Issue 11, Nov. 2004 Page(s):1780 – 1788.

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Results:

- Paro improved the mood of elderly people and made them more active.
- Paro encouraged elderly people to communicate, both with one another and with the nursing staff.
- Urinary tests showed that the ability to recover from stress was improved in the elderly.

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Robots is Therapy

Nao Robot Goes to School to Help Kids With Autism

Robots is Education- Robota at Museum

French National Science Museum , « La Cite de l’Espace », Paris, November2001 – January2003

Robots is Education- Robota at Museum

Monitored the interactions of the users with Robota over 6 months:

- Ran from 10am until 6pm everyday.
- 30 to 100 users per day (mean 43, std 13)
- Interactions lasted between 2 seconds and 5 minutes (mean 35 sec, std, 1.15min)
- Wide range of nationalities(french, english, german, spanish, dutch, swedish)

Robots is Education- Robota at Museum

Monitored the interactions of the users with Robota over 6 months:

- Ran from 10am until 6pm everyday.
- 30 to 100 users per day (mean 43, std 13)
- Interactions lasted between 2 seconds and 5 minutes (mean 35 sec, std, 1.15min)
- Wide range of nationalities(french, english, german, spanish, dutch, swedish)

<u>Type of interactions:</u>

- ~45% (body words), ~20%(naturalistic), ~35% (insulting or abusive language)
- Example of naturalistic trainings:

  « Drink », « Have an Apple », « Give me a kiss», « sing »

Summary

- Promising results have been achieved in the use of toy-like robots for therapy with autistic children, sick children and with elderly people.
- More studies need to be conducted to determine the level of acceptability of these toys by a large population;
- Most of these toys are full-fledged prototypes ready to be commercialized.
- Next step is to move to bigger robots, for use with normal adults in our everyday life.

Today’s Content

1. Social learning and skill acquisition via teaching and imitation
2. Robots in education, therapy and rehabilitation
3. Evaluation methods and methodologies for HRI research

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Evaluation Methodologies

HRI is a new field (about 25 years)

Most studies cannot yet be reproduced (too different hardware)

Evaluation Methodologies

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Like in Psychology, it is difficult to agree on a methodology on how to carry out research.
Should one

- apply quantitative, statistical methods requiring large-scale experiments, i.e. involving large sample sizes of participants,

- or pursue a qualitative approach focusing on case studies and in-depth analysis.

Evaluation Methodologies- Wizard of Oz

The WOZ method involves a human who is (**unknown to the test subjects**) controlling the behaviour of the system, ranging from full teleoperation to partial control of ‘higher level’ decision making processes.

Evaluation Methodologies- Wizard of Oz

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- In (Dahlbacket al 93) a Wizard-of-Oz study was first conducted to explore how people would relate to a service robot, while the design of the robot’s dialogue capabilities was still ongoing.
- A general conclusion from the study was that users need explicit feedback at several levels to understand the state of the robot; in particular, to what degree it has perceived the instructions given, and where it is headed when moving around.

Evaluation Methodologies- Theatrical Robot

- The Theatrical Robot consists of a human instructed to behave and/or appear like a robot.
- The human is a professional such as a mime or person trained to perform pre-scripted behaviours, as needed for experimental protocols, reliably and with high precision.

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In (Robins et al 2006), the mime/theatrical robot mimics the behavior of the doll robot, Robota, to test children with autism's reaction prior to conducting the experiments

Robins, B., Dautenhahn, K. & Dubowski, J. (2006), Does appearance matter in the interaction of children with autism with a humanoid robot?, *Interaction Studies* 7(3), 509–542

