



New Robotics For Factories of the Future

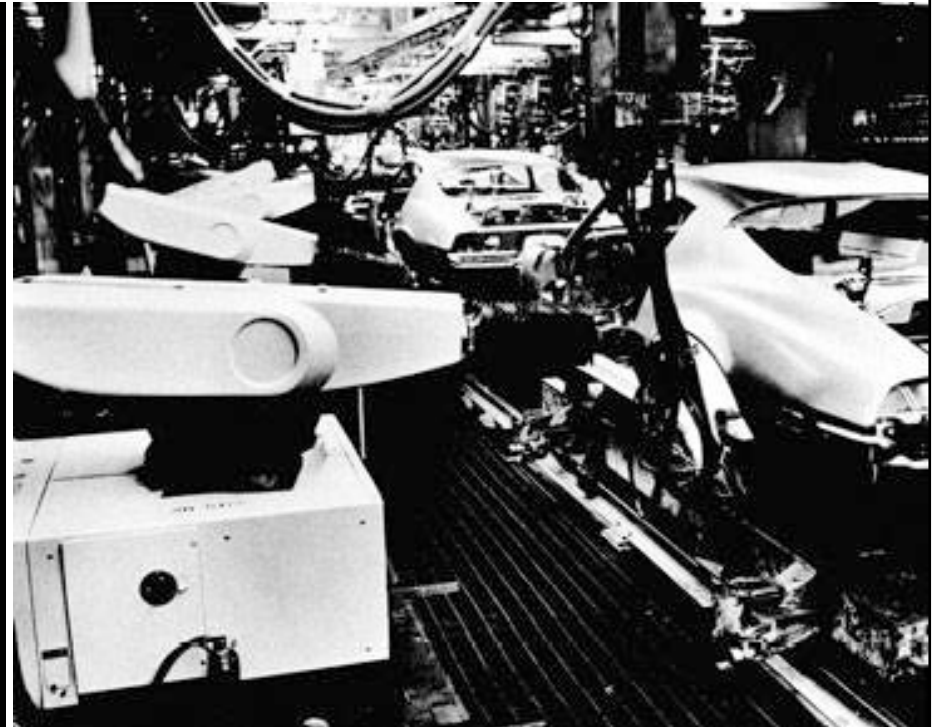
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CNRS and University Pierre and Marie Curie, Paris, France

First Industrial Robot: Unimate (1961)

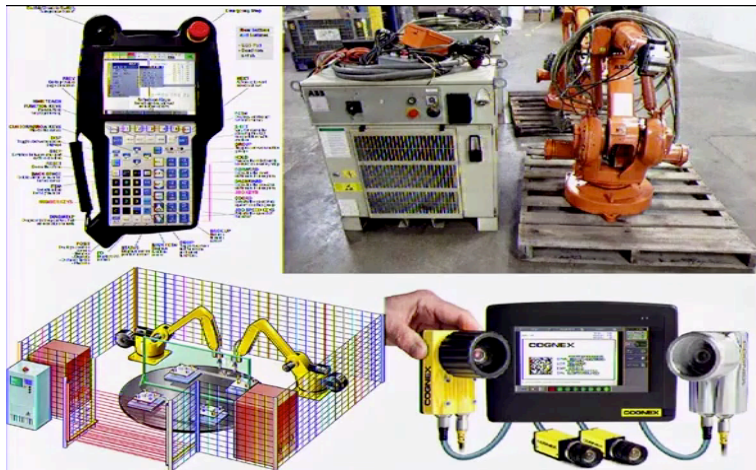
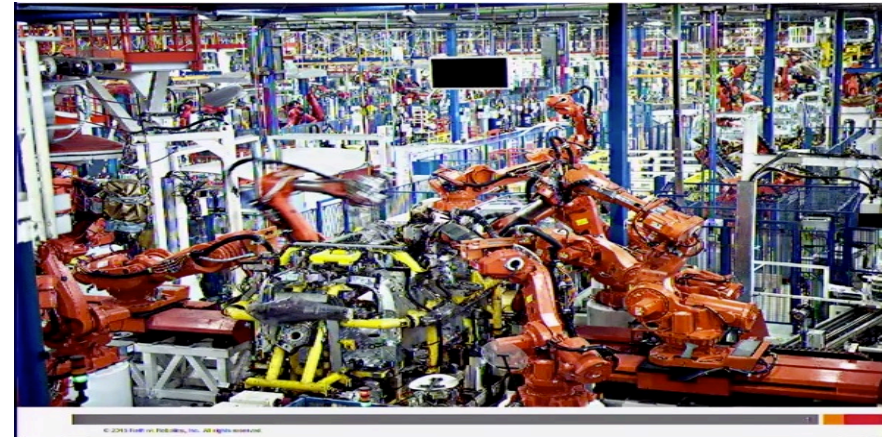


