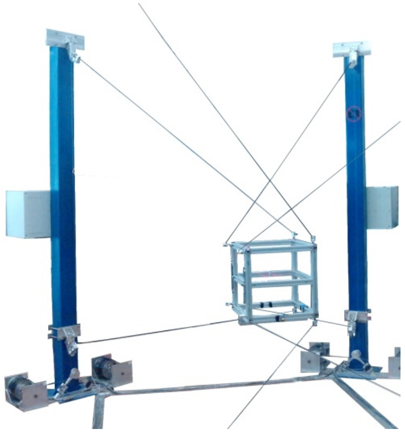
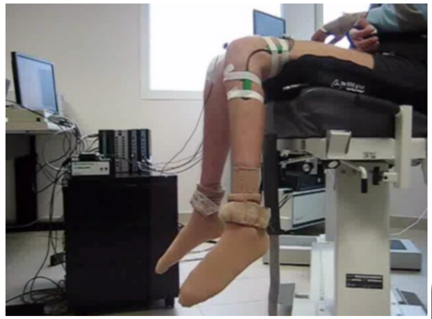
Sensor-based robot control for Physical-Human Robot Interaction

IDH – Interactive Digital Humans

Robotics Department



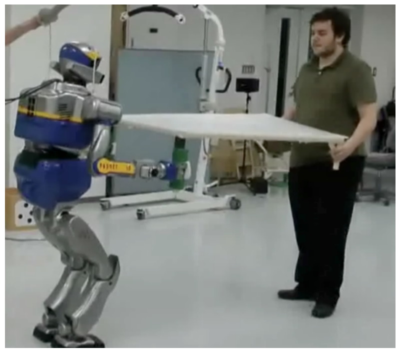
- **DEXTER**
  - Design, control, handling
  - Parallel and medical robotics



- **DEMAR**
  - Modeling and control of human sensorimotor systems
  - Neuro-prosthetics

- **EXPLORE**
  - Guidance, navigation, planning of ground and submarine robot fleet

- **ICAR**
  - Image, signal, vision, coding

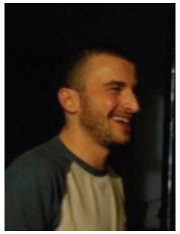


- **IDH**
  - Humanoid robotics, physical HRI

IDH – Interactive Digital Humans

- Permanent staff
  - **Abderrahmane Kheddar** (Res. Dir.)
  - André Crosnier (Full Prof.)
  - Philippe Fraisse (Full Prof.)
  - Andrea Cherubini (Ass. Prof.)



- Engineers
  - Kevin Chappellet, Robin Passama
- Postdoc
  - Karim Bouyarmane, Giovanni De Magistris, Alfonso Montellano Lopez, José Romero Velazquez
- PhD Students
  - Don Joven Agravante, Hervé Audren, Stanislas Brossette, Benjamin Chretien, Benjamin Navarro, Adrien Pajon, Damien Petit, Tu-Hoa Pham, Mohamed Sorour, Vincent Samy, Arnaud Tanguy, Joris Vaillant, Damien Veillard

SCIENTIFIC OBJECTIVES - KEYWORDS

- Human-Humanoid embodiment
- Human modeling for humanoid control
- Humanoid multi-contact planning and control
- Human-Robot physical interaction

Human-robot physical interaction

Short Circuit (1986)

Applications of physical human-robot interaction

- Cobots for the industry


- Assistive robots


- Interactive toys





SOURCES: kinovarobotics.com, blog.robotiq.com, spectrum.ieee.org, aliexpress.com, plioz.com, online-electronica.com, pal-robotics.com, wii.you.fr, mn.uio.no

Objectives of physical HRI

- Safety
- Precision
- Flexibility

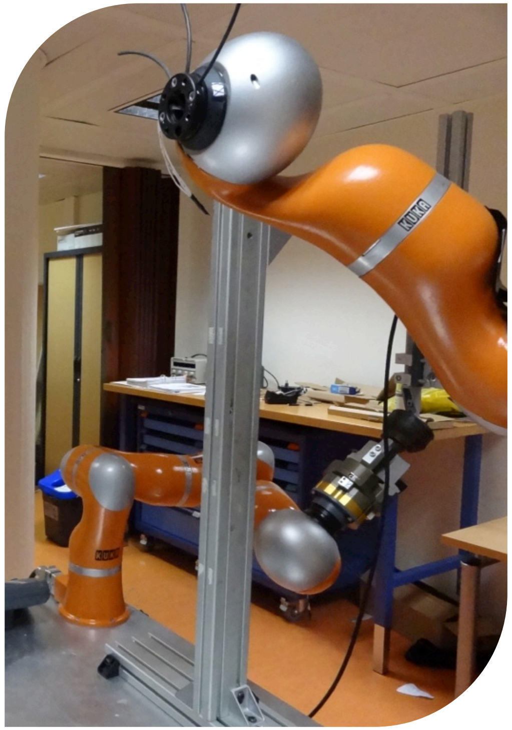
- Intuitive control by the human ➔ intention recognition
- Reactive adaptation instead of optimization

⚠ human solutions are rarely optimal and unique (e.g. QWERTY)