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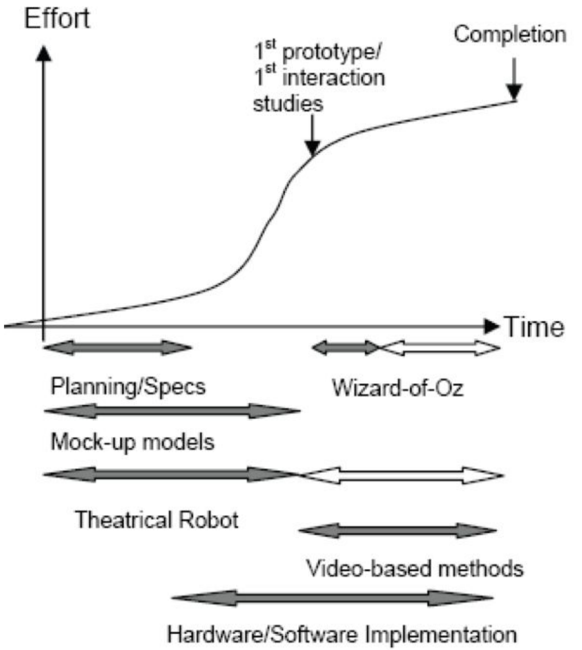
The response of children with autism towards the plain/robotic theatrical robot was notably more social and proactive. The ordinary-human appearance resulted in avoidance behaviour or ‘aloofness’, a typical behaviour that autistic children show towards strangers.

Evaluation Methodologies

Sketch of a typical development time line of HRI robots.



K. Dautenhahn, Methodology & Themes of Human-Robot Interaction: A Growing Research Field, *International Journal of Advanced Robotic Systems, Vol. 4, No. 1 (2007), pp. 103-108.*

Evaluation Methodologies

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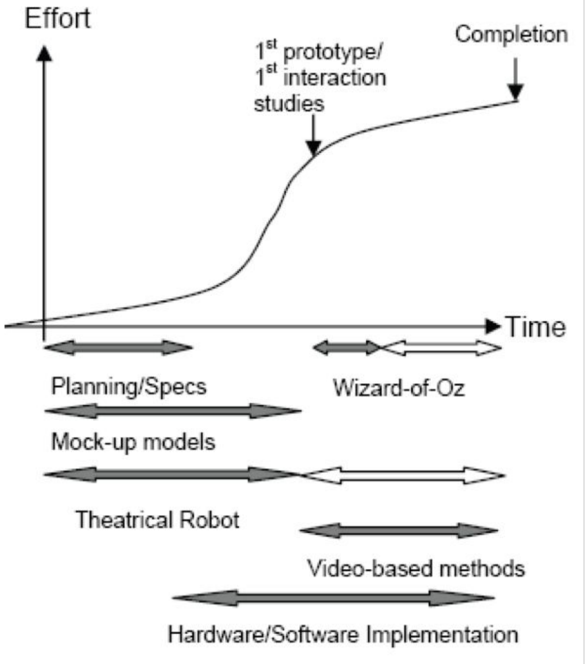
In an initial phase of planning and specification, mock-up models might be used before hardware and software development commences.



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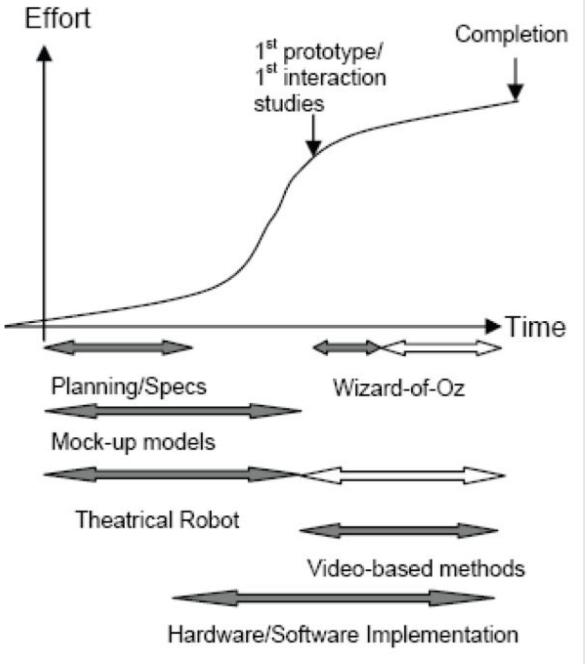

