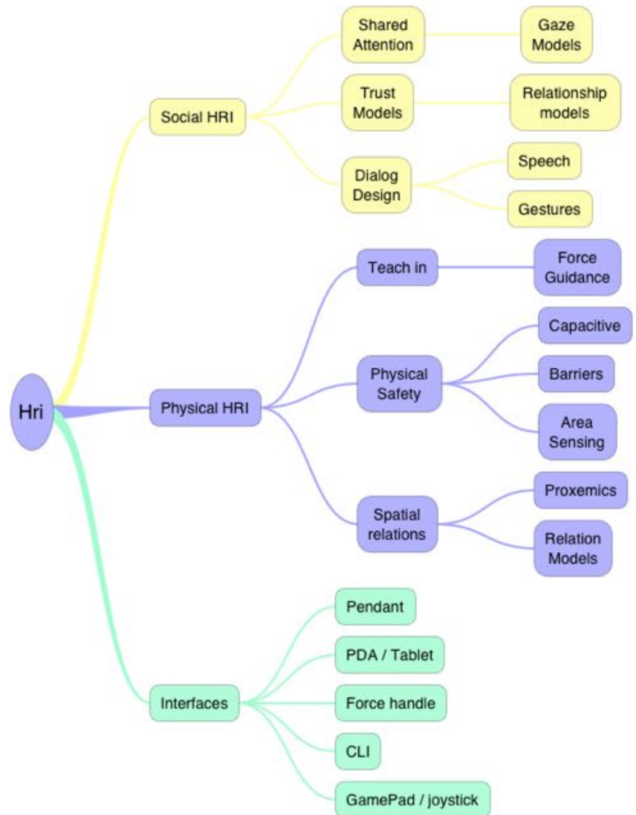
Human Robot Interaction

Henrik I Christensen
CSE @ UCSD

HRI overview



Human-Robot Interaction

- Robot Safety
- Robot Programming
- Application Packages
- Robot Simulation (for deployment studies)
- Next generation human-robot interaction

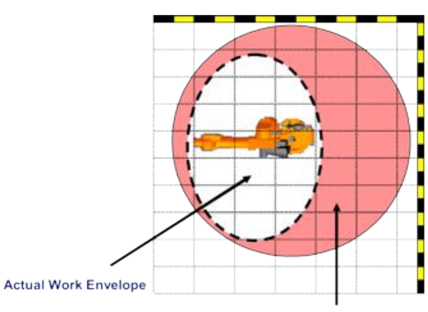
- Material from KUKA, ABB and A. Thomaz @ GT

Safety in commercial systems

- Robot safety is crucial to deployment of systems anywhere
- Commercial systems have extensive mechanisms in place to assist in achieving good standards for robot safety

Safety consideration for deployment in industry

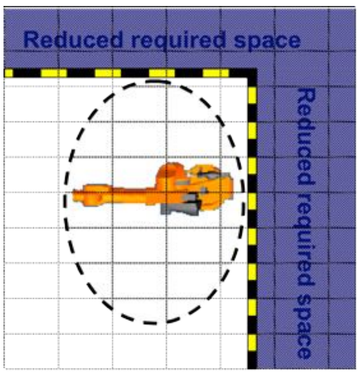
Requirements from Customer (1/7)



- According to today's safety requirements it is not allowed to put safety fences inside the theoretical work envelope of the robot
  - Due to a failure of the robot controller the robot might leave it's programmed path and hit the safety fence
  - Cost effective safety fences are not designed to stop a robot
  - Inside production the robotic application requires more floor space (theoretical work envelope – red) than it really needs (actual work envelope – white)
  - The customer wants to reduce the required floor space to a minimum (approx. 1.500 $ per m²)

Safety consideration for deployment in industry

Requirements from Customer (2/7)



- If the customer wants to put safety fences directly next to the robot's actual work envelope he has to use:
  - Either safety fences that are designed to stop a robot movement – those fences are very expensive as they use macrolon, reinforced frames and special fixtures
  - Or a possibility to monitor the workspace of the robot in a failsafe way – this was possible with the use of mechanical axis range monitoring systems (mechanical proximity switches)

Safety consideration for deployment in industry

Requirements from Customer (3/7)


Axis 1:
3 Ranges

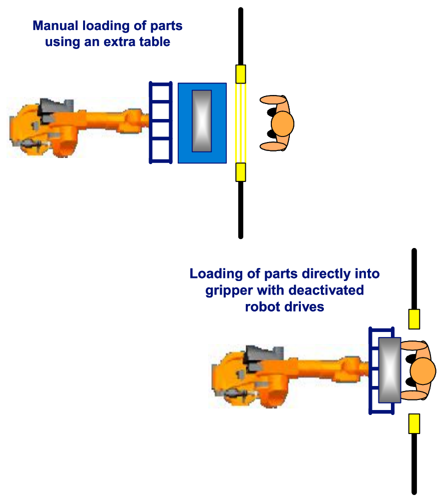

Axis 2:
2 Ranges


Axis 3:
1 Range

- If the customer uses the ABÜ technology s\he has to deal with many disadvantages:
  - Mechanical wearing parts like proximity switches and cams are not wear- and maintenance-free
  - The monitoring functionality is only available for axis 1 to axis 3
  - The monitoring functionality is not available for additional axis and linear axis
  - Unacceptable long commissioning time due to installing and testing mechanical parts and cams
  - Unacceptable long downtime when exchanging robots because mechanical parts have to be exchanged - downtime today approx. 8-10 hours

Safety consideration for deployment in industry

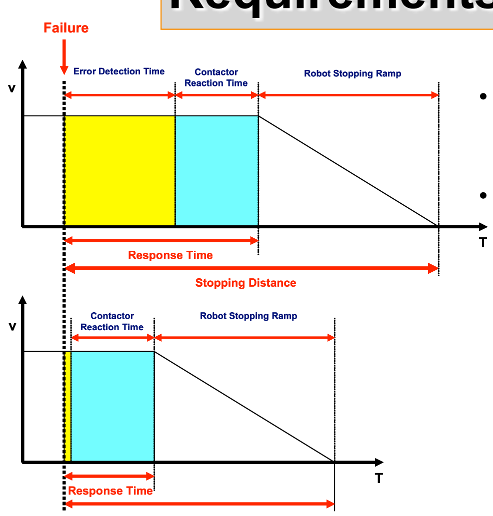
Requirements from Customer (4/7)



- If the application requires a manual loading and/or unloading of parts the customer has to meet several safety requirements:
  - Either the part has to be placed by the worker into an additional table with positioning pins - the table adds costs and needs additional floor space
  - Or when putting the part directly into the gripper the drives have to be safely deactivated – this adds cycle time due to a time delay when activating the drives again

Safety consideration for deployment in industry

Requirements from Customer (5/7)



- To reduce the required floor space for a robotic application it is very important to reduce the stopping distance of the robot in case of a failure:
- The monitoring of the robot by a Safety-PLC using ABÜ-technique adds reaction time to the stopping time (approx. 150 ms - yellow rectangle in top diagram)
  - Failure – robot hits proximity switch
  - Signal is communicated via failsafe bus system to Safety-PLC
  - 2 PLC cycles (worst case) until PLC sets signal to stop the robot
  - Signal is communicated via failsafe bus system to robot
  - Robot stops

Safety consideration for deployment in industry

Requirements from Customer (6/7)

- Centralized safety concepts (one Safety PLC for up to 12 robots) are cost-intensive and rather complex:
  - High cost for cabling as all safety components have to be connected to the Safety PLC (either hard-wired or via a safety bus system
  - Most of the safety components can not be connected directly to a safety bus system – adds cost for additional failsafe I/O modules
  - Huge number of components are connected to the line Safety PLC - slows down communication and cycle time
  - Response time includes Safety PLC cycle time and several communication delays:
    - approx. 120-150ms