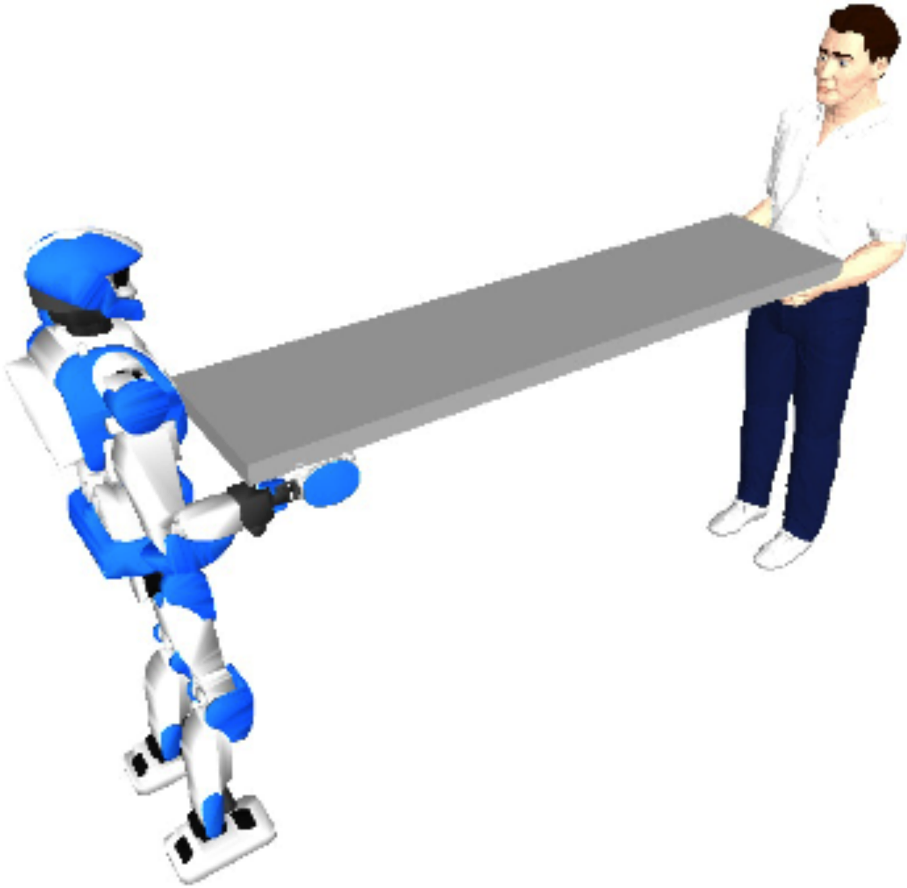
➔ Sensor-based approaches

Vision
Touch

IDH Robotic platforms



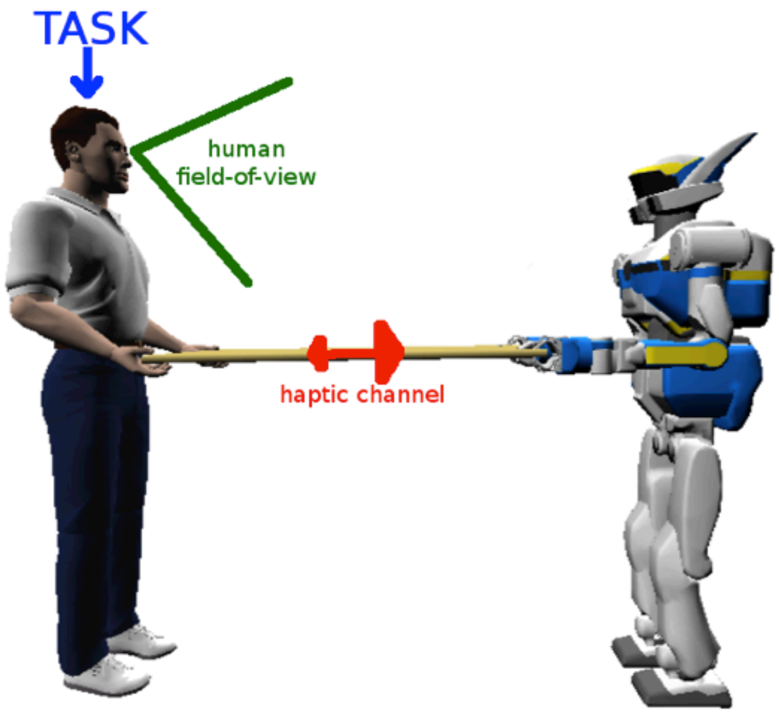
Cooperative object carrying



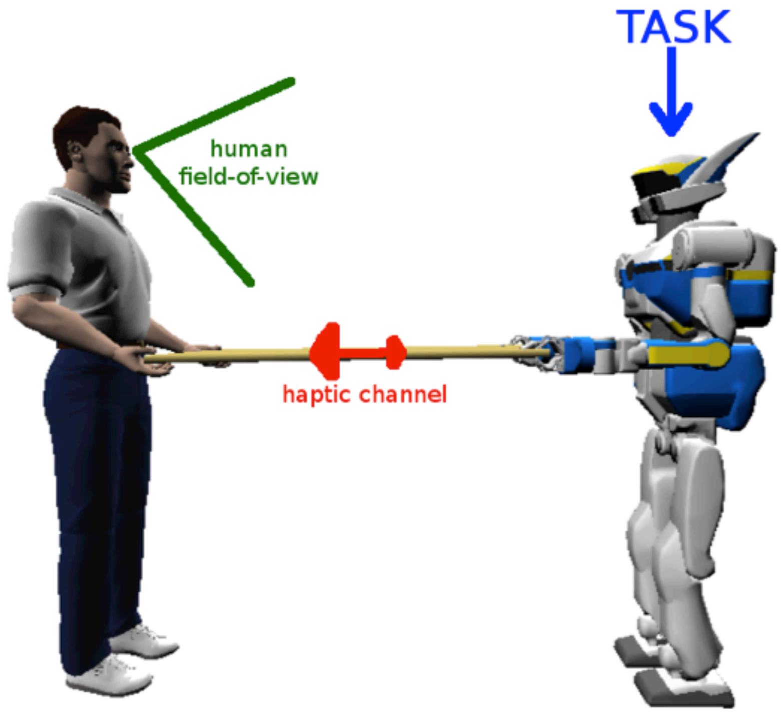