Unimate robot

2 000 kg, 25 000\$

Unimate @ GM

Today's Industrial Robots



- Precise
- Repeatable
- Operate in structured environments
- Not adaptable
- Installation not flexible
- Unsafe

Factory of the Future

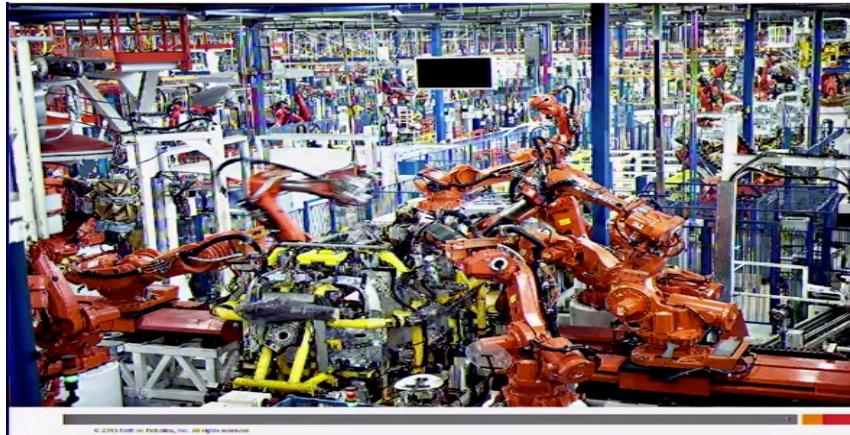
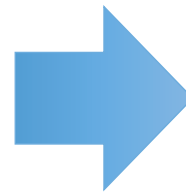
- More complex operations
- Flexibility in manufacturing
- Customization
- Responsiveness to demand
- Shortened lifecycle and timeframes
- Smaller, shorter operations, but that can ramp up and scale
- Closer to the end market
- Low cost infrastructure

Factory of the Future Needs

- *Difficult to achieve with large, fixed, manufacturing plants*
- *Could be better addressed by a combination of qualified labor and new robotics technologies*

Smart human-machine collaborative systems

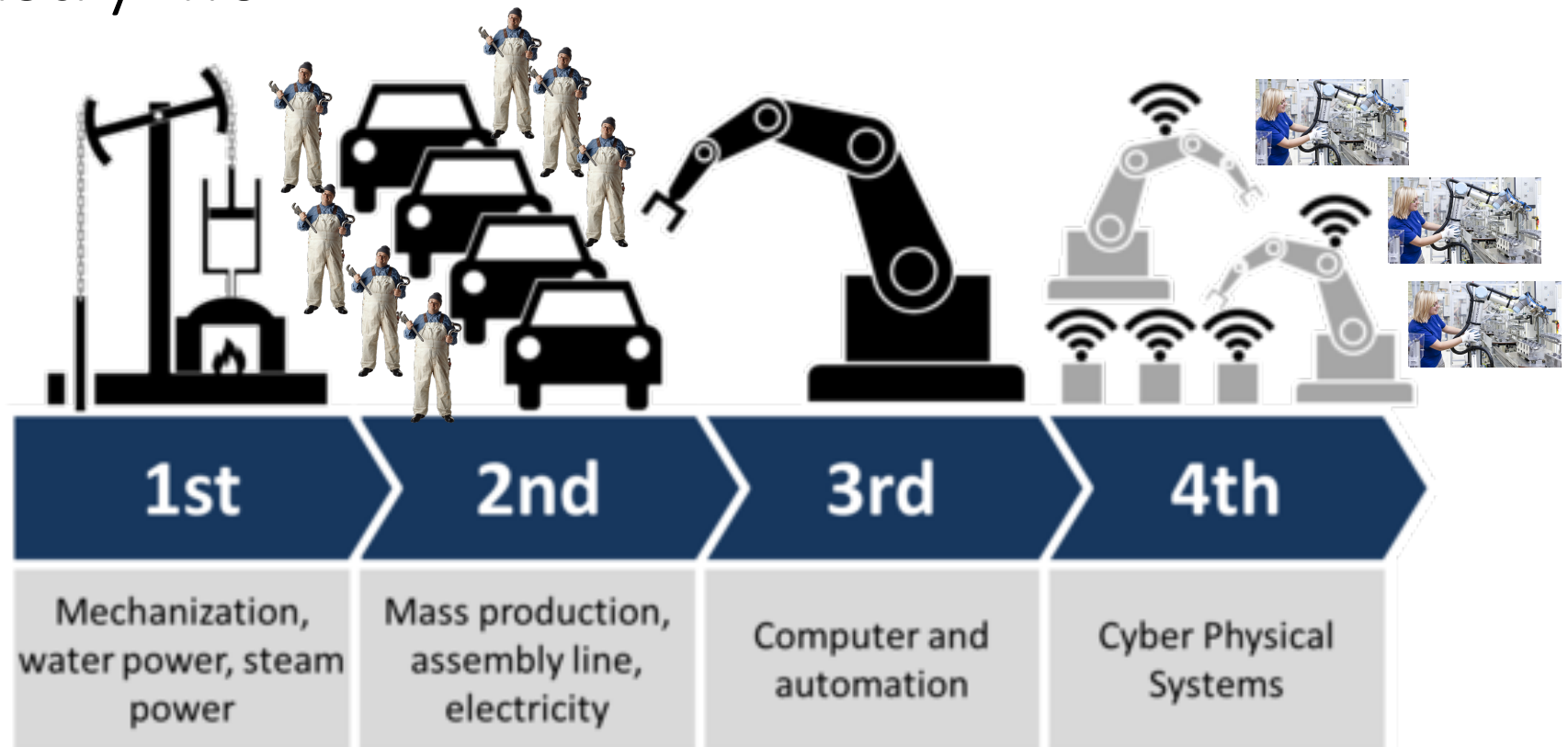
From Automated to Cooperative Manufacturing