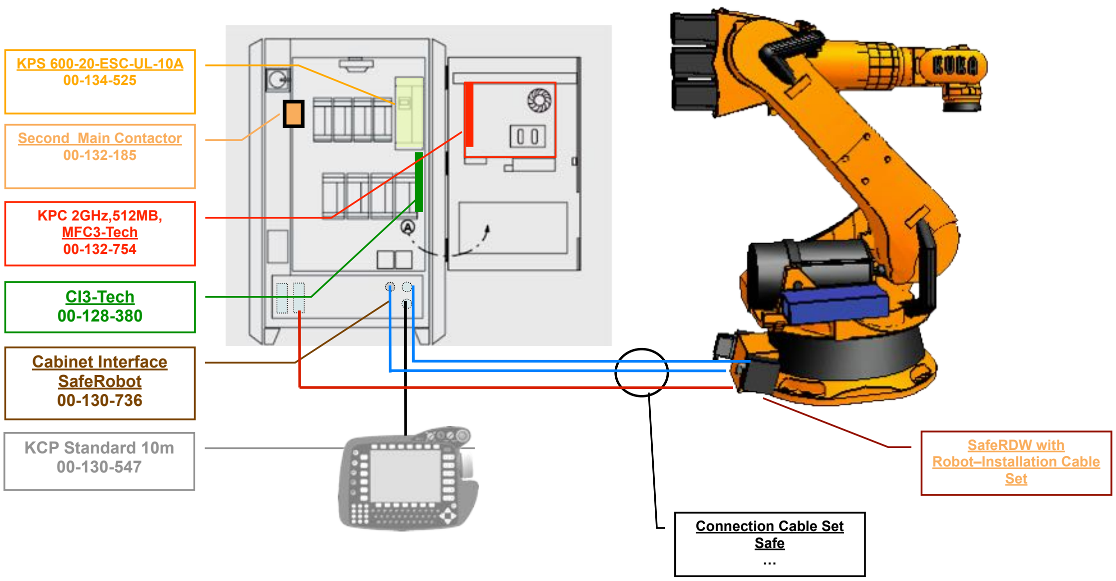
Safety consideration for deployment in industry

Requirements from Customer (7/7)

Summary:

• Reduction of required floor space	approx. 150 $/ft^2
• Use of low price safety fences inside the theoretical work envelope of the robot	approx. 30 $/ft
• Cost-effective axis range monitoring of all axis in a wear- and maintenance-free way	up to 700 $/m
• Reduction of commissioning time for safety functions	approx. 200 $/Robot
• Reduction of downtime when exchanging robots	approx. 200 $/Robot
• Reduction of costs for manual loading systems (table, floor space and additional safety components)	up to 7.000 $
• Reduction of costs for Safety PLCs, safety components and safety communication	up to 30%

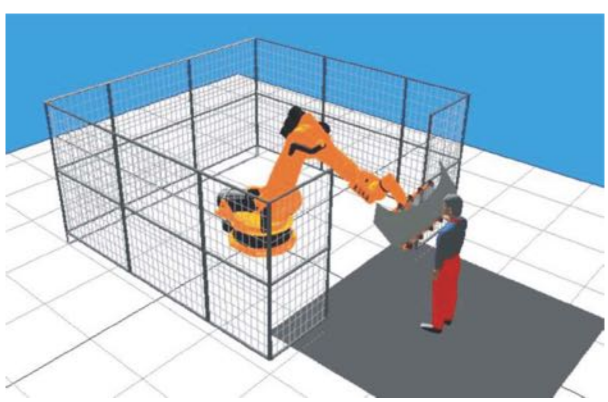
Product Example - SafeOperation



Product Example – SafeOperation

Standstill monitoring (activated by a safe input)

- Drives remain in operation during the stop sequence and the brakes are not activated - the SafeRDC monitors the stop of the robot
- The robot is in a safe operational stop, but may nonetheless move within the axis angle tolerance despite the standstill monitoring
- The axis angle tolerance is specified separately for each individual axis
  - Axis angle tolerance 0.01°...1°



Strategies for programming of robots

- Todays robots are programmed using procedural programming!
- Trajectory following by jogging the system along a trajectory

Human Robot Interfaces

- Consideration of possible interfaces to make robots easier to use on the factory floor
  - Simulation of process prior to deployment
    - Intg of process, CAD, and program to visualize
  - Speech interface to talk to the robot
  - Use of a smart pen to provide input (the ANOTO)
  - Design of structured dialogs to drive process / example welding

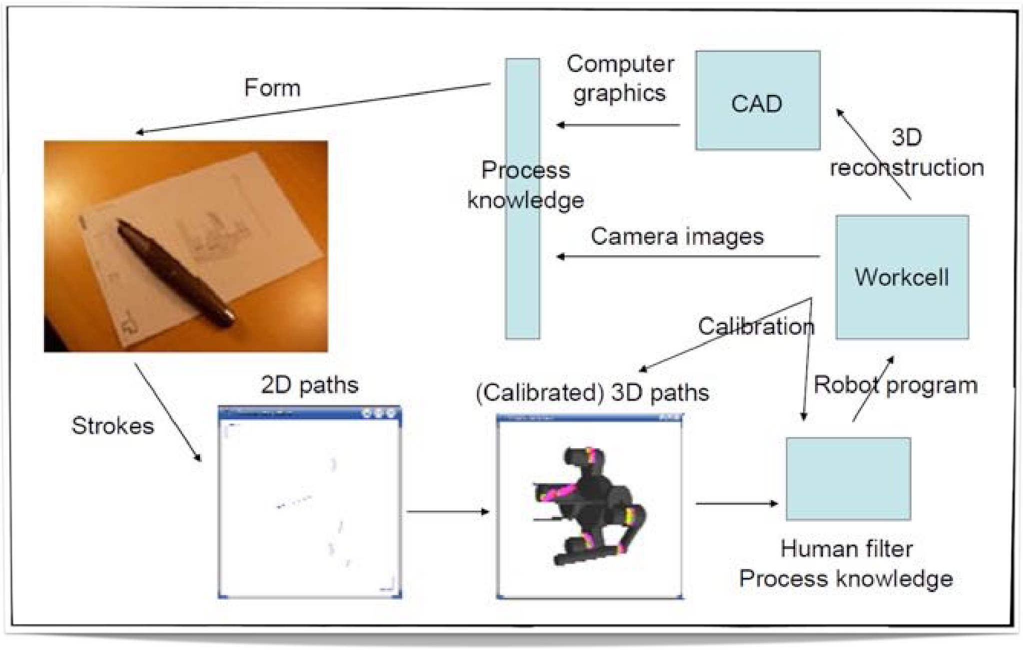
Pen Based Interfaces

- Started to see smart pens with Bluetooth & USB interfaces
- Easy interfacing includes sound input and "pen gestures"

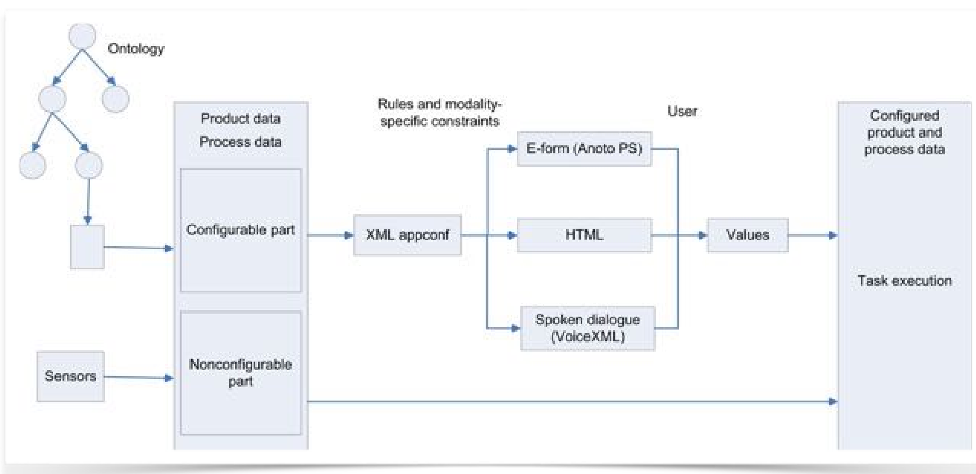
HRI using new types of interfaces

- Using structured dialogs combined with new interfaces such as the anoto pen
  - How to structure the dialog to enable limited choice
  - Identification of cut points in the foundry
  - Organization of check box type dialogs

New Interfaces

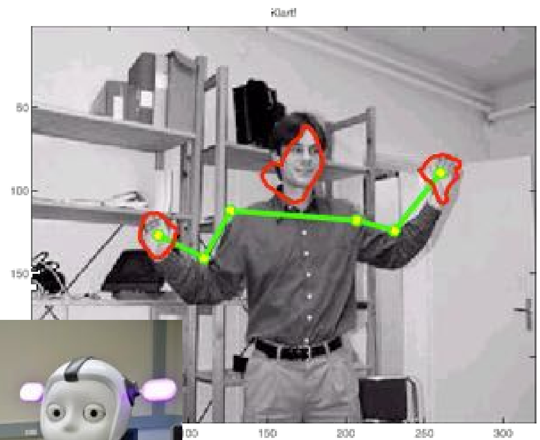


Knowledge based design of robot applications



- How can modern tools from knowledge engineering be utilized to structure processes and organize the different aspects of a process