Why touch/haptics?

"communication channel"

Robot as a "pure follower"

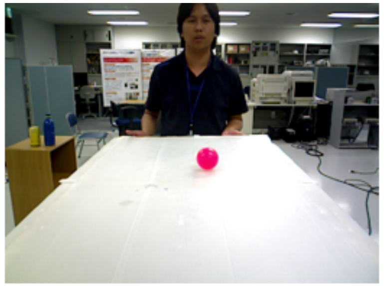


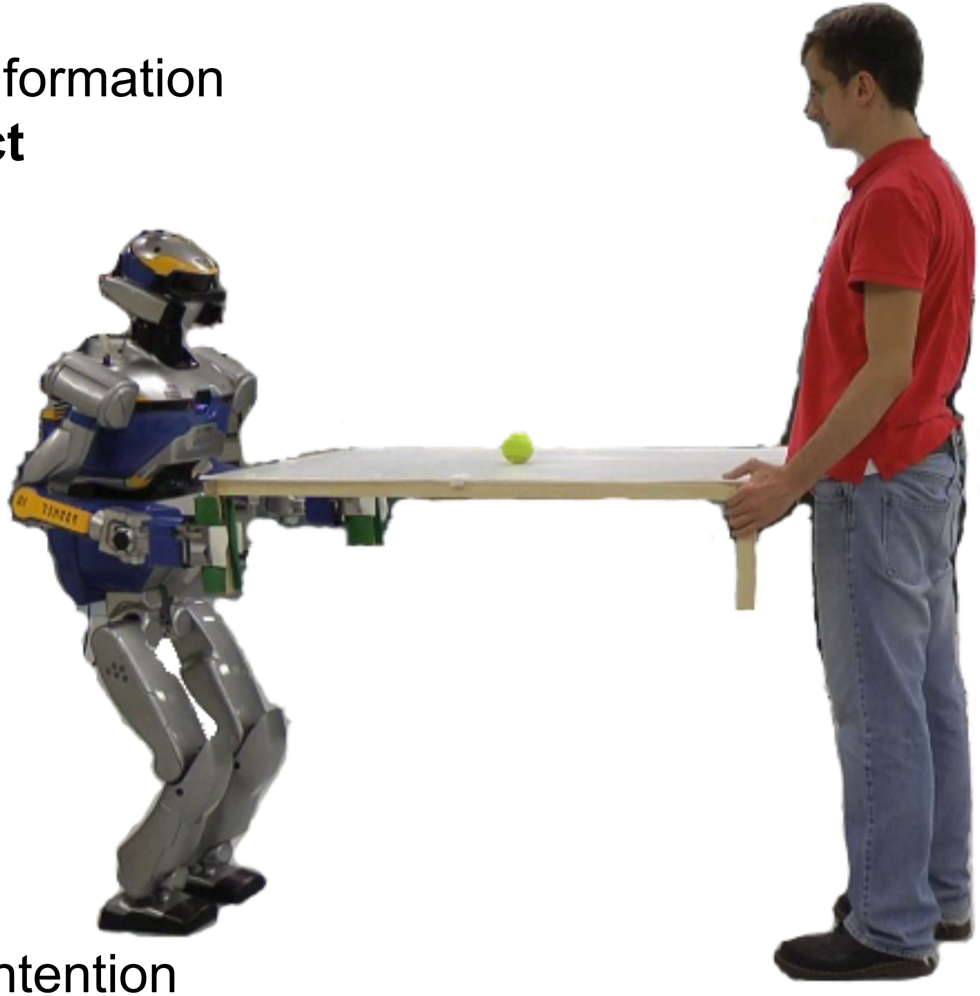
Robot as a "pure leader"



Why vision?

