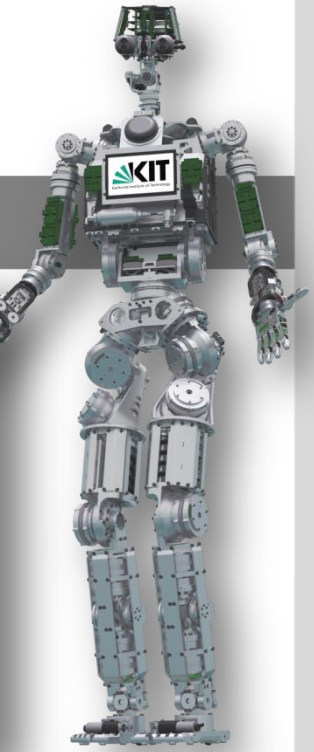
Karlsruhe Institute of Technology

High Performance Humanoid Technologies

Humanoid Robotics Research at KIT

Tamim Asfour

Institute for Anthropomatics and Robotics, High Performance Humanoid Technologies



http://www.humanoids.kit.edu

http://h2t.anthropomatik.kit.edu

Institute for Anthropomatics and Robotics

10 Labs, approx. 150 members

- High Performance Humanoid Technologies

Asfour

- Vision and Fusion

Beyerer

- Humanoids and Intelligence Systems

Dillmann

- Intelligent-Sensor-Actuator System

Hanebeck

- Intelligent Industrial Robotics

Hein

- Cognitive Systems

N.N.