Multi-Modal Interfaces

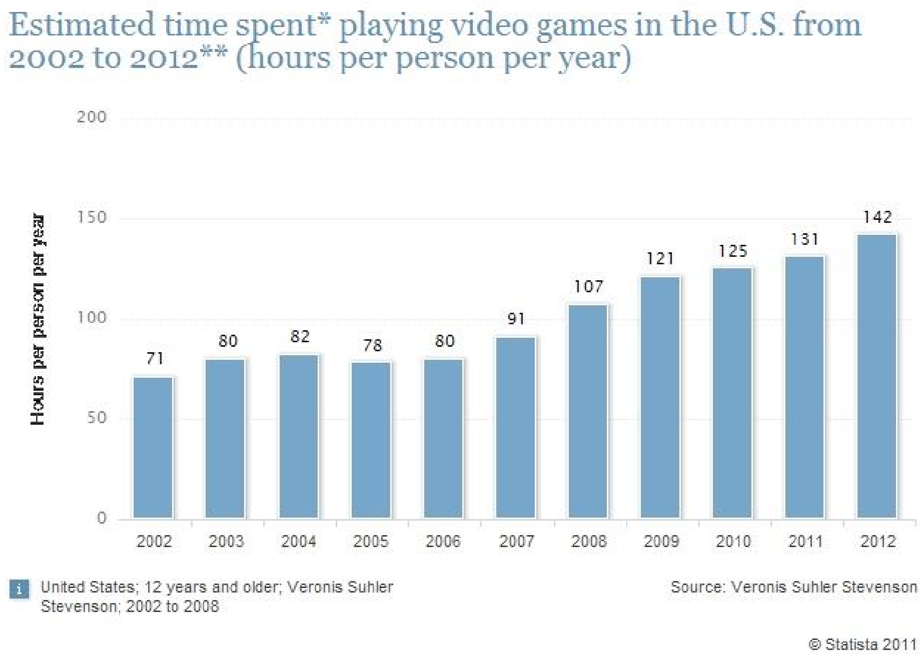


- Providing natural interfaces for interaction with systems
- Using PDA, Speech, Gesturing, Body Pose
- Natural interaction as done between humans

Gestures for Task Learning

- Human teacher uses both speech and gesture to direct the robot
- Gesture glove allows the teacher to optionally control the robot for a short time

First person games



They are experts on

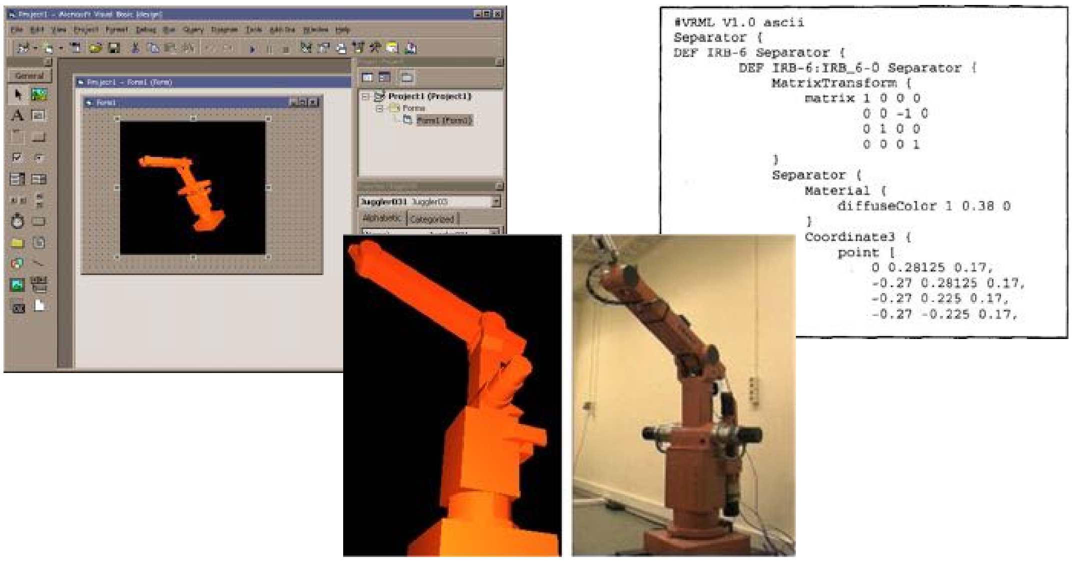
VS

Using Simulation in the Programming Process

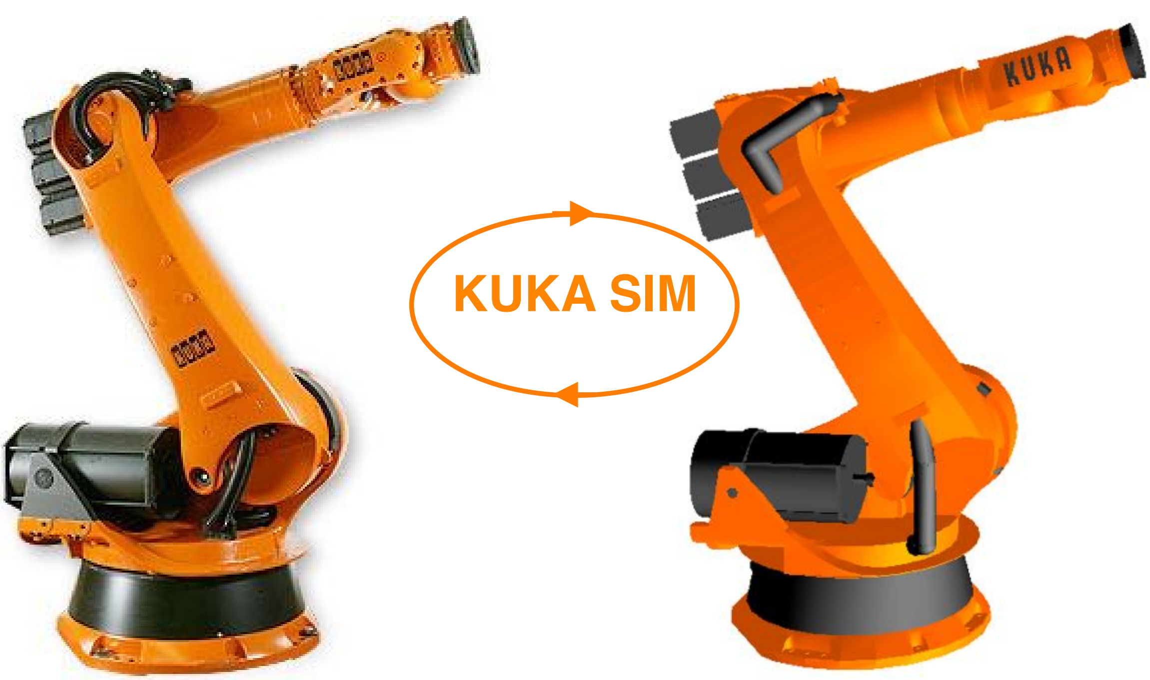
- Simulation is a “cheap” way to evaluate systems before deployment of a full system
- Tremendous progress on simulation systems and virtual reality
  - Primarily driven forward by gaming community and new hardware for game visualization (GPUs)
- Components based design for quick visualization of robot systems

Simulation example

Using simulation in design of systems



KUKA SIM



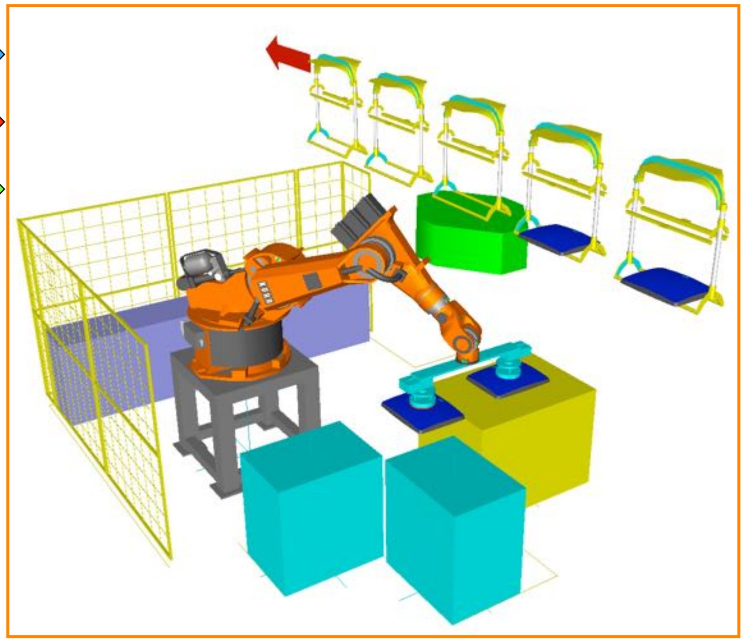
Robot Simulation

Simulation environments that matches operation on the real platform (including timing)