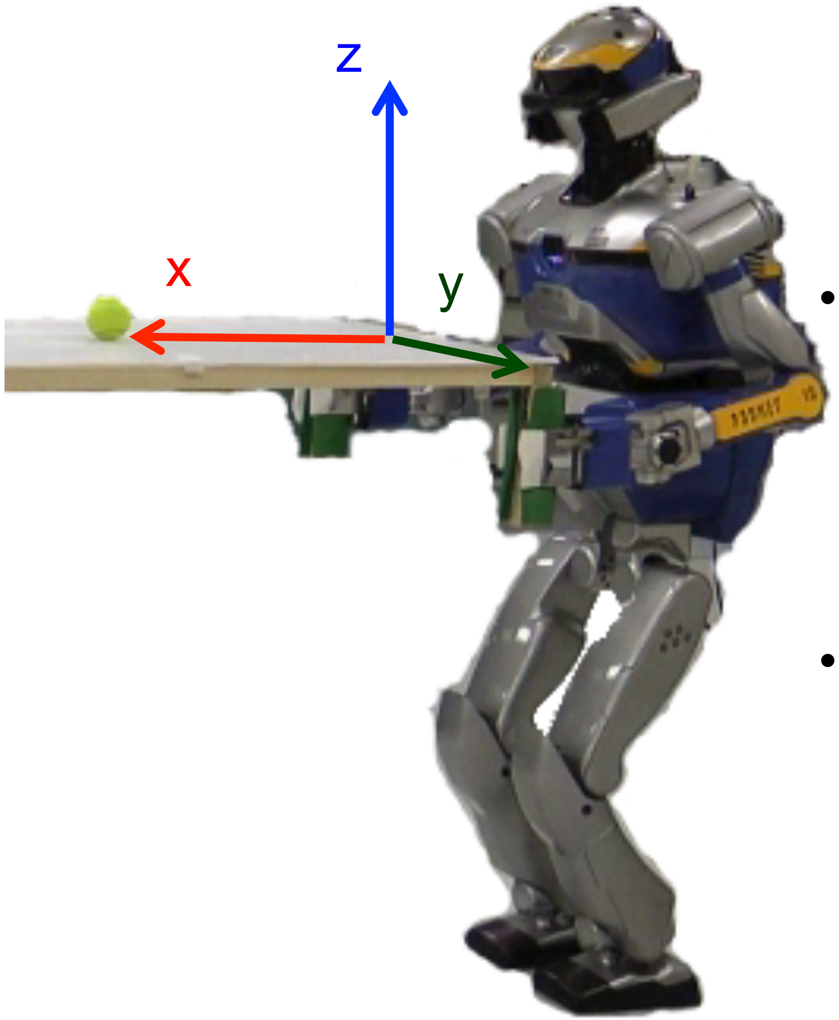
- Complementary to haptic information
  - contact vs. **non-contact**
  - local vs. **global**