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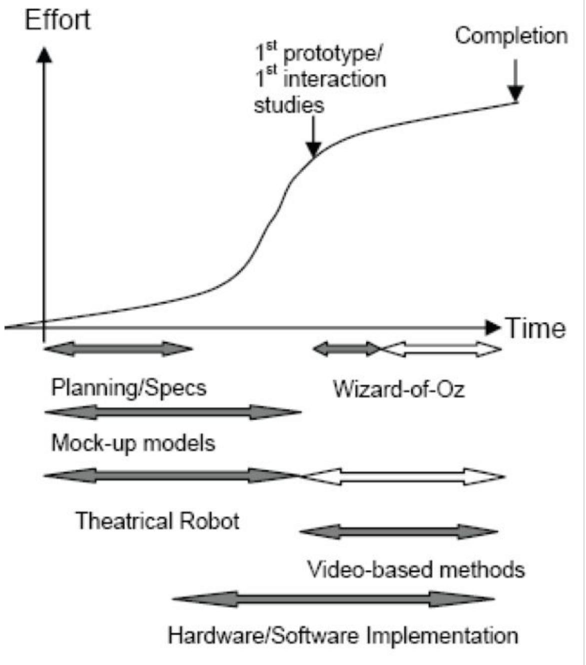

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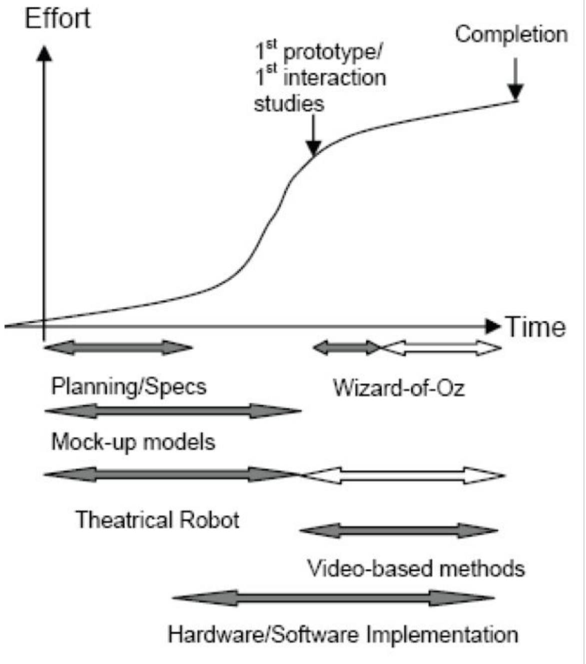
The Theatrical Robot paradigm allows one to conduct interaction studies even from the early phase of planning and specification onwards throughout the whole development of the robot.



Evaluation Methodologies

Robots are not people!

It is a misconception that results from human-human interactions can be directly applied to human-robot interaction.

Even if it has been shown that people behave towards artifacts, i.e. computers, in many ways socially, e.g. attribute personality to them, reciprocate favours etc.,...

... as long as robots and humans are distinguishable, and this will still be the case for many years to come, people are likely to not treat them identically to human beings.

Evaluation Methodologies

- The evaluation of interactions between robots and humans, different types of interactions, and individual robot and human behaviors requires adequate metrics and guidelines
- Metrics are not comparable due to bias towards application specific measures
- What to evaluate?
  - **Behaviors**
  - **Ways of interactions**
  - **Social and psychological aspects**
  - **Technical characteristics and objective measures: success rates, interaction time, error rates...**

Evaluation Methodologies

- **Why evaluation is important?**
- Comparison of HRI systems, protocols, robots (embodiment), social acceptance
- Feasibility, Efficiency, Safety
- Impact on the user: rehabilitation, usability, societal impact
- User experience
- To improve the way Humans are interacting with robots

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- Social and psychological aspects
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Evaluation Methodologies

Methodology:

- Large sample sizes of participants: statistical analyses, quantitative methods, large-scale experiments, population/robot modes comparisons
- Case studies: single-case analysis, qualitative approaches
- Longitudinal analyses: repeated measurement of subjects over time

Most studies cannot be reproduced…

Evaluation Methodologies

Metrics

- Task effectiveness: How well a Human-Robot team accomplishes some task?
- Neglect tolerance: Autonomy of a robot with respect to some task
- Robot attention demand: How much a robot is demanding?
- Fan-out: Number of robots simultaneously operating

Olsen and Goodrich, Metrics for evaluating Human-Robot Interaction, Proc. NIST Performance Metrics for Intelligent Systems Workshop, 2003

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Evaluation Methodologies

Task effectiveness:

- How well a Human-Robot team accomplishes some task?
    - Time-based metrics: speed of performance
    - Error metrics: mistakes, damage
    - ...