- Computer Vision for Human Computer Interaction

Stiefelhagen

- Interactive Systems

Waibel

- Intelligent Process Control and Robotics

Wörn

- Applied Technical Cognitive Systems

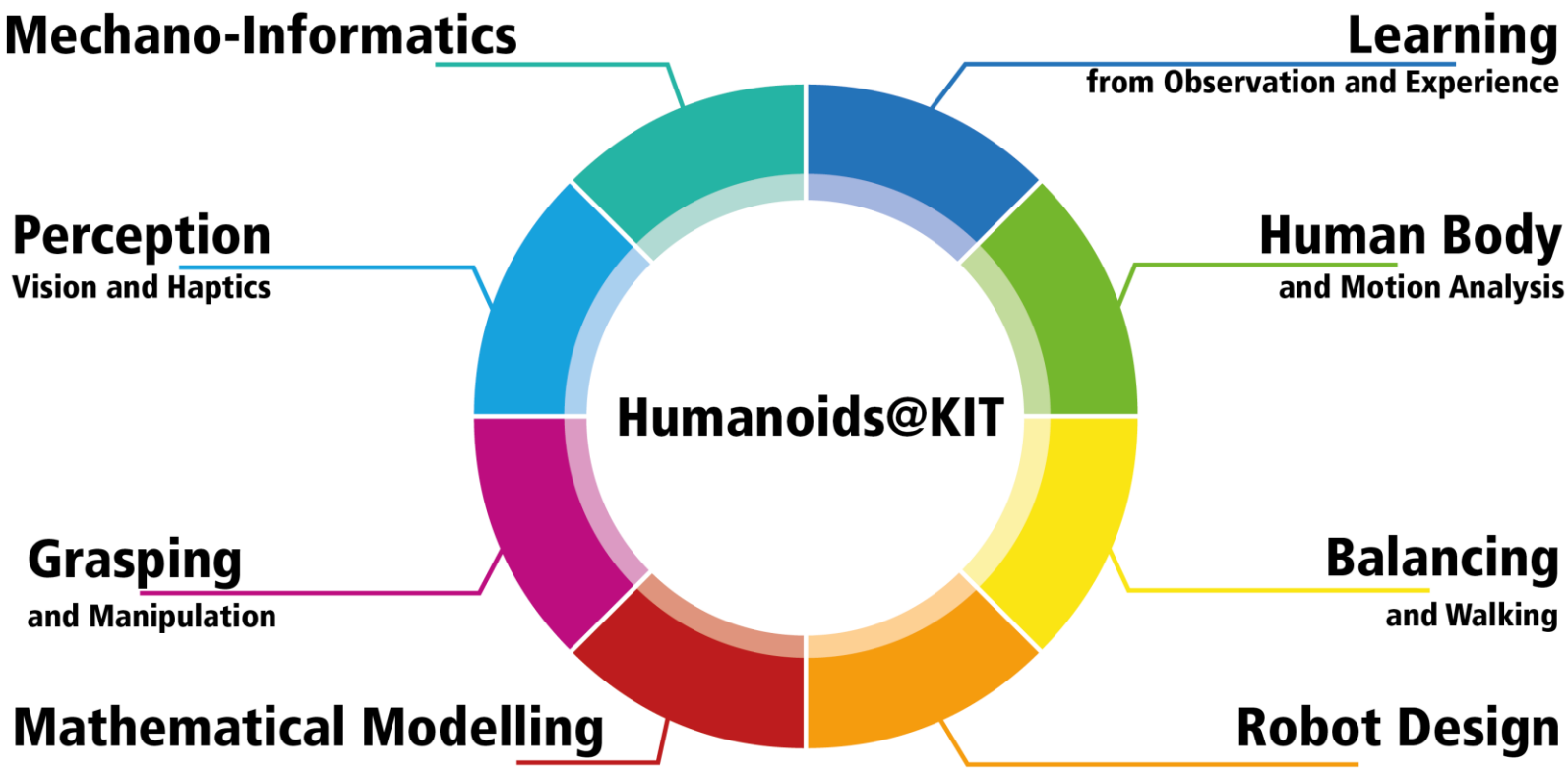
Zöllner

H2T team

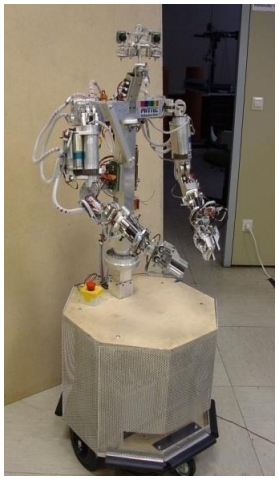
Karlsruhe Institute of Technology

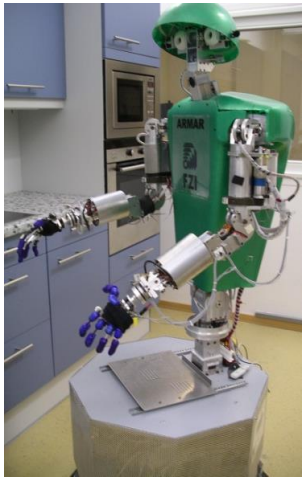
Humanoids@KIT

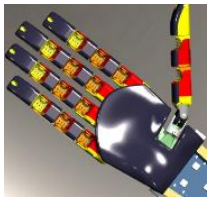
H²T Research Topics

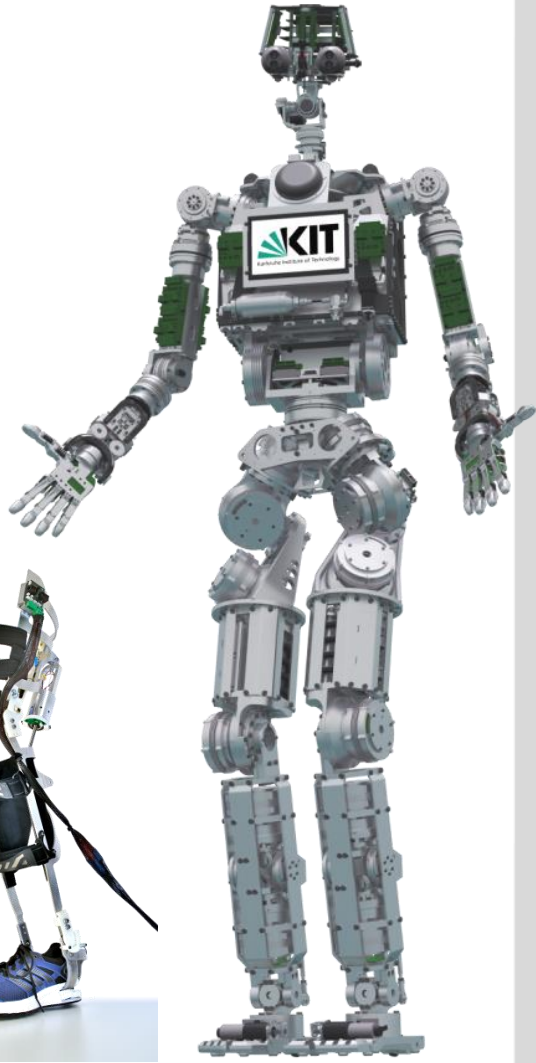


The ARMAR Family: The systems