- Recognition of the human intention

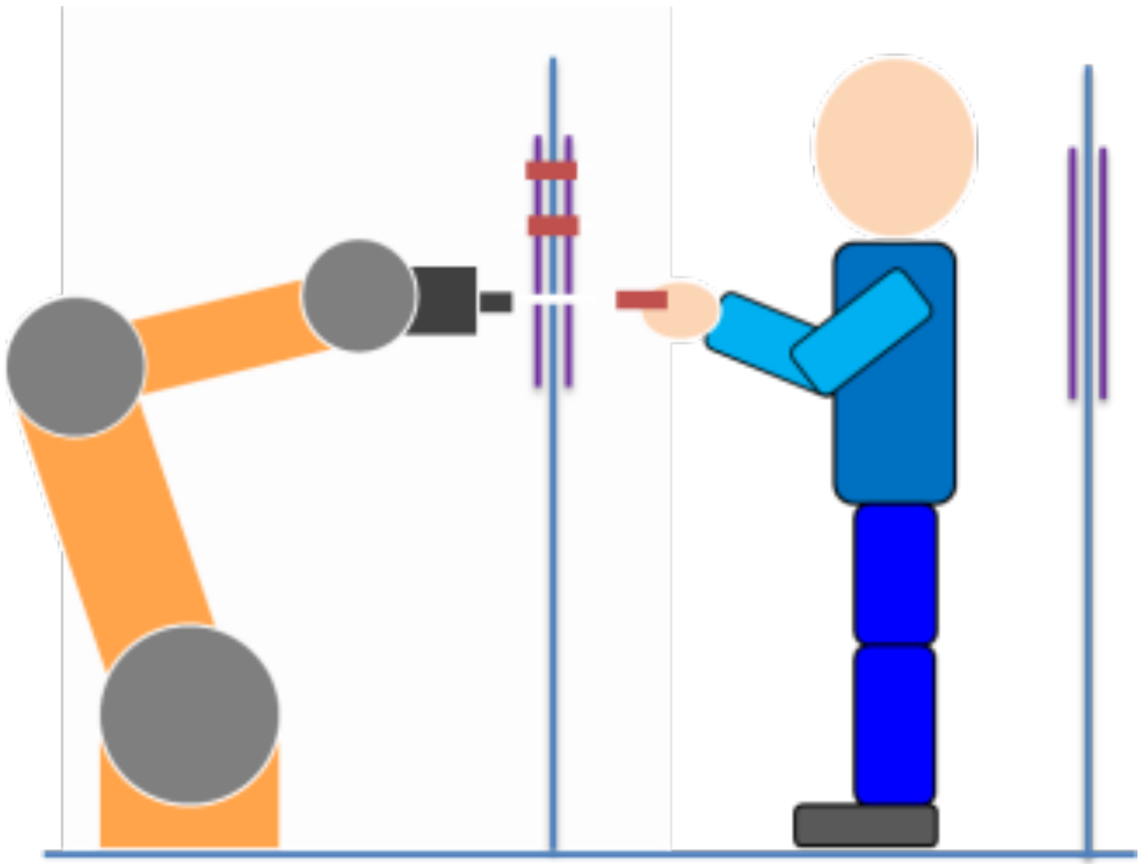
Merging vision and touch



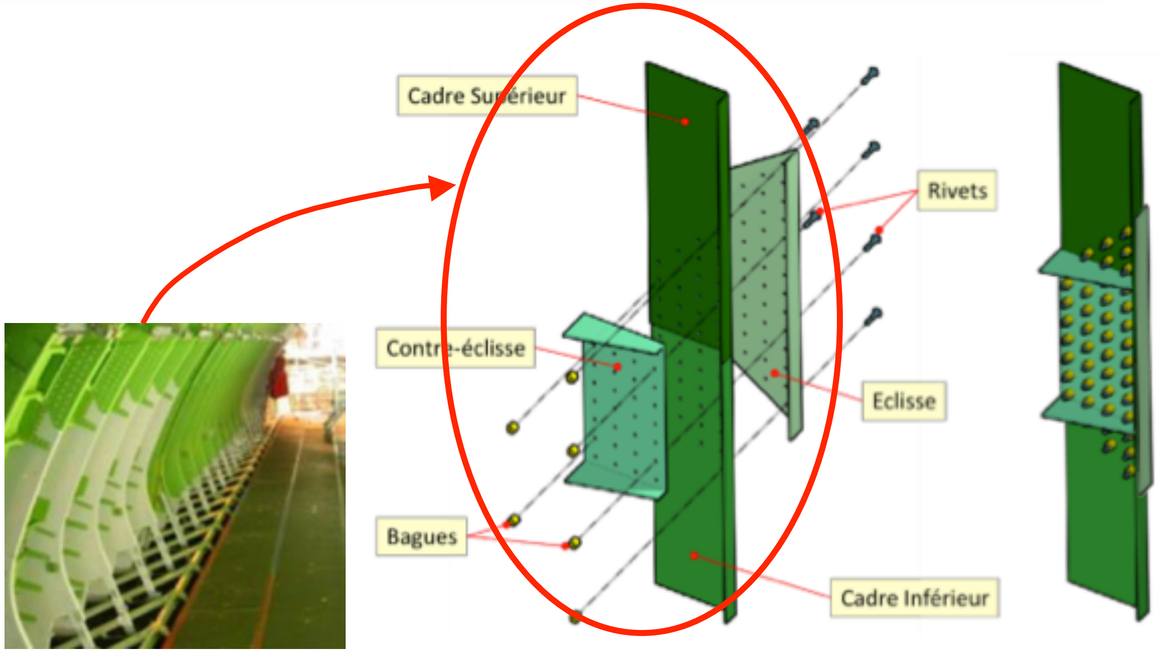
- X Y Φ_Z **help the human**
  force control
- Φ_Y **keep table flat**
  force control + desired yaw
- Z Φ_X **avoid ball from falling**
  force control + visual control