25/06/16

FoF, IFIP 2016, Sorèze

Industry 4.0



Christoph Roser at AllAboutLean.com." - Own work

Robotics for F-o-F

- Advanced sensing, perception and control
- Mobility and Dexterity
- Coping with uncertainties
- Autonomous actions and decision making
- Learning and adaption to the tasks and to the environment
- Human-machine interaction and cooperation; interfaces
- Multiple connected cooperating systems; cyberphysical systems.

From Safe Robot Motion ...



Kuka LW Arm
Courtesy DLR,
Sami Haddadin 9

To Compliant Control...



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Sawyer Robot
By Rethink Robotics ¹⁰

To Human-Robot co-habitation...



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Kawada Nextage robot

FoF, IFIP 2016, Sorèze

© NHK – « Next robots » ¹¹

To Human-Robot co-operation



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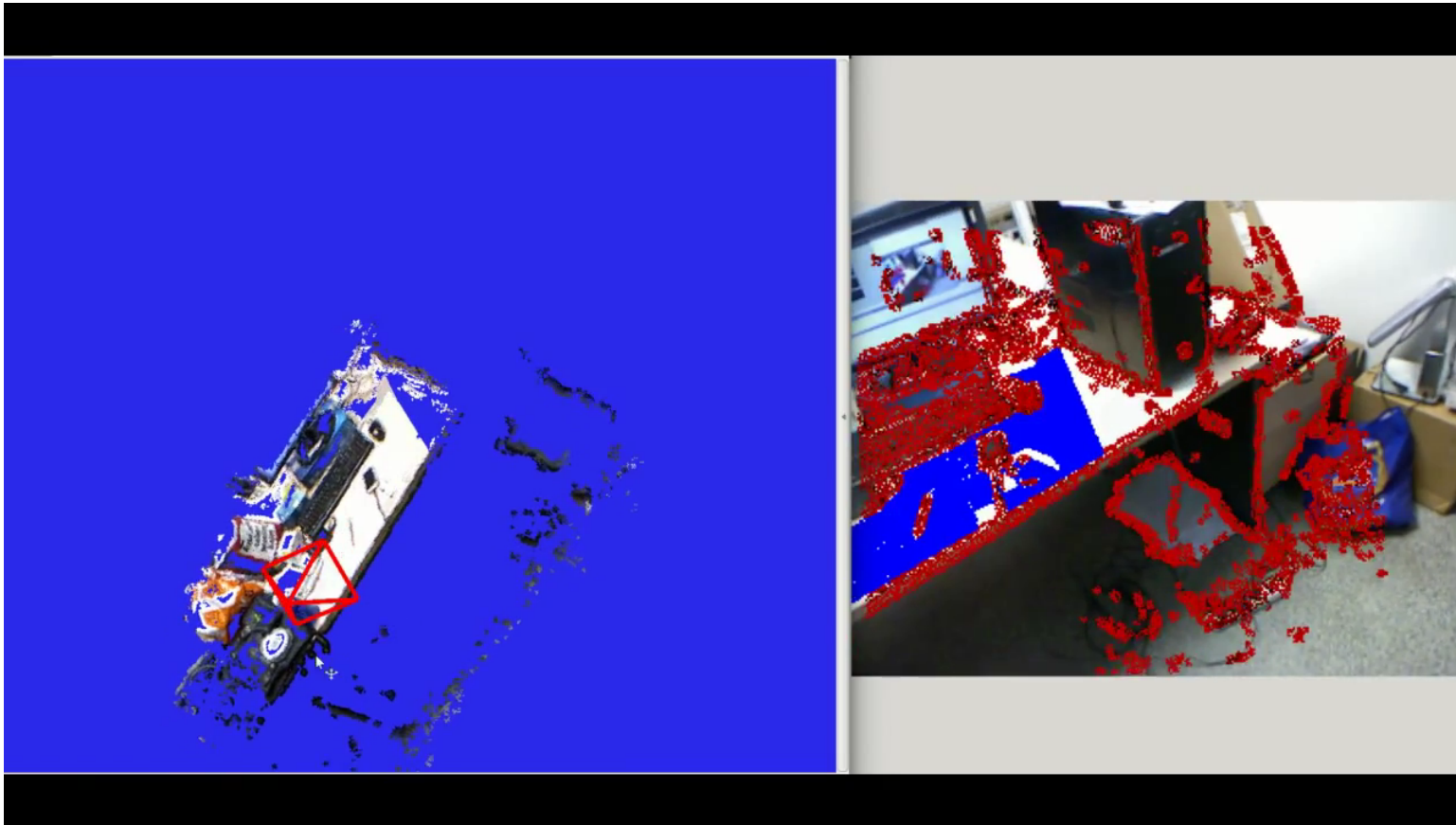
FoF, IFIP 2016, Sorèze