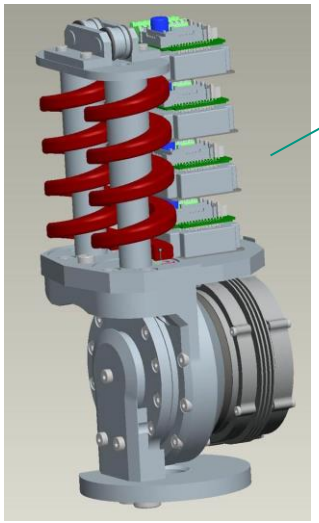


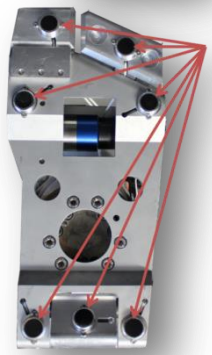


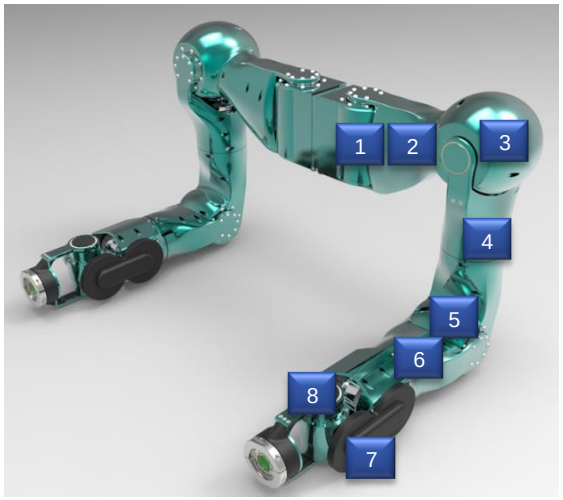


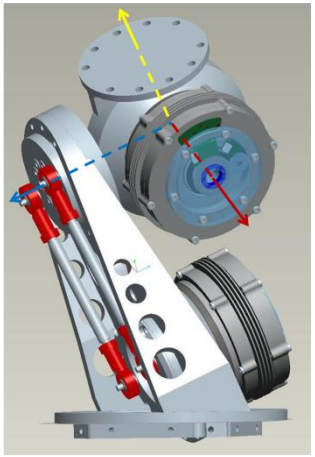


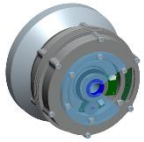
The ARMAR Family: The mechatronics

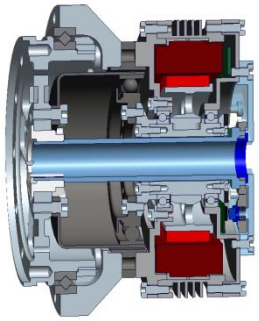


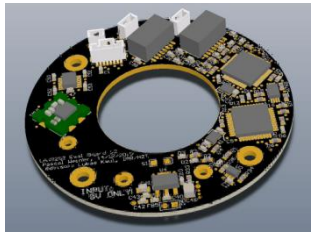


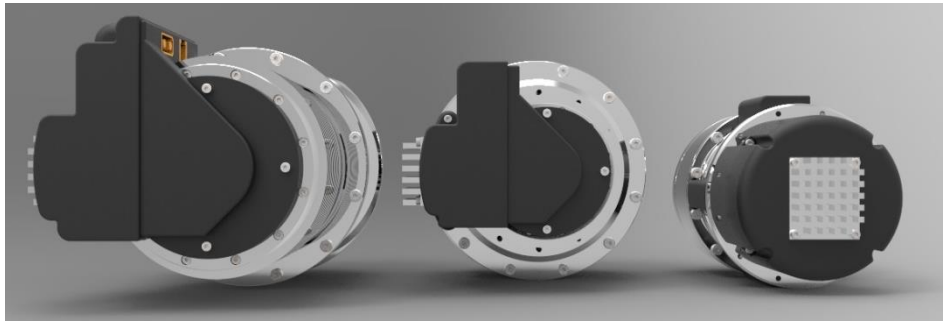












Humanoids in the real world

- Engineering Humanoids
- Grasping and manipulation
- Learning for human observation
- Natural Interaction and communication