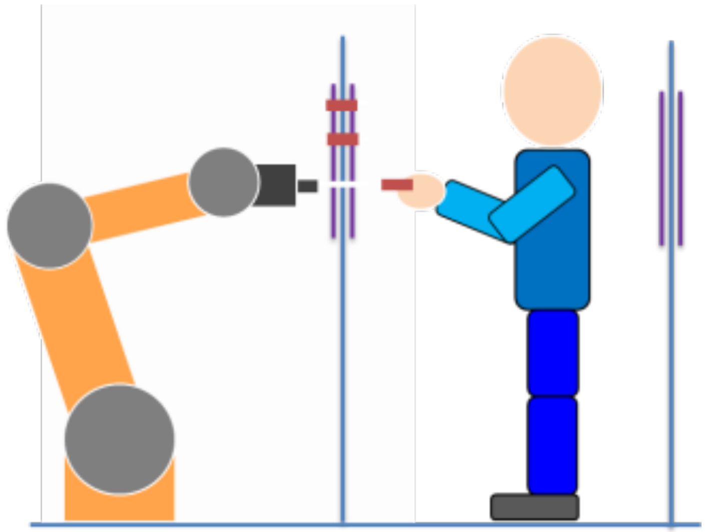
Results

Collaborative manufacturing

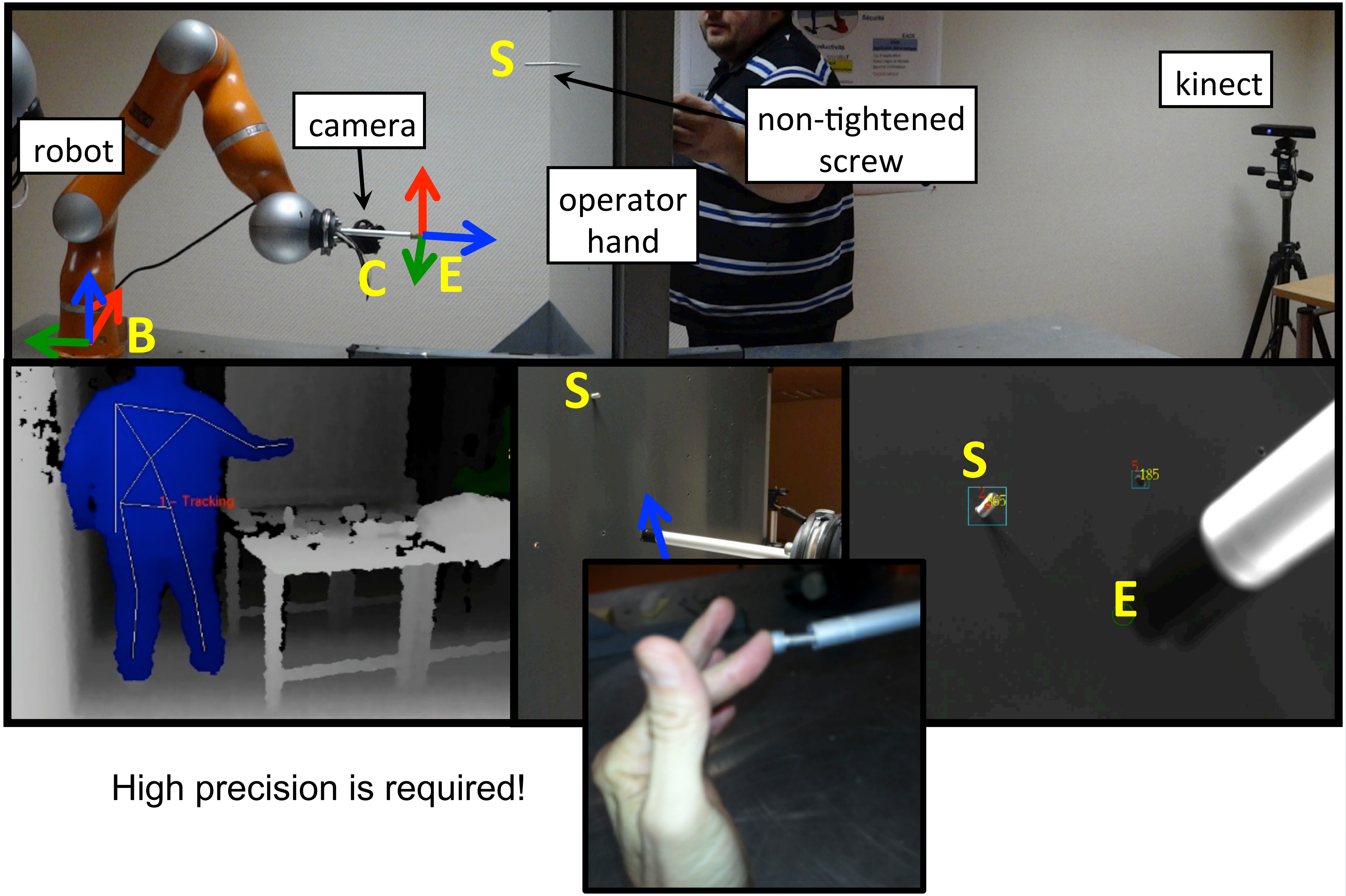


Collaborative screwing





Collaborative screwing

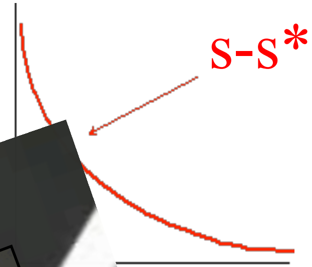


High precision is required!