Viewer

Layout

Pro



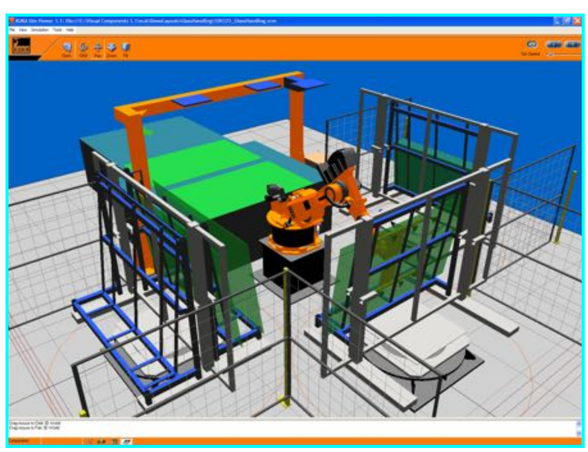
KUKA Sim Viewer

KUKA Sim Layout

KUKA Sim Pro

1st Level: KUKA Sim - Viewer

Viewer



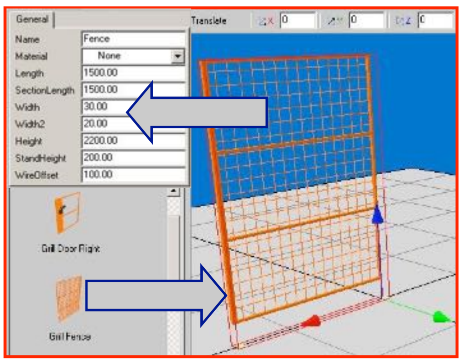
KUKA Sim – CAD Import

Layout

Pro

KUKA Sim **V1.1**:
Daten Import:

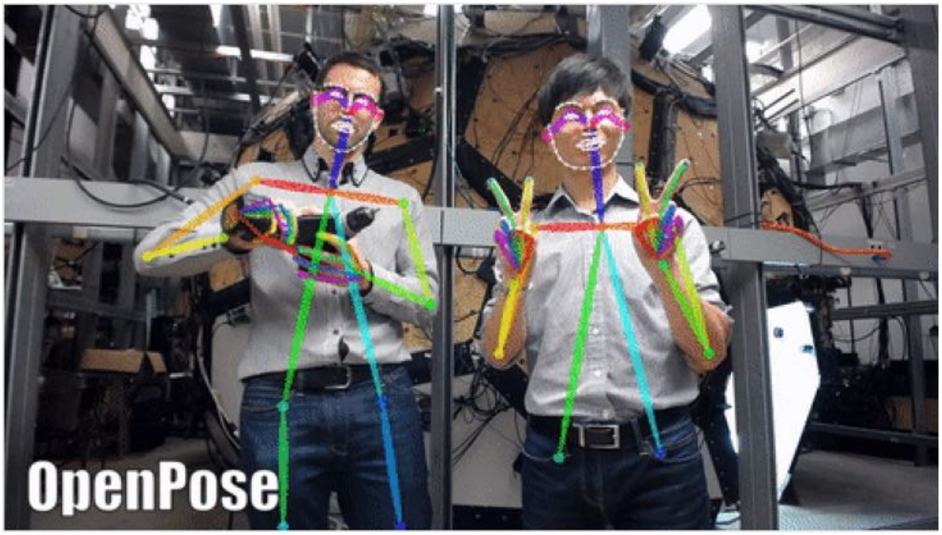
Components and Layouts (*.vcm,*.rsc)
Packages (*.vcp)
3D Studio (*.3ds)
DXF format (*.dxf)
Igrip/Quest/VNC geometry (*.*)
RobFace r4 file (*.rf)
ASCII Stereo lithography file (*.stl)
BINARY Stereo lithography file (*.stl)
VRML v1 file (*.vrml,*.wrl)



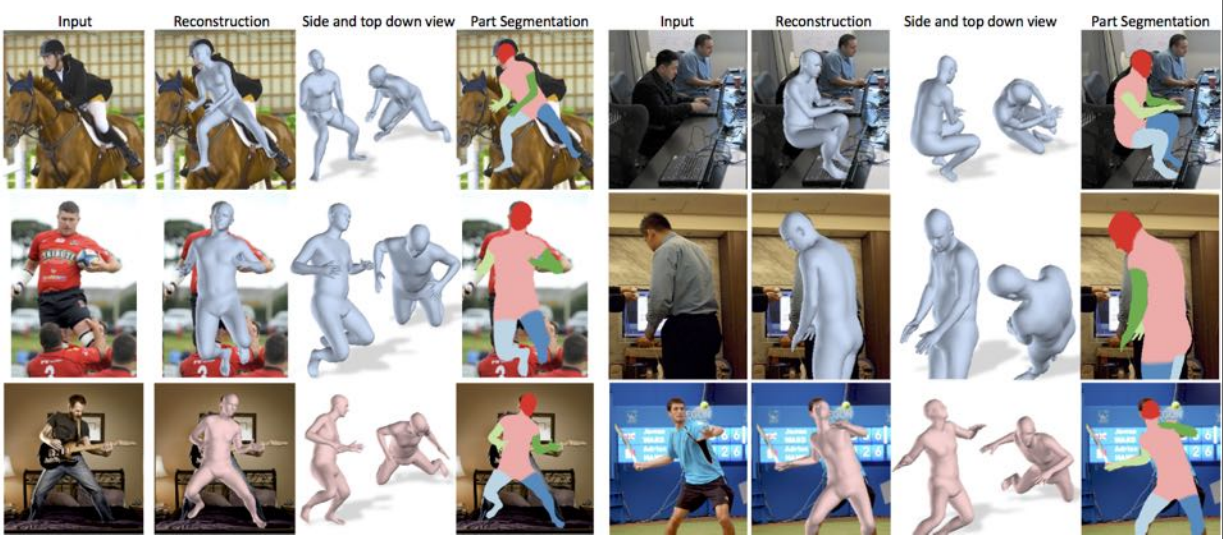
Daten Export:

3D Studio (*.3ds)
DXF format (*.dxf)
Igrip/Quest/VNC geometry (*.*)
RobFace r4 file (*.rf)
ASCII Stereo lithography file (*.stl)