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ARMAR-IIIa and ARMAR-IIIb

- 7 DOF head with foveated vision
  - 2 cameras in each eye
  - 6 microphones
- 7-DOF arms
  - Position, velocity and torque sensors
  - 6D FT-Sensors
  - Sensitive Skin
- 8-DOF Hands
  - Pneumatic actuators
  - Weight 250g
  - Holding force 2,5 kg
- 3 DOF torso
  - 2 Embedded PCs
  - 10 DSP/FPGA Units
- Holonomic mobile platform
  - 3 laser scanner
  - 3 Embedded PCs
  - 2 Batteries
- Weight: 150 kg

Fully integrated humanoid system

ARMAR-III in the RoboKITchen

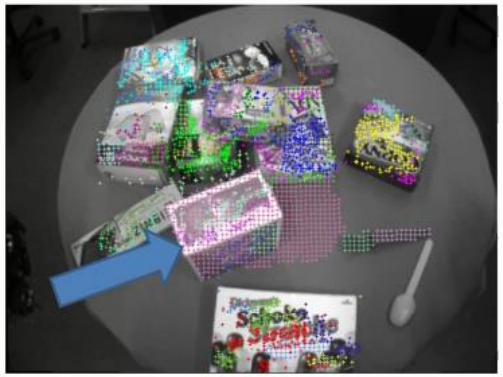
- Object recognition and localization
- Vision-based grasping
- Hybrid position/force control
- Combining force and vision for opening and closing door tasks
- Collision-free navigation
- Vision-based self-localisation
- Multimodal human-robot dialogs
- Continuous speech recognition
- Learning new objects, persons and words
- Audio-visual tracking and localization
- …

Combining vision, action and haptics for grasping

Initial object hypotheses

Generate hypotheses based on Color, Geometric primitives and Saliency

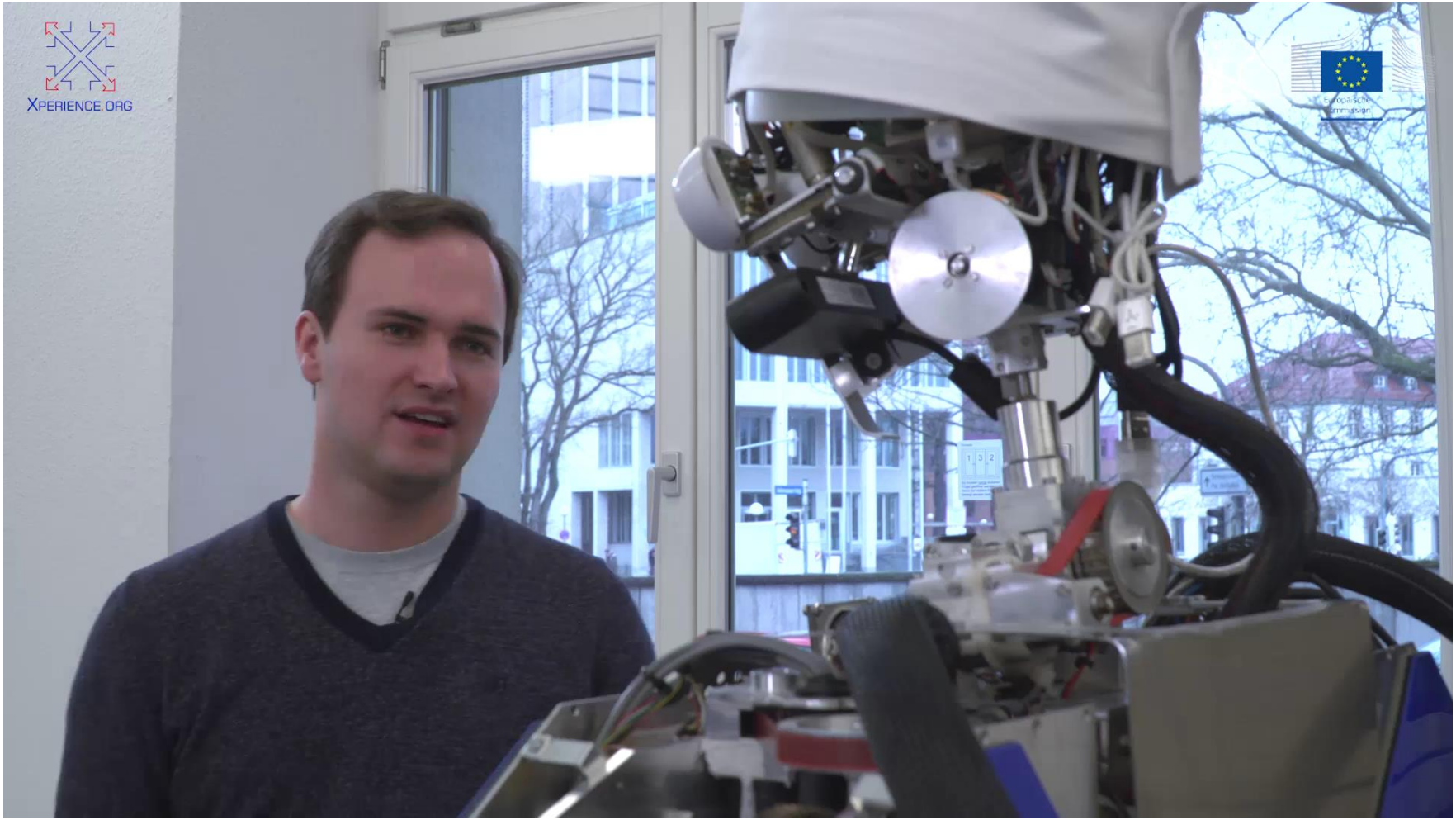
Hypothesis 49 is chosen for verification by pushing