- Metrics are task specific
- Overall task effectiveness is best measured after the task is complete

Olsen and Goodrich, Metrics for evaluating Human-Robot Interaction, Proc. NIST Performance Metrics for Intelligent Systems Workshop, 2003

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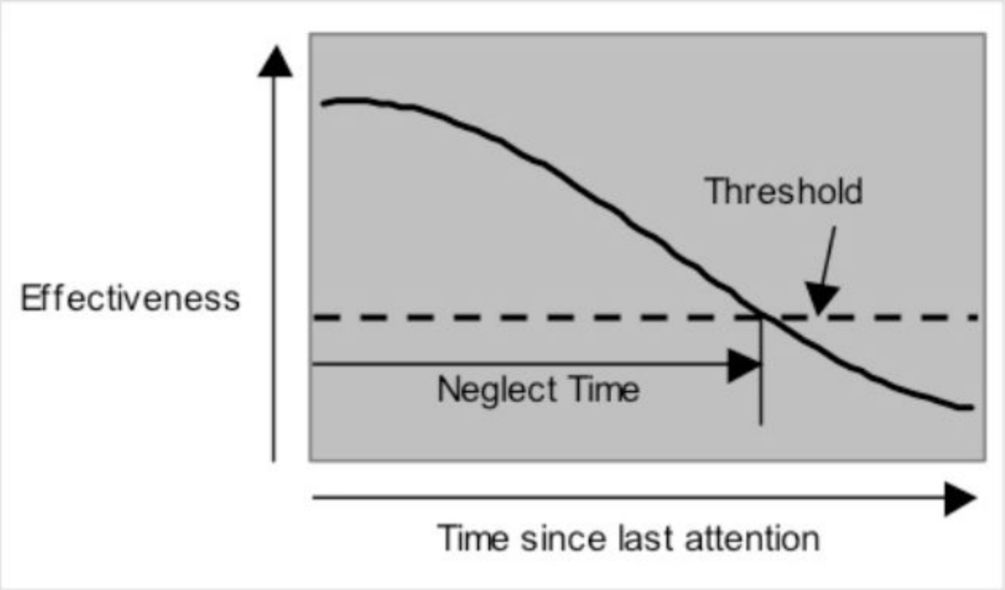
Evaluation Methodologies

Neglect tolerance (NT):

- Measures the autonomy of a robot with respect to the task
- Measures of how robot's effectiveness declines over time when the robot is neglected by the user



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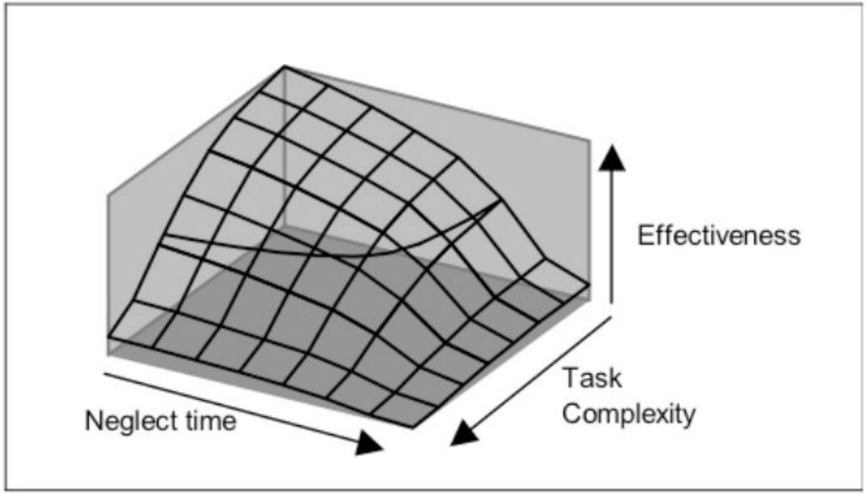
Evaluation Methodologies

Neglect tolerance (NT):

Measuring neglect tolerance: Amount of time that a Human can ignore a robot

Function of task complexity:



Evaluation Methodologies

Neglect tolerance (NT):