BIOMETRICS

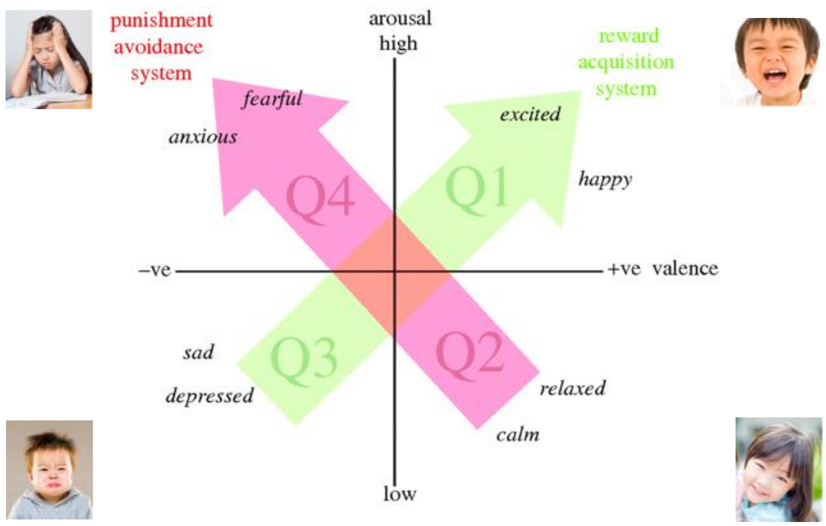


Source: OpenPose, CMU/GitHub



Source: Kanazawa et al, CVPR2018

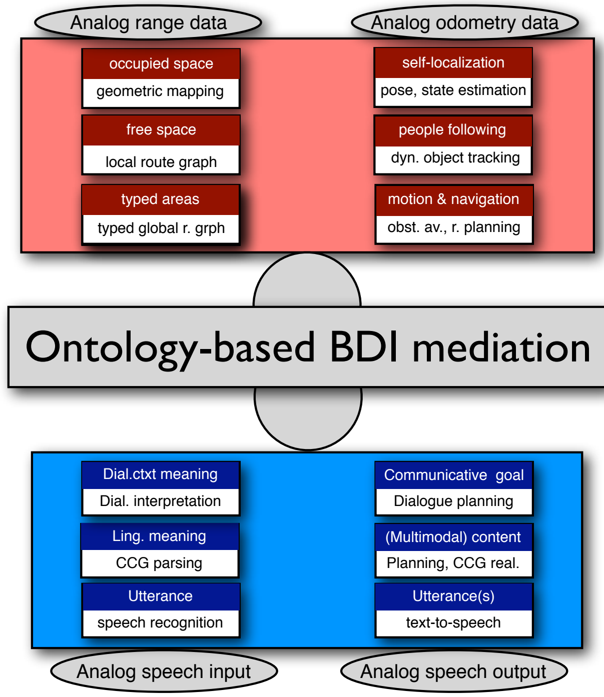
Affective states



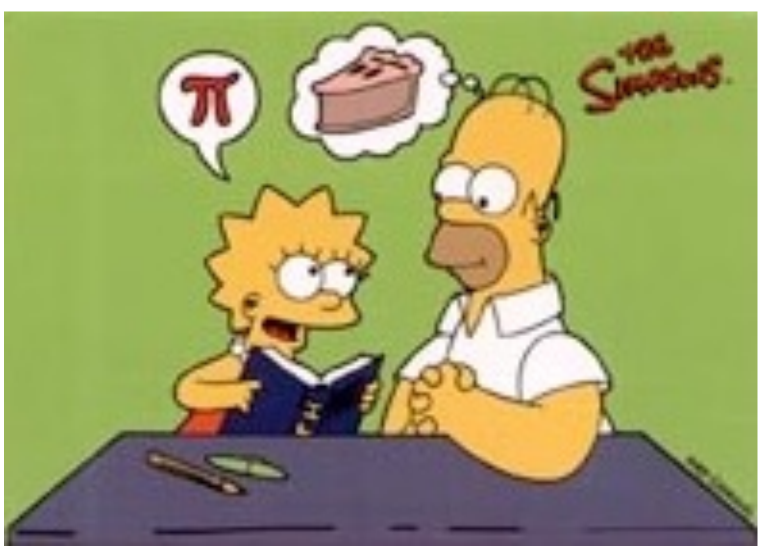
Spoken dialog interfaces

- Tremendous progress on spoken dialog systems
- Natural language processing
  - Definition of a dialog structure
  - Open-ended vs closed vocabulary
  - Semantic parsing
  - Action Generation
- Lets do a small example

Interface Architecture

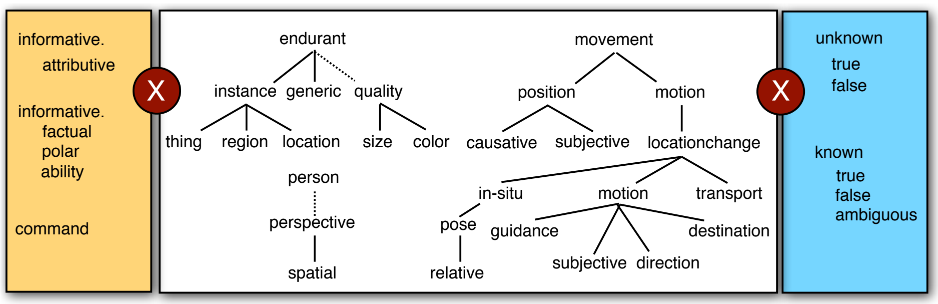


We need an ontology!

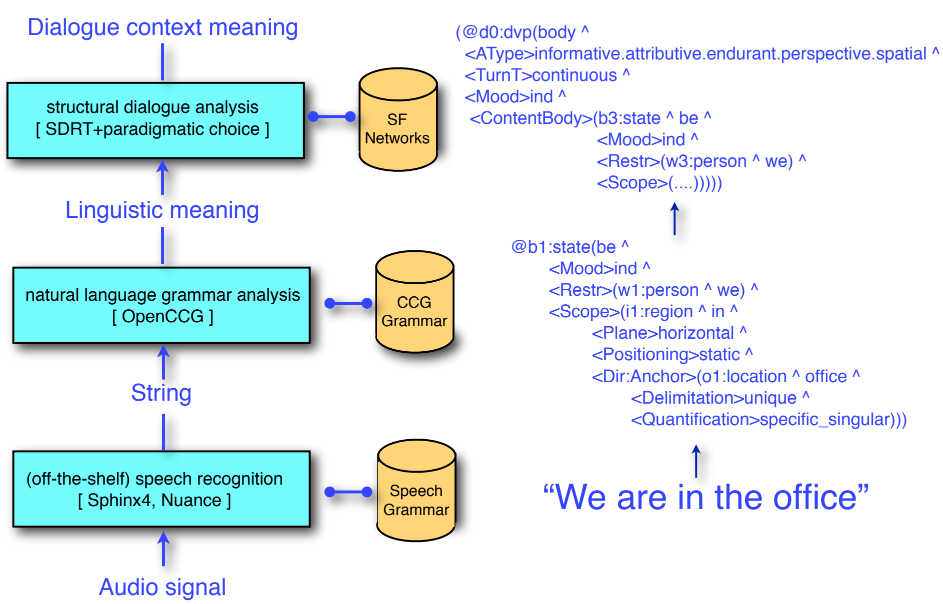


Definition of ontology

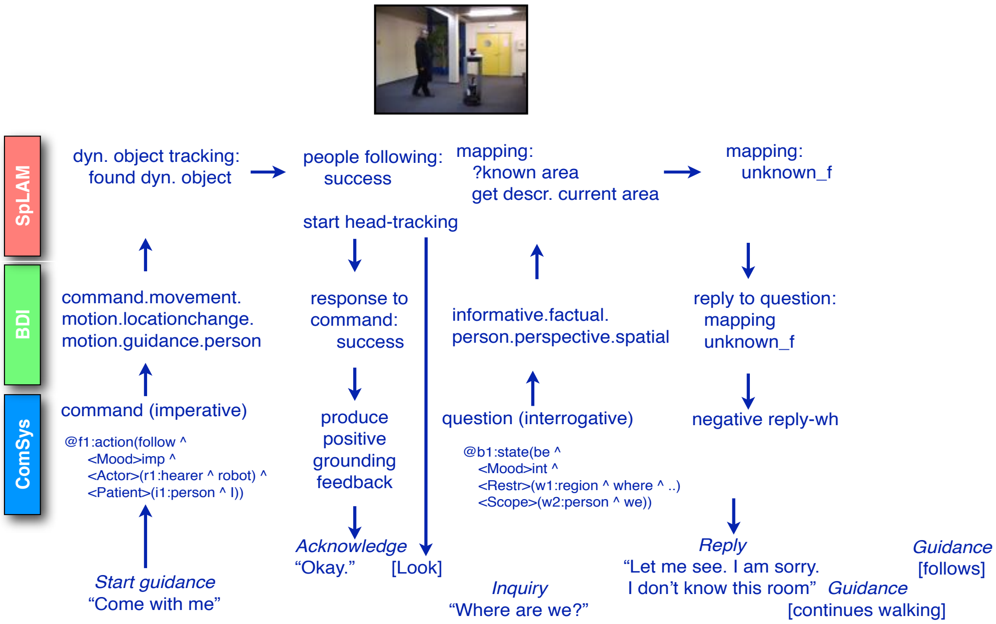
- Cross Modal contents association
  - Meaning: propositional contents + intention + context
  - Ontology for propositional truth and intention
  - Multi-valued truth system
  - Kruijff et al (2006)