European Commission

XPERIENCE.ORG

Integrating language, planning and execution with OACs



What‘s next?

- SecondHands: A robot assistant for industrial maintenance
  - 5 years project in Horizon 2020 (2015 – 2020)
  - Ocado, KIT, Sapienza, EPFL, UCL
- The robot will provide help to maintenance technicians in a warehouse environment
- We expect advancement in the automation of the relatively unexplored domain of production machine maintenance
- Reduction in production machinery maintenance costs

Humanoids in the real world

- Grasping and manipulation
- Learning for human observation
- Natural Interaction and communication

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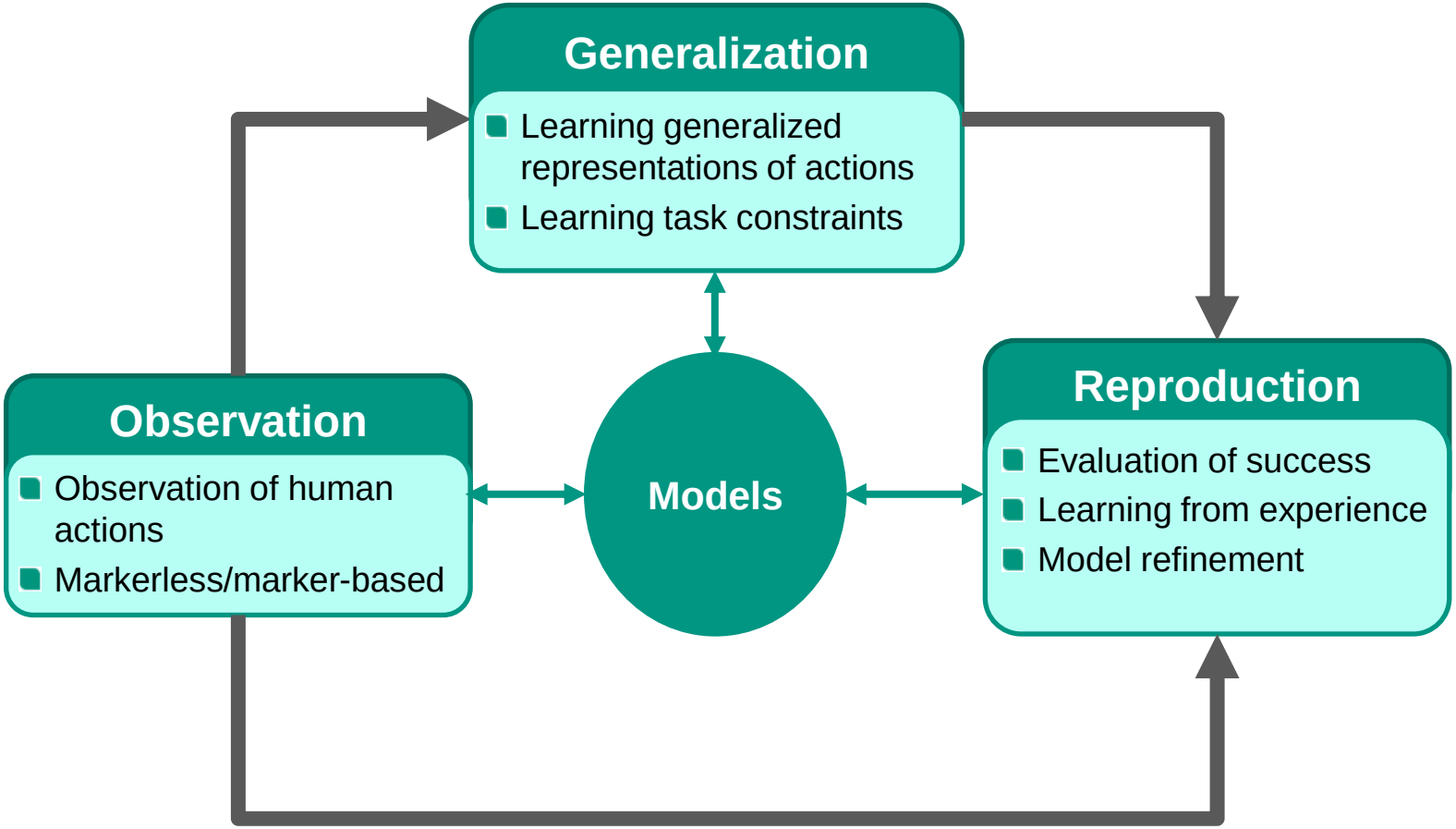
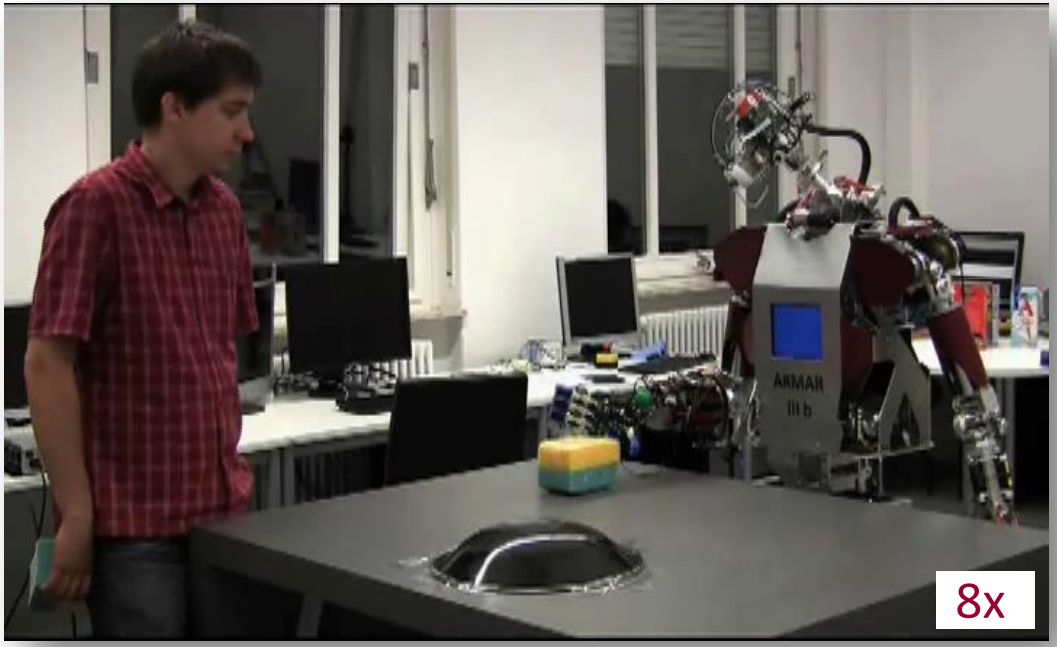
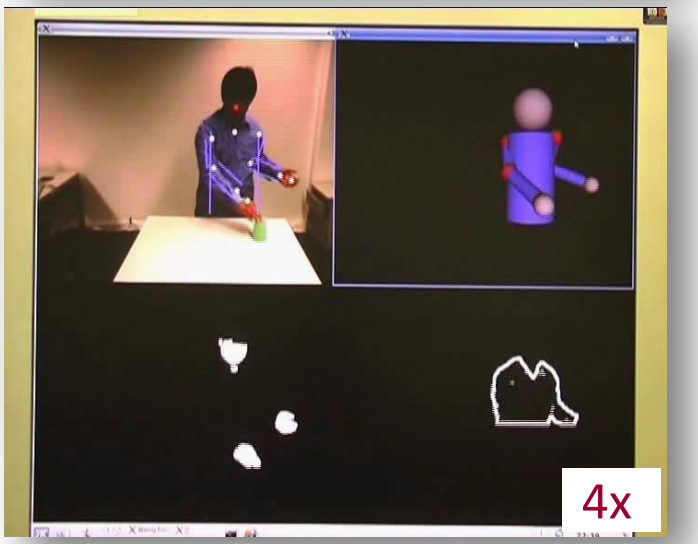
Learning from human observation