Measuring neglect tolerance: Amount of time that a Human can ignore a robot

- "Place the robot at a some random location in a problem world and giving it a random goal to achieve and measure the time that the robot is effective: the elapsed time during which the robot makes progress towards that goal before dropping below the effectiveness threshold"

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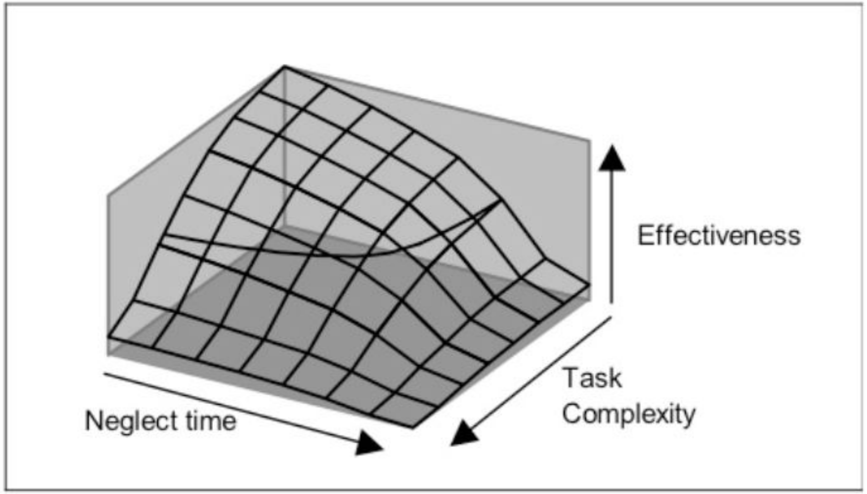

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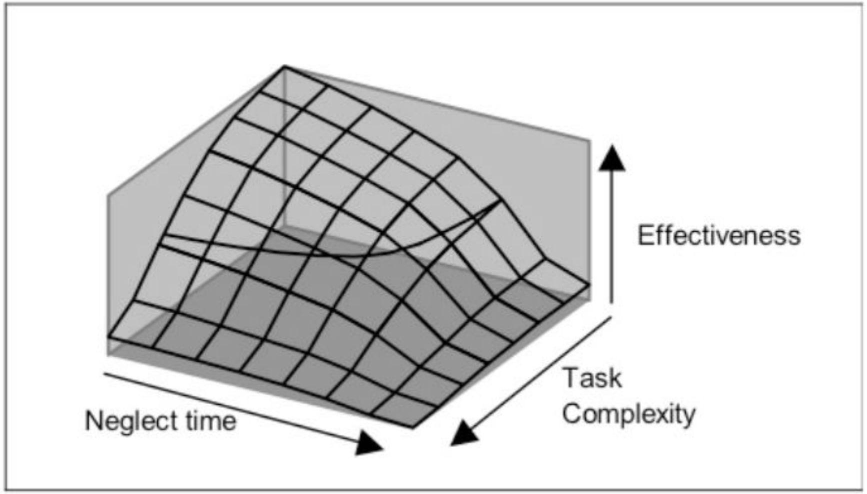

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Evaluation Methodologies

Robot Attention Demand:

- How much a robot is demanding (RAD).
- Measure of the fraction of total time that a user must attend to a given robot
    - Interaction effort (IE): can be the amount of time required to interact with the robot

Amount effort that the user must expend interacting

$$RAD = \frac{IE}{IE + NT}$$

- RAD is unitless quantity that represents the fraction of a human's time that is consumed by interacting with a robot

Examples:

- The teleoperated robots have a small NT and RAD approaches to 1: the user can focus on other things besides interacting with the robot
- Reducing RAD can be done by increasing NT or decreasing IE but not always (NT ang IE are NOT independent)

Evaluation Methodologies

Robot Attention Demand:

- From RAD, you can also define the user's free time:

$$FT = 1 - RAD$$

- Fraction of the task that the user does not need to pay attention to the robot
- It can also be used to measure RAD
    - One way it to give to the user a robotic task and a secondary task

Olsen and Goodrich, Metrics for evaluating Human-Robot Interaction, Proc. NIST Performance Metrics for Intelligent Systems Workshop, 2003

Evaluation Methodologies

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Evaluation Methodologies

Fan-Out :