Baxter Robot
By Rethink Robotics ¹²

Robotics and Related Technologies and Capabilities for Industry 4.0 and Smart Cities

- High resolution sensing
- Vision and 3D perception; augmented reality
- Self localization and environment mapping
- Compliant robot arms and safe elastic actuators
- Dexterous manipulation
- Reactive task execution
- Perception of humans
- Human-Robot cooperation and Joint actions

Visual Localization and Mapping



Human Aware Motion Control



Dexterity



3x
Object and
obstacle
detection

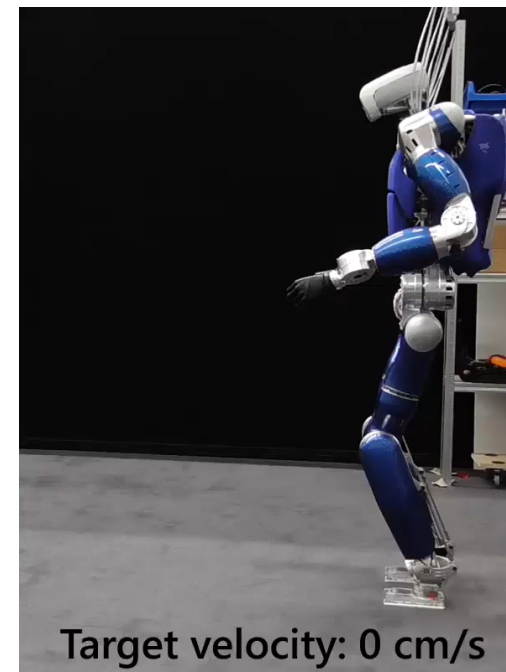
FP7 Project
HANDLE @
ISIR
handle-
project.eu

Full Body Motion Planning and Control for Humanoid Robots



Complex activities synthesis

Icub@ISIR



Walking controller

ISIR
in cooperation
with DLR

Interaction With Humans

■ Performing Actions with Humans:

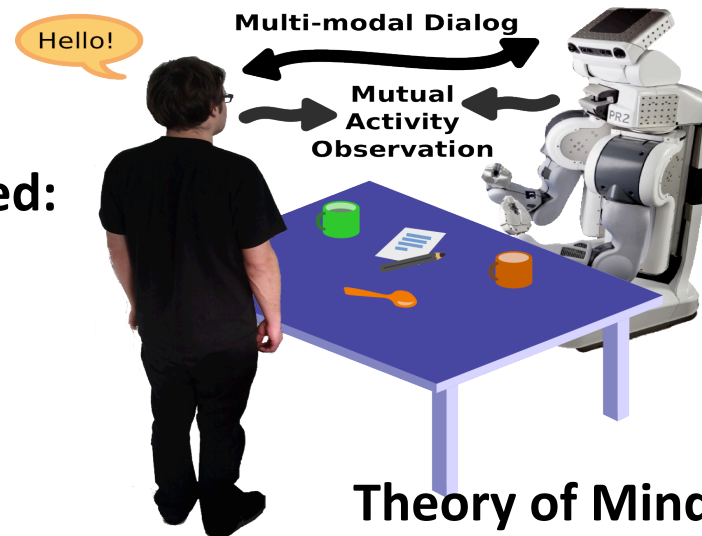
- Efficiency
- Safety
- Acceptability
- Intentionality
- Legibility

■ Plan-based, situation-based:

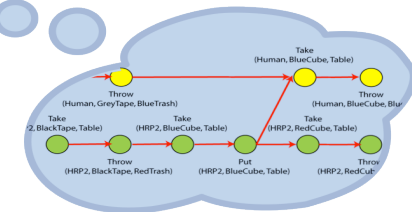
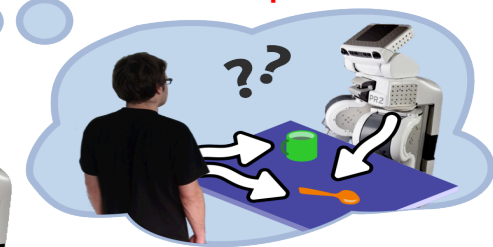
- Reasoning
- Anticipation
- Pro-active behaviour
- Reactive behaviour

Human and Robot Share Tasks and Space Models from human-human interaction

Cooperative task achievement
Situation Assessment



Perspective taking

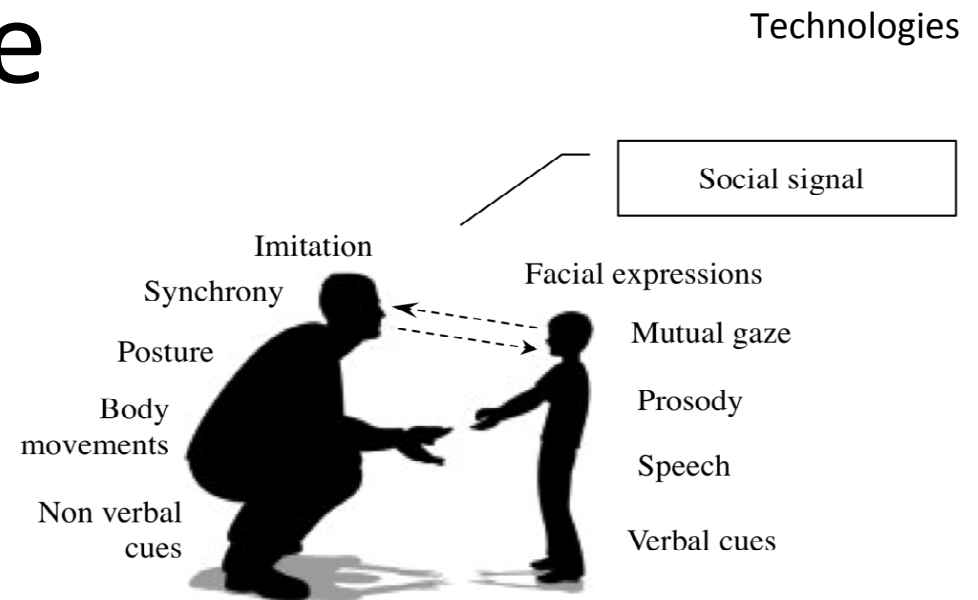
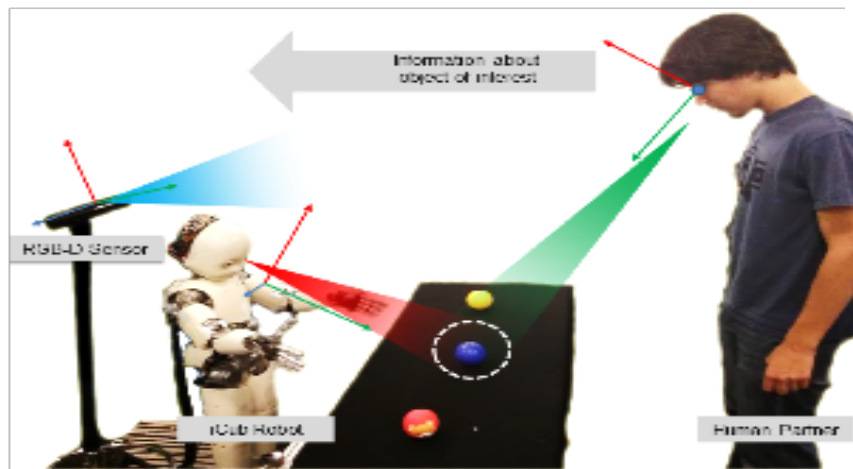