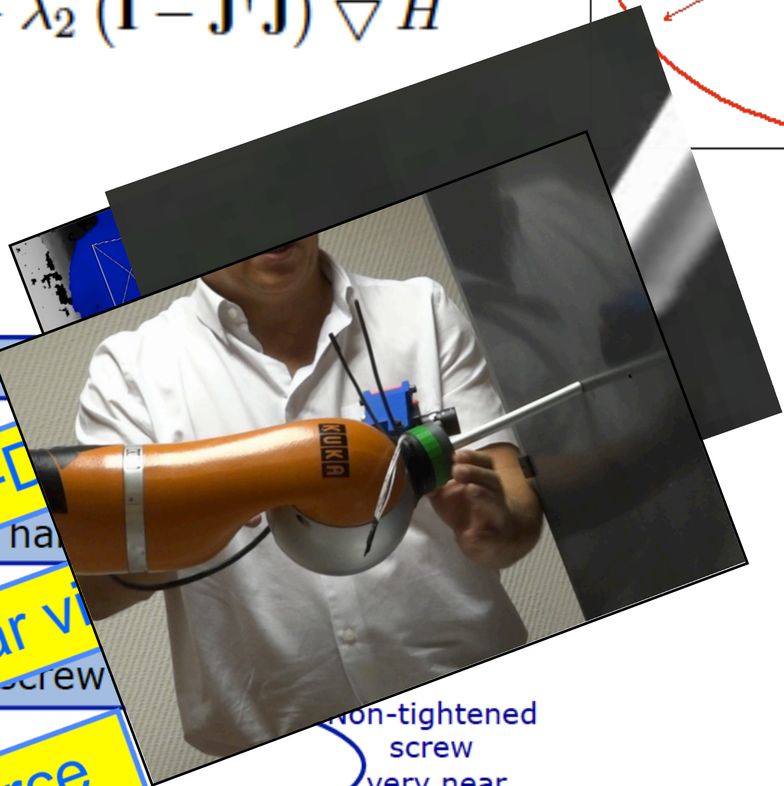
Task control framework

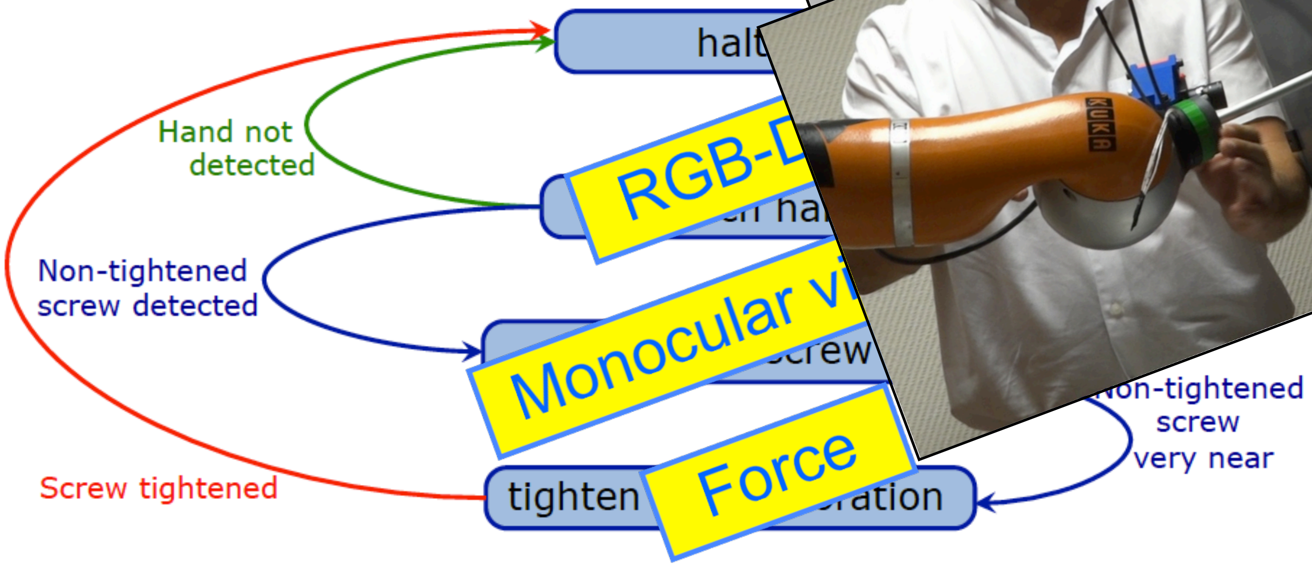
Given **task** $\mathbf{s}$ and joint velocities $\dot{\mathbf{q}}$: $\dot{\mathbf{s}} = \mathbf{J}\left(\mathbf{q}, \mathbf{s}\right)\dot{\mathbf{q}}$

$$\dot{\mathbf{q}} = -\lambda_1 \mathbf{J}^{\dagger}\left(\mathbf{s} - \mathbf{s}^*\right) - \lambda_2\left(\mathbf{I} - \mathbf{J}^{\dagger}\mathbf{J}\right) \triangledown H$$



Here, four tasks are used





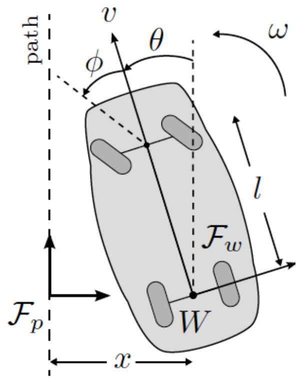
For each, we must define $\mathbf{s}$, $\mathbf{s}^*$ and $\mathbf{J}$.

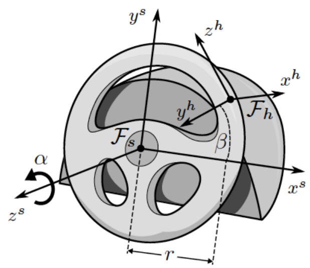
Results

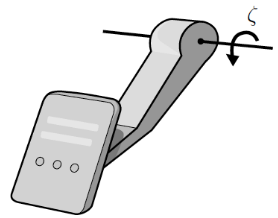
Collaborative assembly

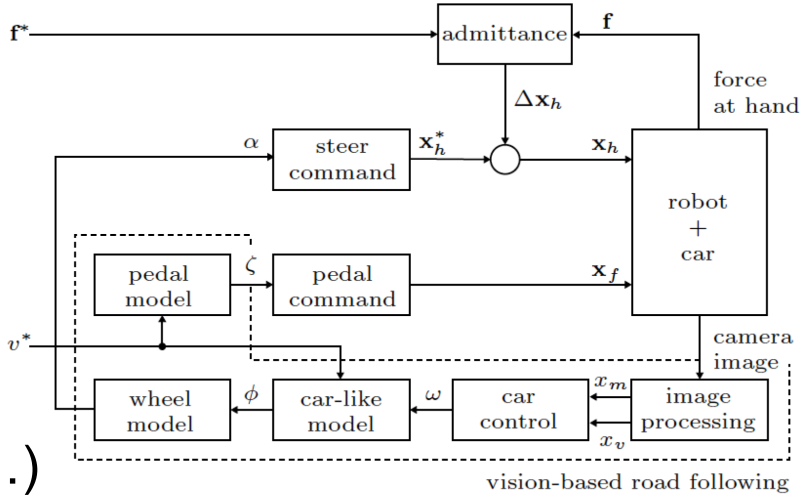
- Rzeppa joint collaborative assembly
- Very strong interaction with the environment and human!!
- Nominal trajectory is pre-taught…
  …then deformed by an admittance controller
- Vision is used as security trigger