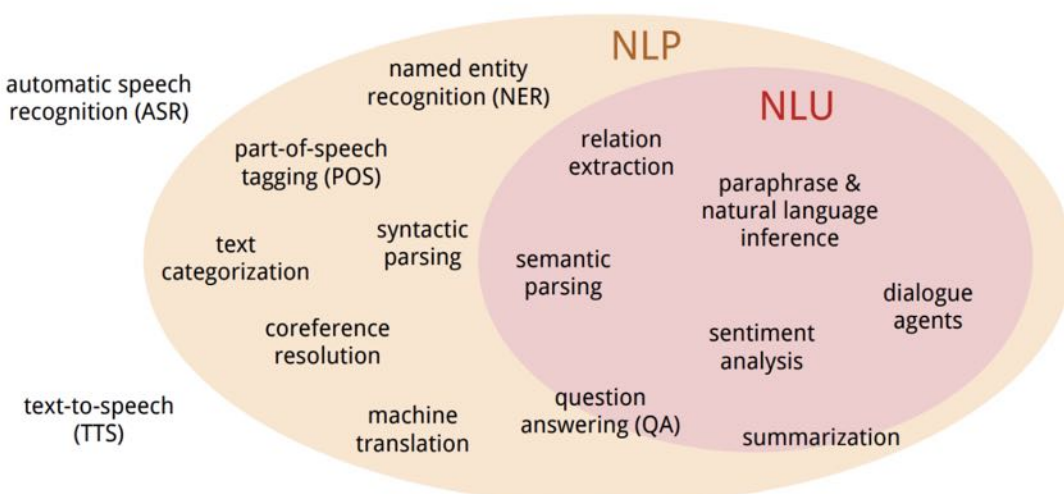
Spoken Language Processing



Simple Example



Terminology: NLU vs. NLP vs. ASR



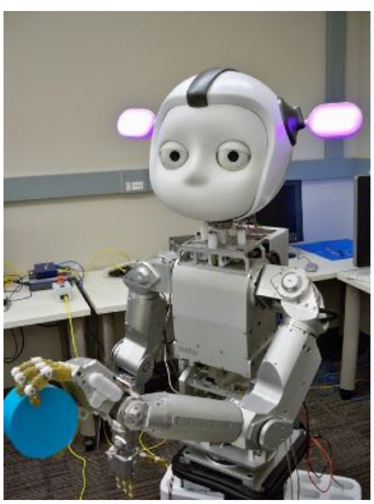
Language is Hard

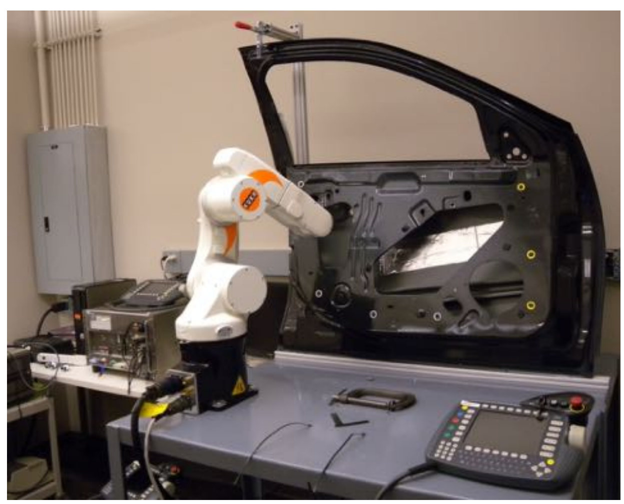
Source: Daily Mail

Assembly of industrial objects such as a door

- How can we simplify programming?
- Can we easily transfer to a running line?
- Can we combine speech, gesture, ... ?

Door Assembly - GT Platforms Utilized





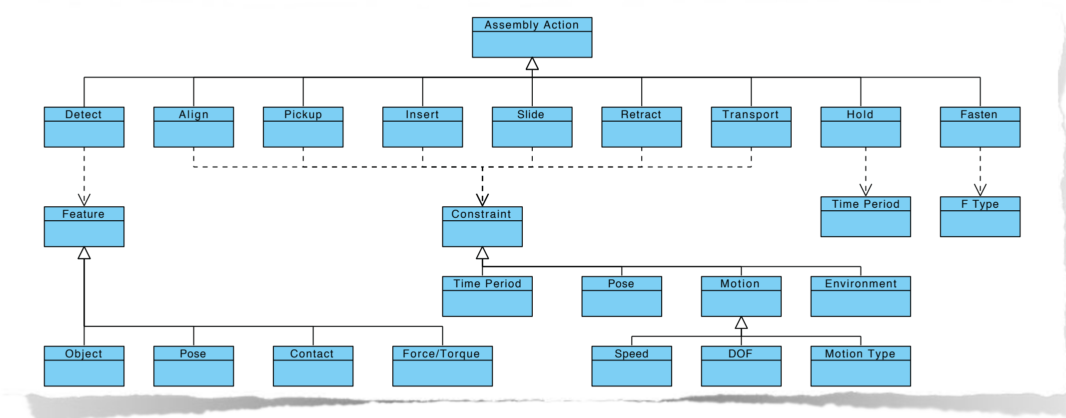
Interactive Task Acquisition

- Human teacher uses speech and gesture to direct the robot through a new task
- Robot generalizes task model/plan
- Progress: focus on door assembly using actions and relational features in the taxonomy

Interactive Task Acquisition

- Human guides robot through task examples
- Infers task model from seen relations between parts

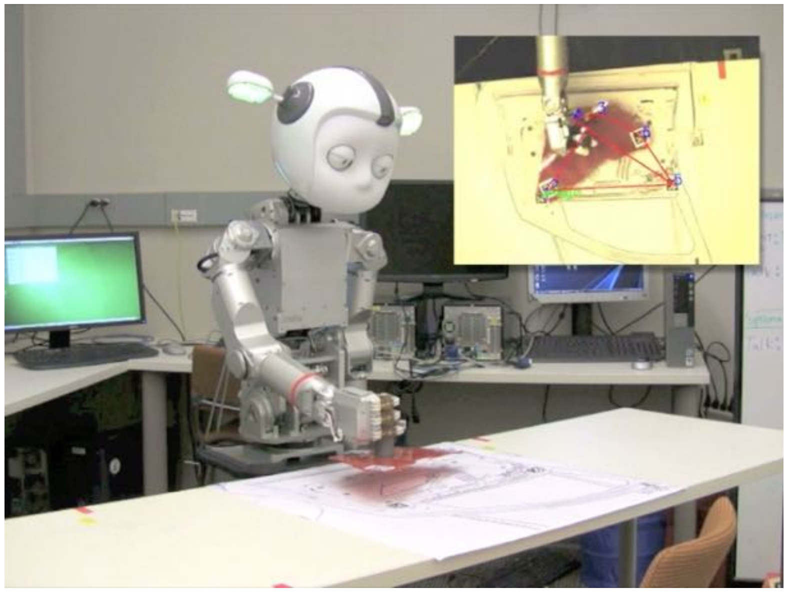
Definition of taxonomies or ontologies for control



Learn & Execute

Task	Acquisition		Execution	
	Recog.	Params	Percept	Control
Alignment	Dual Obj	Rel. Pose	Rec/Servo	3D Servo/
Pickup	Obj/Action	Obj Desc	Rec/Servo	Servo
Insert	Obj/Action	Pos / Const	Vision/Force	Seq /
Slide	Action	Start/End	1-2D Force	Impedance
Retract	Action	Space	NA	Path Plan
F. Screw	Action	Torque	Force	Insert/Torque
F. Snap	Action	Force/Event	Force	Force Disc

Gestures for Task Learning



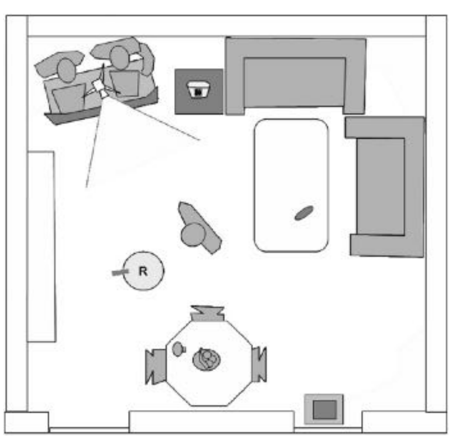
Example process for car assembly

Task Transfer to Execution Platform

- Learned model has general assembly task representation, independent of sensors/actuators
- Some features of the model need to be grounded in the new domain (e.g., object names/parts)
- Pointing recognition will allow for interaction about transfer between domains

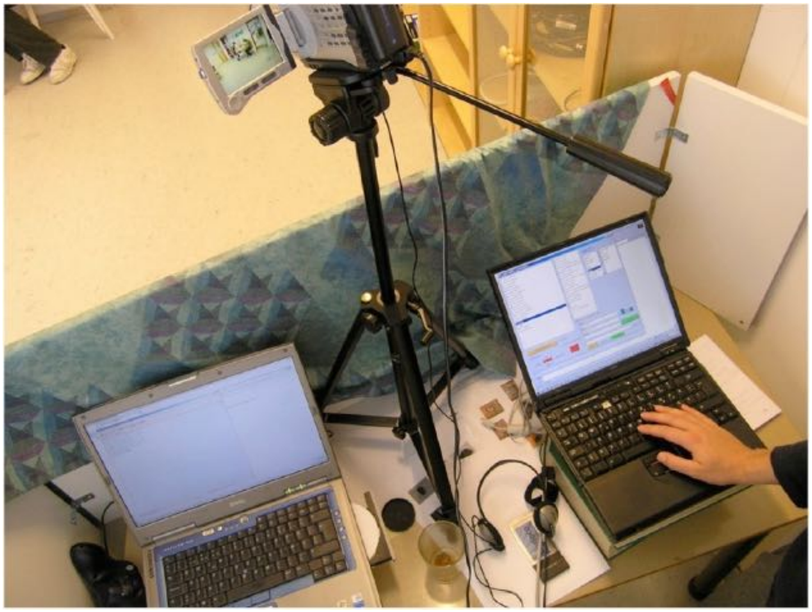
Gestures for Task Transfer

Setup of the Woz Scenario for initial tests



- Navigation in a living scenario
- Specify the key objects / places in the environment
- Verify places as needed
- Gestures and spoken dialogue is available