Planning joint actions

Theory of Mind: Predicting of, and reasoning on human activity and mental state

Social Intelligence

- ▶ Shared tasks
- ▶ Second-perspective taking
- ▶ Dynamics of interaction (synchrony)
- ▶ Object learning; interaction with humans
- ▶ Cooperation for task achievement

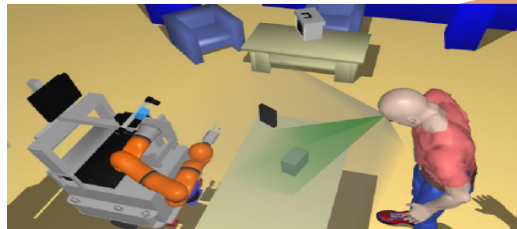


Perspective Taking

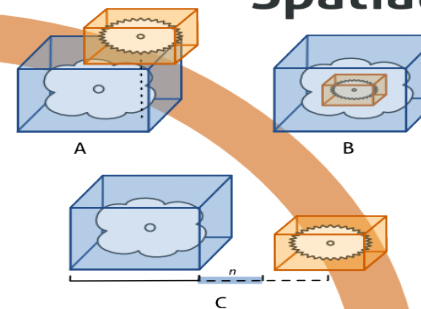
Visual perspective: Field of View, gaze, percentage of visible object meshes

Human affordances: Reachability and collision-free reaching motion.