- One way to leverage Human attention is to allow a user to operate multiple robots simultaneously:
  - To accomplish some tasks more quickly and effectively: surveillance, exploration...
- Measure of the effectiveness of a Human-Robots team using FAN-OUT
- Fan-Out is an estimate of the number of robots that a user effectively operates at once

$$FO = \frac{1}{RAD} = \frac{IE + NT}{IE}$$

- FO increases as NT becomes large relative to interaction effort
- Task effectiveness increases as more robots are added to the task

Evaluation Methodologies

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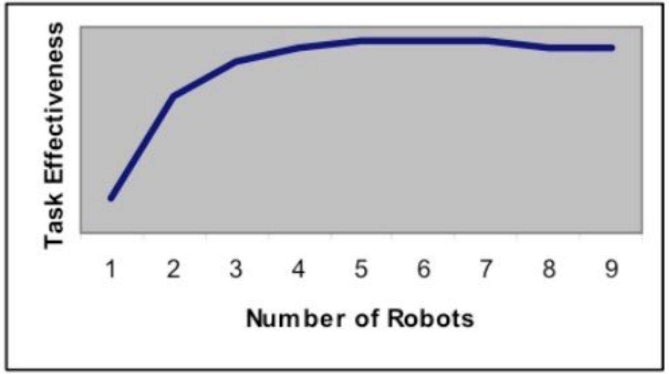

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Evaluation Methodologies

Other Common metrics

- Steinfeld et al proposed 5 metrics for task-oriented Human-Robot Interaction with mobile robots:
    - Navigation
    - Perception
    - Management
    - Manipulation
    - Social

Steinfeld et al., Common Metrics for Human-Robot Interaction, HRI 2006

Evaluation Methodologies

Usability
Social acceptance
User experience
Social Impact

USUS evaluation framework

- New technologies have considerable impact on various factors of the interaction between Humans and robots:
    - usability, user experience, social acceptance and social impact
- These factors have to be investigated with appropriate measurements and approaches
- This is the purpose of the theoretical and methodological evaluation framework USUS:

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

Usability
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USUS evaluation framework

- ***Usability***
  - The term usability refers to the ease of using object
  - ISO924111:1998 defines usability as:
    - "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction"
  - In HRI, it is usually measured as performance/effectiveness and efficiency

Evaluation Methodologies

Usability
Social acceptance
User experience
Social Impact

Usability

Evaluation Methodologies

success rate or task completion rate

Effectiveness

Usability

Usability
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Evaluation Methodologies

success rate or task completion rate

Effectiveness

rate or speed at which a robot can accurately and successfully assist Humans

Efficiency

Usability

Usability
Social acceptance
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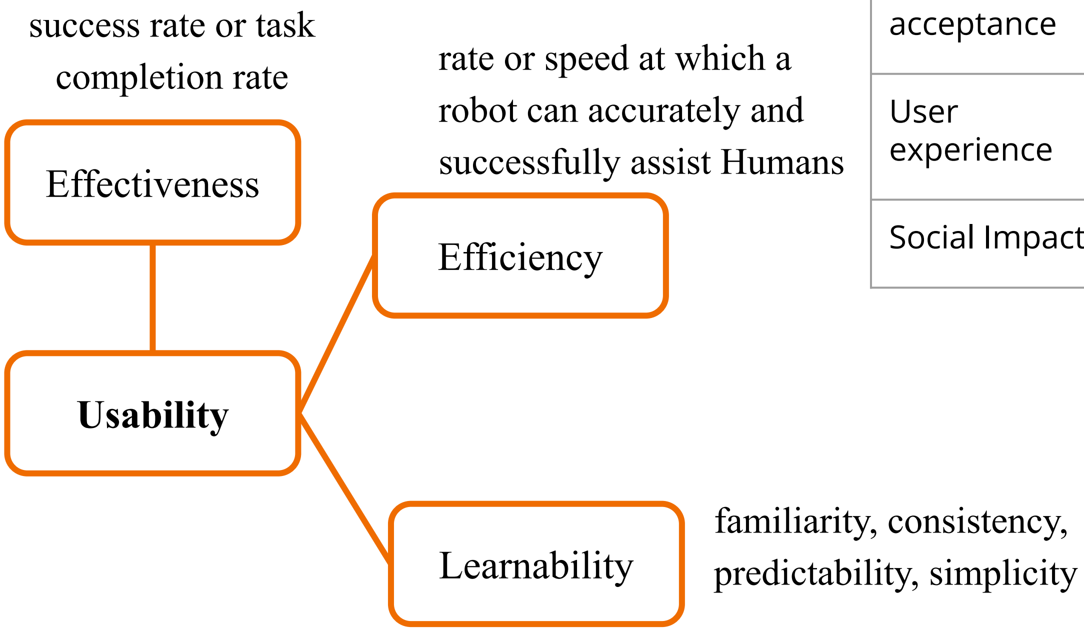
Social Impact