Woz Setup



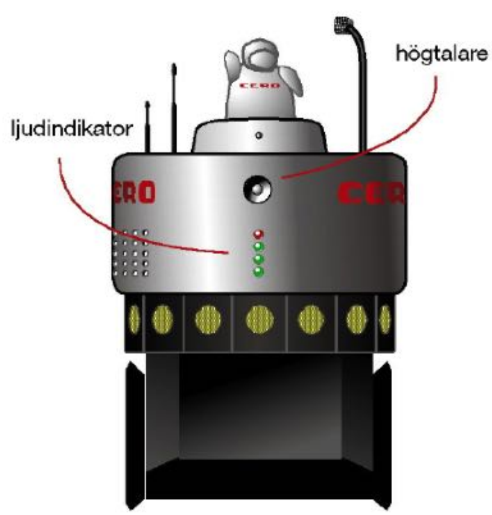
Scenario

Example Video

CERO

- An Early Study

- Simple transportation
- Fetch cup of coffee
- mail delivery, ...
- long-term tests



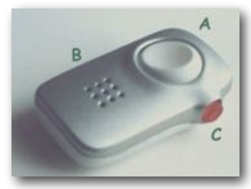
CERO

- Tasks
  - Drive to position x (kitchen, office,...)
  - Fetch coffee, deliver mail, ...
- Interface
  - Dialogue system
  - PDA interface
  - WWW interface
- User test over a period of 3 months

CERO System

- Mobile platform
- Box for deliveries
- A simple user interface
- Design is crucial

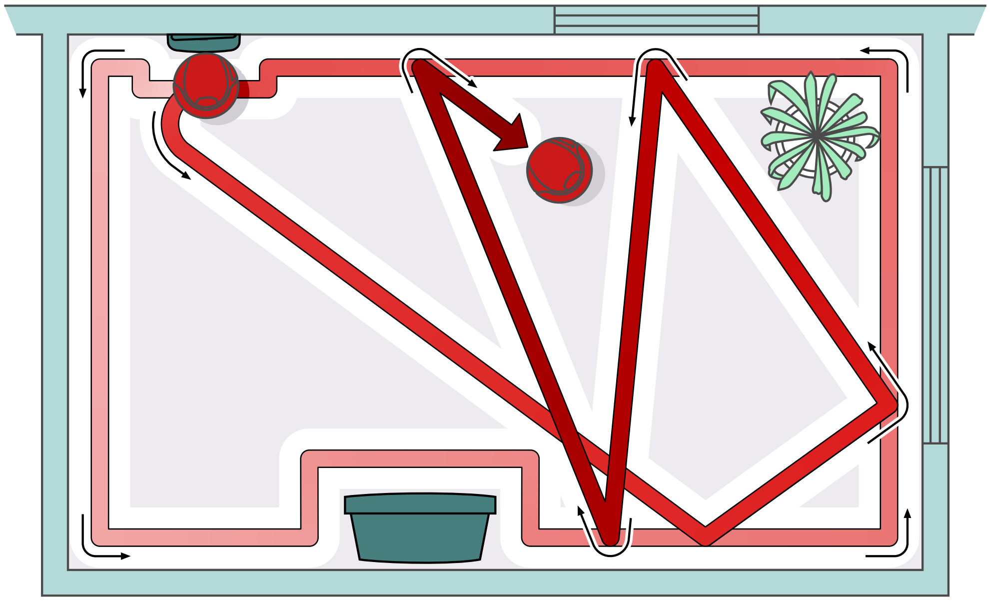
CERO Interface



Example - Trilobite motion strategy

- Cleaning of rooms
- Autonomous coverage
- Efficient handling
- Inexpensive to implement

Trilobite motion strategy



Second Example

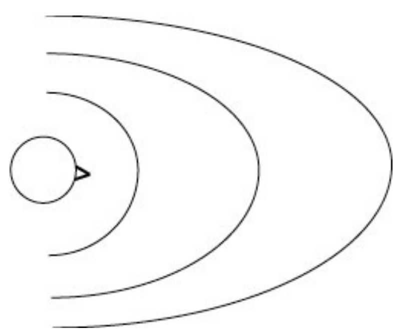
- What are some of the long-term implications of interaction with robots?
- Can we trust short-term interaction
- What about adaptation to robots
- How does dynamic behavior influence the perception of a robot
  - The italian driver experience?

Example - Passage

- How to behave in presence of people
- Social rules of engagement
- Embedding into a context

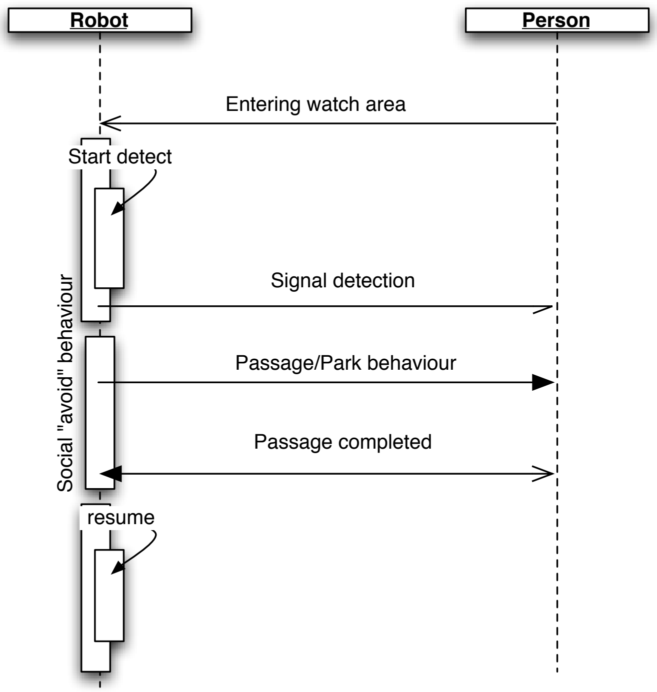
Social Rules - Proxemics

- Human-Human Distance studied in psychology [Hall, 1966]
- Regions considered
  - Intimate < 10 in
  - Personal 10-40 in
  - Social 40-100 in
  - Public space > 100 in