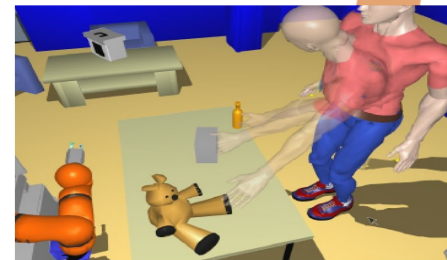
Visibility



Spatial relations

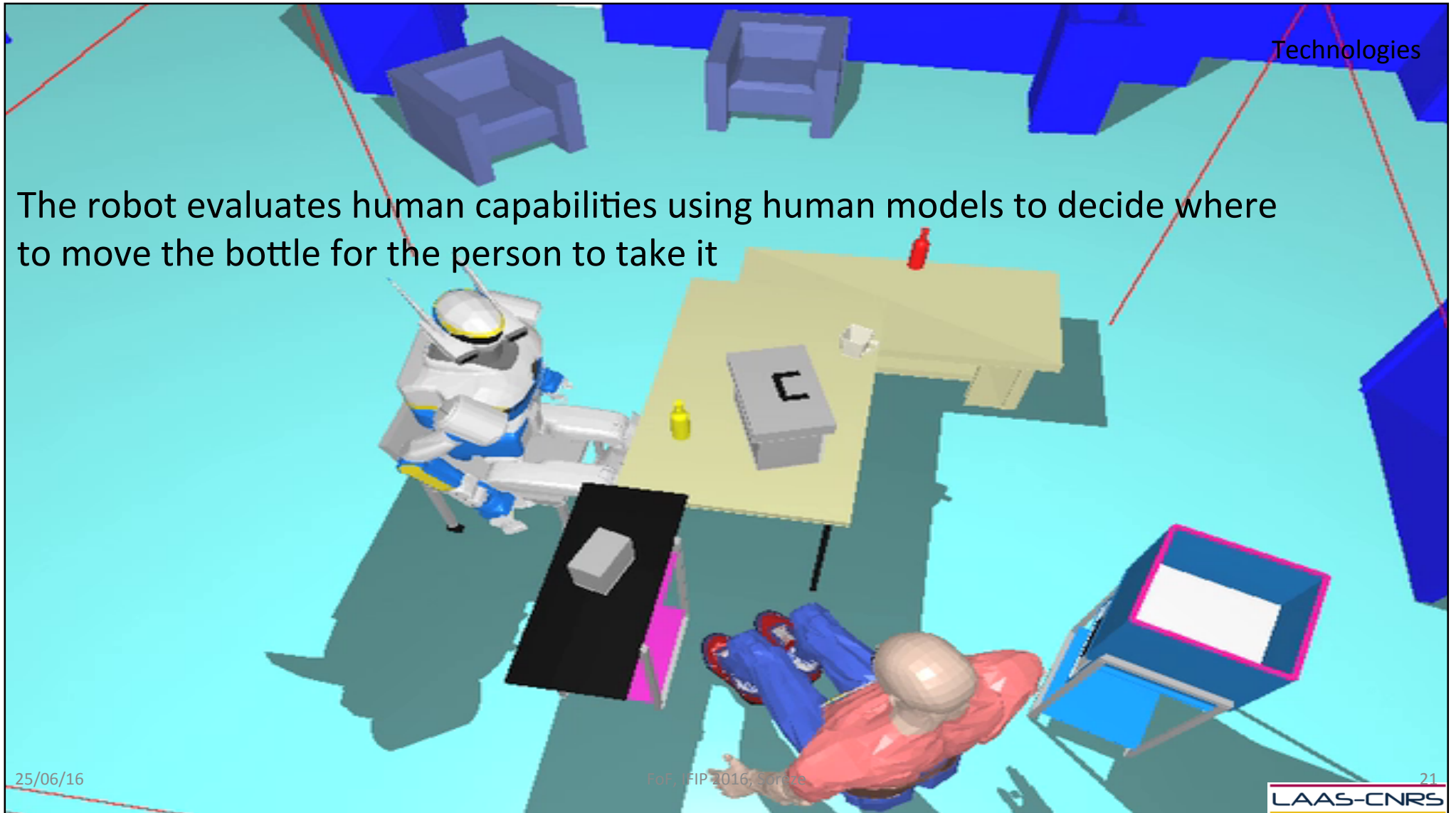


Relative locations



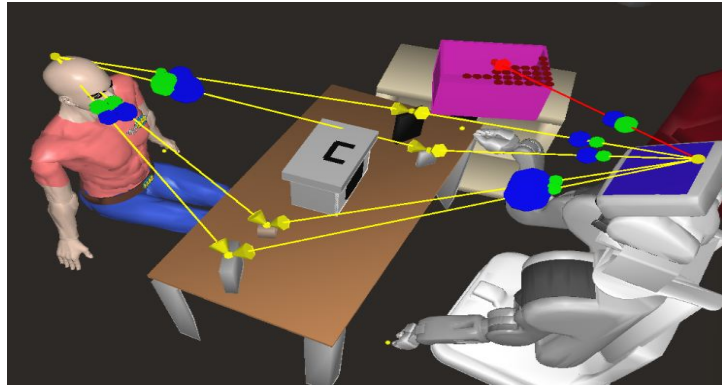
Reachability

The robot evaluates human capabilities using human models to decide where to move the bottle for the person to take it

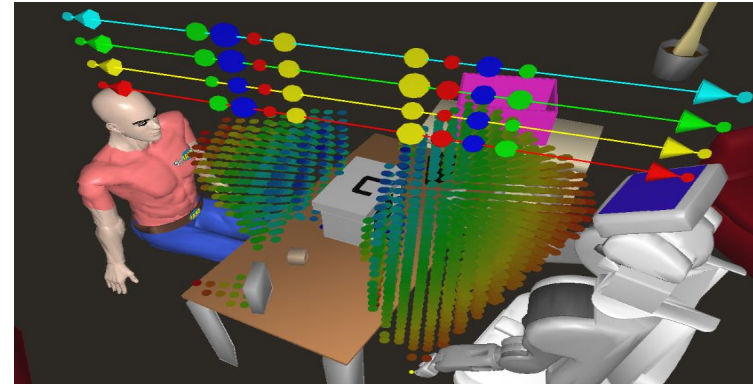


Example

Technologies

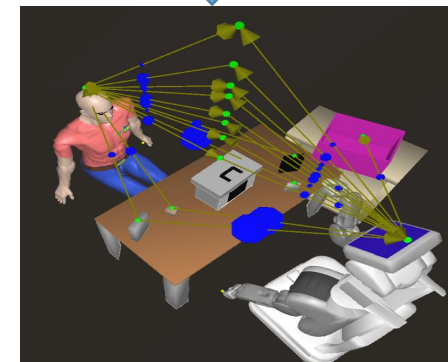


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Who can do what with which object with which effort.

Who can do what for whom, with which effort and where.