Evaluation Methodologies



Usability
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Evaluation Methodologies

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success rate or task completion rate

Effectiveness

rate or speed at which a robot can accurately and successfully assist Humans

Efficiency

Usability

Learnability

Flexibility

Evaluation Methodologies

success rate or task completion rate

Effectiveness

rate or speed at which a robot can accurately and successfully assist Humans

Efficiency

Usability

Robustness

Flexibility

Learnability

error preventing, responsive and stable

Usability
Social acceptance
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Evaluation Methodologies

Usability
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success rate or task completion rate

rate or speed at which a robot can accurately and successfully assist Humans

Utility

Effectiveness

Efficiency

Usability

Robustness

Flexibility

Learnability

error preventing, responsive and stable

Evaluation Methodologies

USUS evaluation framework

Indicators for usability

- **Effectiveness**: "the accuracy and competences with which users achieve specified tasks" => success rate or task completion rate
- **Efficiency**: "the resources expended in relation to the accuracy and completeness with which users achieve goals" => rate or speed at which a robot can accurately and successfully assist Humans
- **Learnability**: "How easy can a system be learned by novice users?" => familiarity, consistency, predictability, simplicity
- **Flexibility**: "describes the number of possible ways how the user can communicate with the system"
- **Robustness**: Novice users will produce errors when collaborating with robots, thus an efficient HRI system has to allow the user to correct its faults on his/her own. => error preventing, responsive and stable
- **Utility**: "How an interface can be used to reach a certain goal or to perform a certain task?"

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social acceptance

- There is a need to find out the reasons why people accept robots in order to avoid rejection in a long term.
- "The demonstrable willingness within a user group to employ technology for the tasks it is designed to support"
- Acceptance is culture dependent
- It depends on the user experience
- USUS framework defines social acceptances as "an individual's willingness based on interaction experiences to integrate a robot into an everyday social environment"

Usability
Social acceptance
User experience
Social Impact

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

Usability
Social acceptance
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USUS evaluation framework

Social acceptance

Social acceptance

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social acceptance

Performance expectancy

Social acceptance

Usability
Social acceptance
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Social Impact

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social acceptance

Performance expectancy

Social acceptance

Effort expectancy

Usability
Social acceptance
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Social Impact

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social acceptance

Performance expectancy

Social acceptance

Attitude toward using technology

Effort expectancy

Usability
Social acceptance
User experience
Social Impact

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Indicators for evaluating Social Acceptance

- Performance expectancy: defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance.
- Effort expectancy: defined as the degree of ease associated with the use of the system. Extent the user perceives a system will be easy to use.
- Attitude toward using technology: defined as an individual's overall affective reaction to using a system. Sum of all positive or negative feelings and attitudes about solving working tasks supported by a robot.

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Indicators for evaluating Social Acceptance (cont.)

- Self efficacy: relates to a person’s perception of their ability to reach a goal.
- Forms of grouping: The question arising is whatever Humans can also share identity with robots.
- Attachment: The term was originally used to explain the bond develops between a Human infant and its caregiver. Emotional attachment can be seen as the sum of cumulated emotional episodes of users’ experiences with a device in various context areas.
- Reciprocity: describes the principle of give-and-take in relationship, but in can also mean the mutual exchange of performance and counter- performance.

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

Usability
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USUS evaluation framework

User experience

"Aspects of how people use an interactive product:

- *The way it feels like in their hands,*
- *How they understand how it works,*
- *How they feel about it while they're using it,*
- *How well it serves their purposes*
- *How well it fits into the entire context in which they are using it."*

Users' experience are related to a system and are embedded in a specific situation.