Manipulation of sophisticated machinery





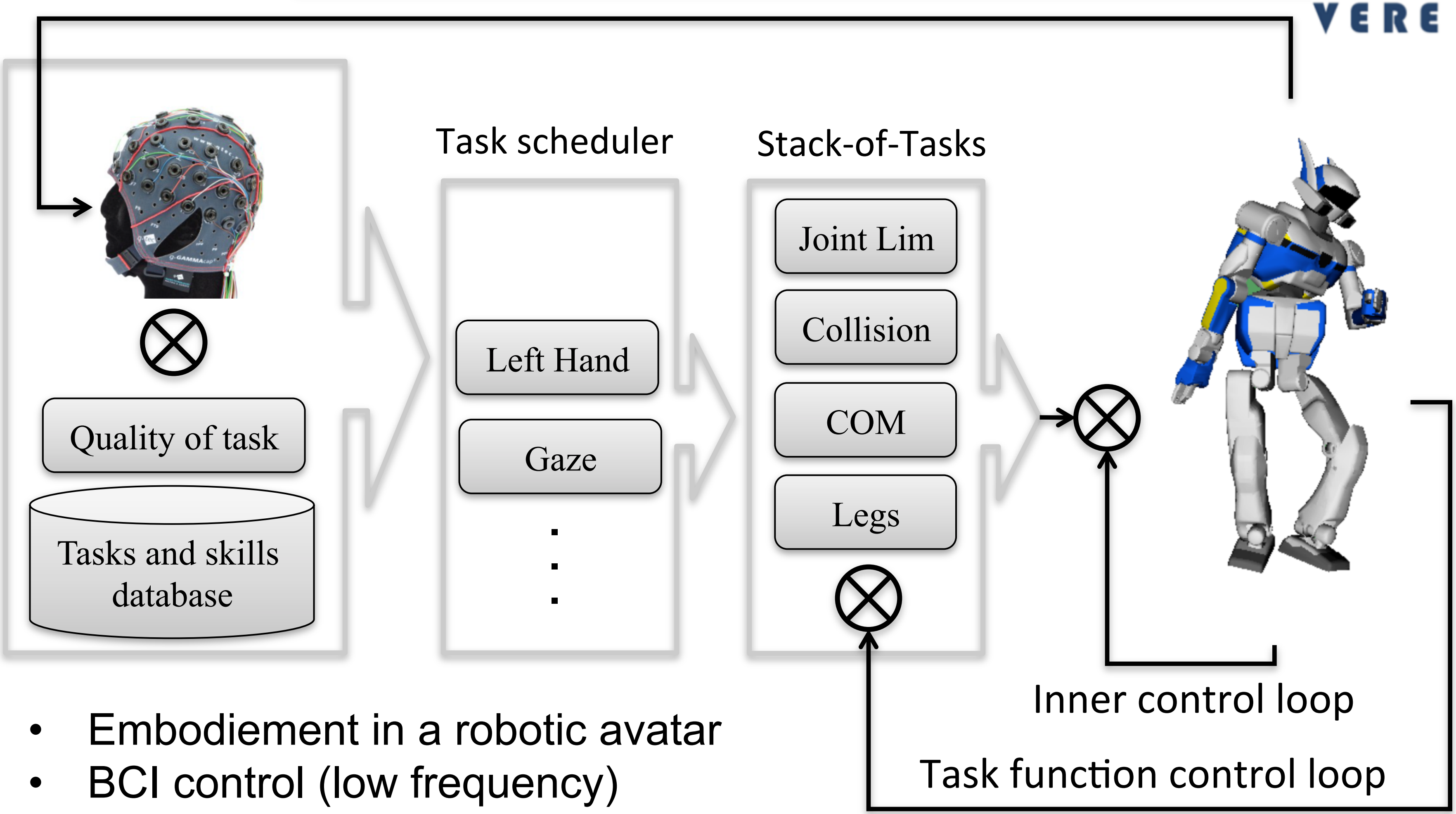




- Simulated environment (for now…)
- Vision used for:
  - lane detection (feedback for steering)
  - velocity estimation (feedback for accelerating)
- Haptics used to guarantee safe interaction with the environment

Results

Human-humanoid embodiement



- Embodiement in a robotic avatar
- BCI control (low frequency)
- Shared control aided by visual tools:
  - object detection/recognition
  - simultaneous localization and mapping
  - human body part recognition/interaction

Semi-autonomous pick and place

- Vision used for object recognition and pose tracking
- Model+feature based object tracker
  (BLORT – Blocks World Robotics Vision Toolbox)

Semi-autonomous navigation and interaction

Vision used for :

- robot localization, based on D6DSlam [Meilland, Comport, 2013]
- precise positioning, with ARUCO fiducial markers [www.uco.es]

Conclusions

Vision is a fundamental sensor in robotics applications

- rich
- cheap (including depth)
- usable (numerous open libraries off the shelf)

Open problems

- Real-time computation
- Robustness to evolving environments (light variation, soft materials…)
- Generality
- Knowledge sharing between CV and ROB communities!