Affordance Graph

Logistics: Connected Multi-Robot System

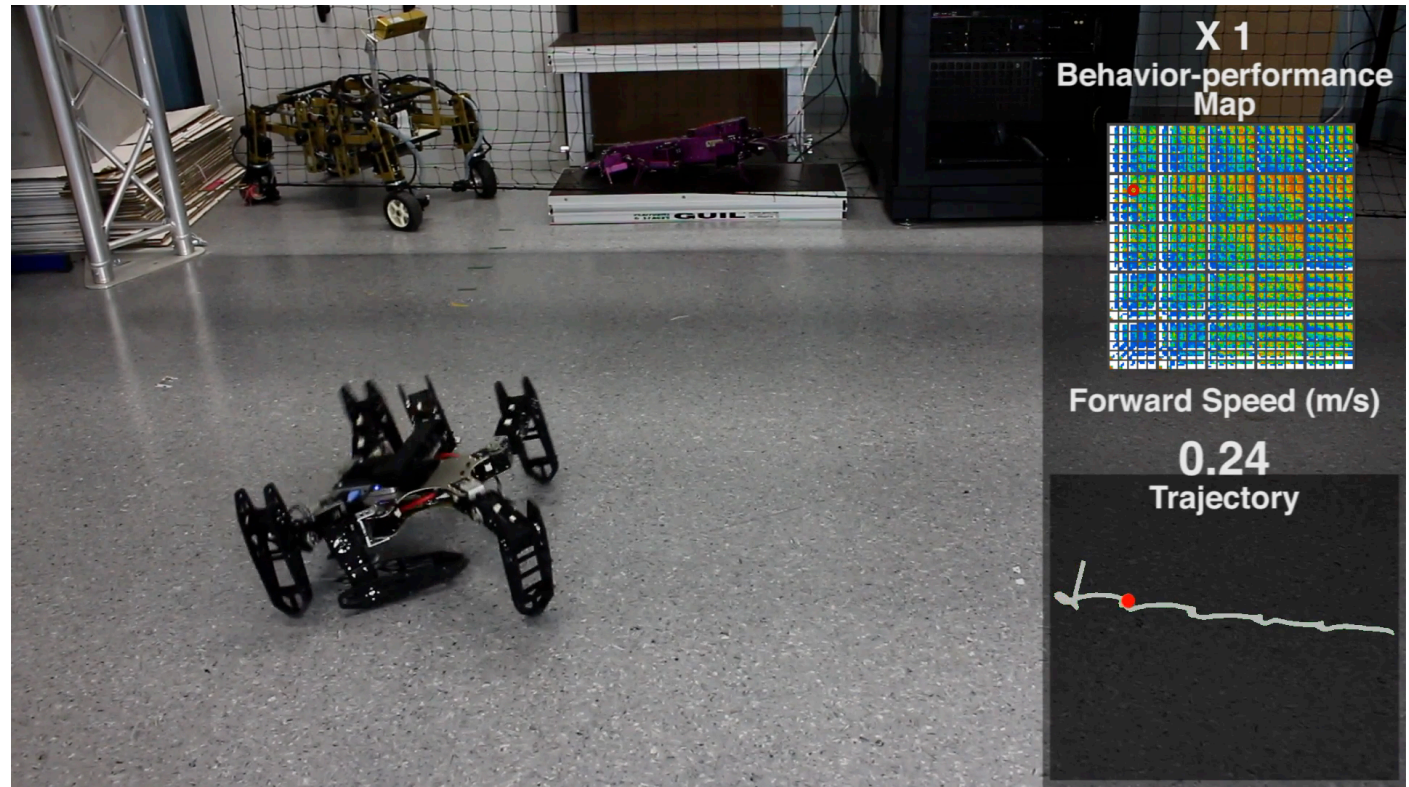


Kiva Robots
Amazon

Resilience, Adaptation and Reconfiguration

Cully, A., Clune, J., Tarapore, D., and Mouret, J.-B. ISIR

Robots that can adapt like animals. Nature, 521.7553 (2015)



A Few ELS Issues in Deploying Robots in Factories

- Jobs and impact of workforce
- Workplace adapted to the human
- Acceptability and adoption
- Privacy, surveillance
- Production process organization; interoperability
- Norms and standards



Some Dependability Issues

- Data protection
- Dependable systems and reconfigurable systems
- Dependable autonomous systems
- Dependable interactive systems
- Dependable distributed cyberphysical systems
- Dependability and interoperability

Concluding Remarks

- Robots are important components of Smart factories and, later Smart cities
- Safety and security are essential for deployment in these contexts.
- Robot autonomy and Human-robot interaction are key for the integration of robots, in factories, at home, in public spaces
- ELS issues should be considered in robot deployment