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Indicator for evaluating User experience

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Indicator for evaluating User experience

- Embodiment: describes the relationship between a system and its environment and can be measured by investigating the different perturbatory channels like morphology, which has impact on social expectations.

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

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- Human-oriented perception: tries to simulate Human perception by tracking human features, interpreting speech… but also communicating facial expressions

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- Co-experience with robots: How individuals develop their personal experience based on social interaction with others.

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social impact

- “describes all effects the introduction of robotic agent consequences for the social life of a specific community (ranking into account cultural differences) in terms of quality of life, working conditions and employment, and education”

Usability
Social acceptance
User experience
Social Impact

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social impact

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social impact

- Quality of life, health and security: new therapy possibilities, security aspects...

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

USUS evaluation framework

Social impact

- Quality of life, health and security: new therapy possibilities, security aspects...
- Working conditions and employment: includes all aspects affecting how people carry out their job and how employers take care of their employees (working times, organization...).

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Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

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Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

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- Education: New software, new sciences and new disciplines require new types of education. Preparation for utilization of robots, in the physical manner and in psychological manner too.
- Cultural context: whole range of practices, customs and representations of a society. Example: Japanese or South Koreans interact with robots in quite different manner than in Europe.

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

User-centred evaluation approach

Qualitative research is combined with quantitative measures for the evaluation approach.

Table 1: The Methodological Mix

	Methods	Expert Eval	User Studies	Questionnaires	Physio. Measures	Focus Groups	Interviews
Research Objectives							
Usability							
	Effectiveness	X	X				
	Efficiency	X	X				
	Learnability	X	X				
	Flexibility	X	X				
	Robustness	X	X				
	Utility			X			X
Social Acceptance							
	Performance Expectancy			X		X	
	Effort Expectancy			X		X	
	Attitude toward Using Technology			X			
	Self Efficacy			X		X	
	Forms of Grouping			X		X	
	Attachment			X		X	
	Reciprocity			X			
User Experience							
	Embodiment			X		X	
	Emotion			X	X	X	
	Human-Oriented Perception			X			
	Feeling of Security			X	X	X	
	Co-Experience			X		X	
Societal Impact							
	Quality of Life			X		X	X
	Working Conditions			X		X	X
	Education			X		X	X
	Cultural Context			X		X	X

Evaluation Methodologies

Expert evaluation:

- **Heuristic evaluation:** Find and describe usability problems on the basis of fundamental principles. The result is a list of all detected usability problems ranked according to their severity.

- **Cognitive walkthrough:** is conducted by at least 2 usability experts assessing the usability of a system based on predefined task structures. The expert evaluators try to imagine how a typical (potential) user would solve a task with the assumption of minimizing the cognitive load.

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

User studies:

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

User studies:

- **Laboratory-based:** User studies are used to provide empirical evidence to answer a concrete research question or hypothesis. This enables observers to see first-hand protocol usability problems. User studies are normally audio and video tapes so that researchers can go back and refer to what subjects did, and how they reacted.

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- **Wizard of OZ:** To allow user testing in very early stages of the prototype. A Human "wizard" simulates the system features in interaction:
    - Advantages: safety, security, relevant social cues
    - Drawbacks: Is the perception of the robot measured or the perception of a Human "wizard"?

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009

Evaluation Methodologies

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Evaluation Methodologies

Standardized questionnaires:

- A questionnaire is research instrument that consists of a series of questions with the purpose of gathering statistically analyzable data from the participants -

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- They allow the researcher to explore participants” attitudes, beliefs, and desires in great depth.
- Focus groups are structured discussion about specific topics and moderated by a trained leader.

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In-depth interviews:

- Expert interviews: “person-to-person” discussion, share knowledge
- Delphi studies: Find a solution for a complex problem statement. Discussions with several experts.

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Evaluation Methodologies

Evaluation Methodologies

Summary

- Metrics and evaluation should be User-centred
- Combining qualitative and quantitative measures
- Typical scenarios are very important for the community.
- Multi-disciplinarity in the evaluation but also the development.

Evaluation Methodologies

USUS evaluation framework

Social acceptance

Usability
Social acceptance
User experience
Social Impact

Weiss et al., The USUS Evaluation Framework for Human-Robot Interaction, New Frontiers in Human-Robot Interaction, 2009