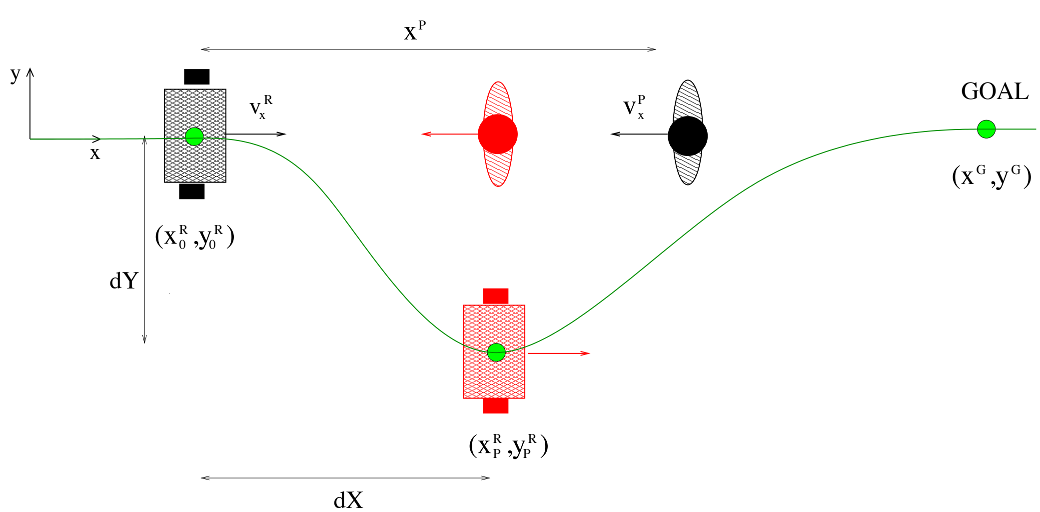


- There are cultural variations

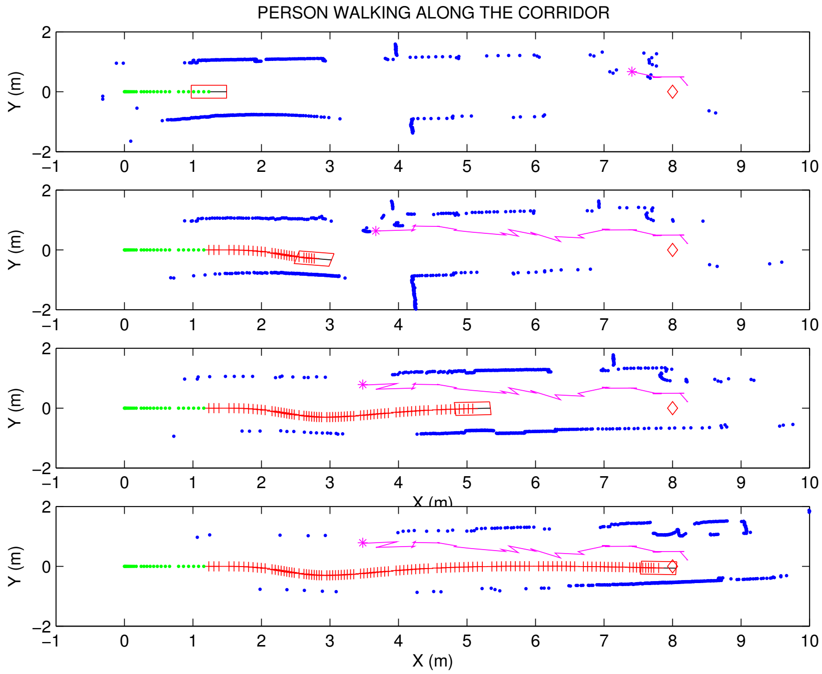
Passage Behavior



Control Design

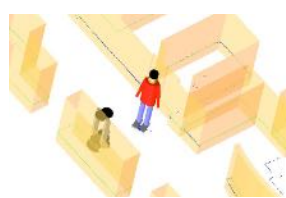


Early Result

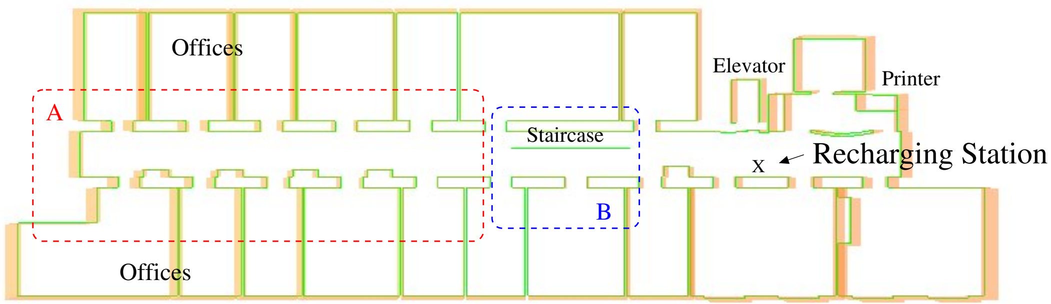


Early Evaluation

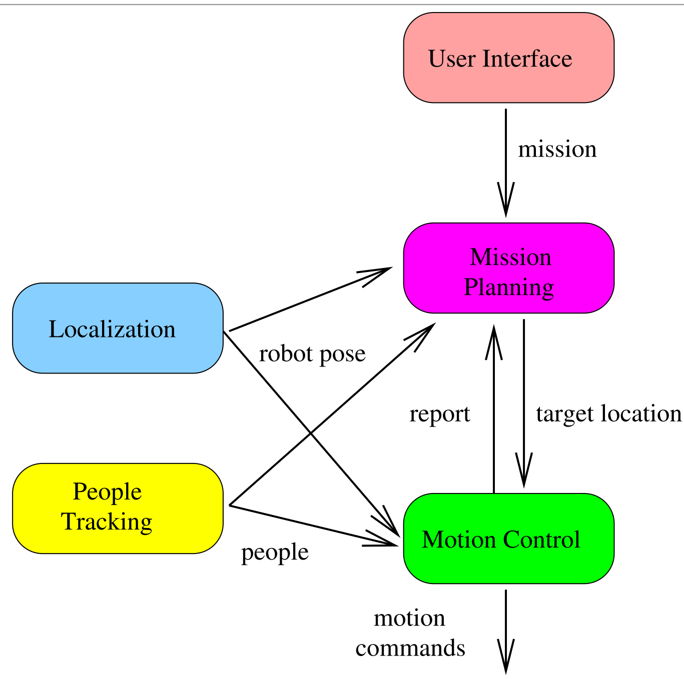
- Setup is too artificial to enable real evaluation
- The variety of situations is large
- Useful to consider a more credible scenario
- Long term evaluation?



Layout of Environment

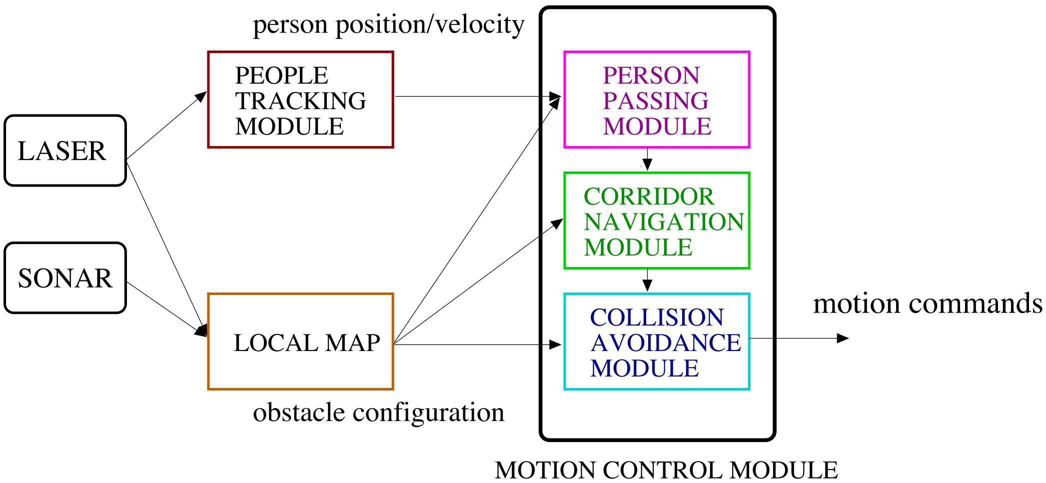


Embedding in a system



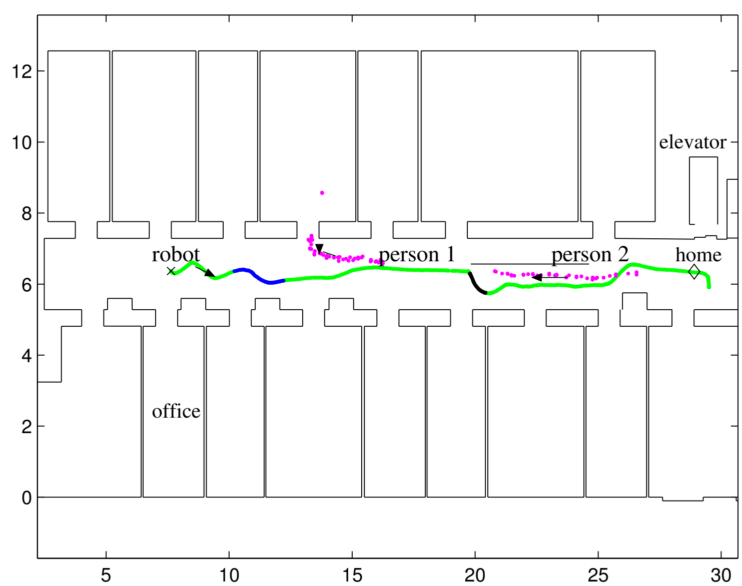
Simple GUI

Architecture



Embedding for evaluation

Person Passage



Evaluation Results

Period	Missions	Pers Pass	Park	Total
1' week	28	5	32	37
2' week	38	5	29	34
3' week	26	3	25	28
6' week	33	1	34	35
8 weeks	171	21	161	182

TritonBot

Next Generation Interfaces

Src: Seismic

Lessons

- Significant personal variations
- Adaptation over time must be considered
- Early evaluation using WoZ efficient
- “easy” to fool people
- The data material can be overwhelming
  - Distance, Dialog, Sensor Data, ...
- A careful design is required to make it manageable

HRI Summary

- Traditional interfaces based on CNC history
- Adoption of new types of interface modalities
    - Gestures, Speech, ...
- Simulation is also being adopted
- Extensive use of application packages to manage complexity
- Safety is essential to design of all systems
- HRI is one of the fastest growing areas in robotics
- Few HRI studies that are centered on real industry cases