Learning from observation

- Building a library of motion primitives
- Dynamic movement primitives (DMP) for discrete and periodic movements



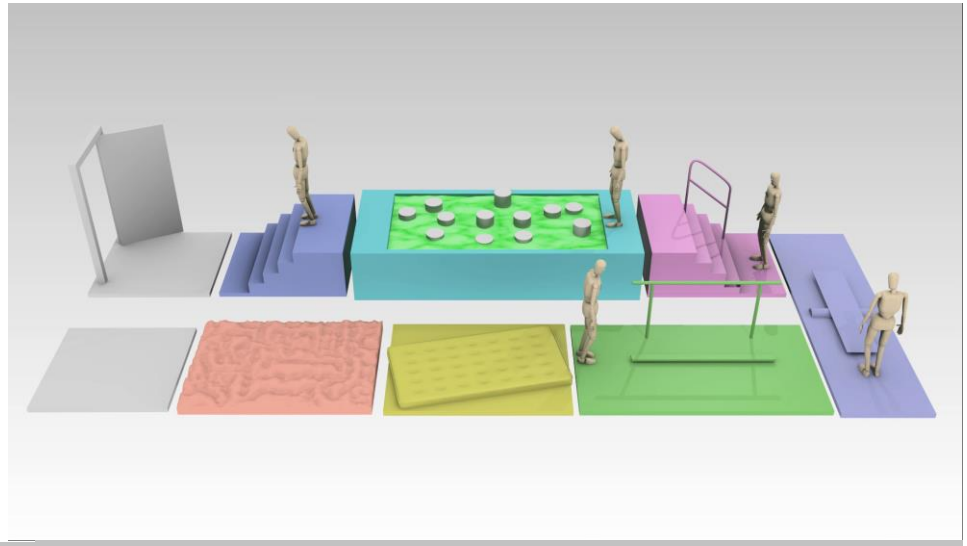


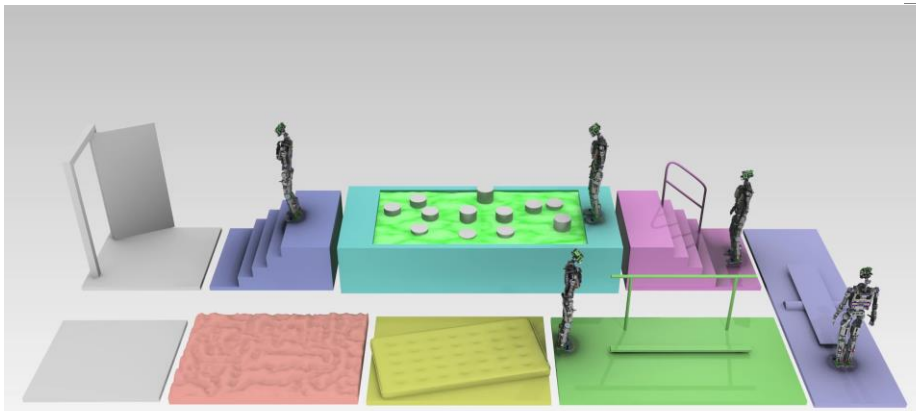
Humanoids 2006, IJHR 2008, Humanoids 2007, ICRA 2009, Humanoids 2009, TRO 2010, Humanoids 2012, IROS 2013, RAS 2015

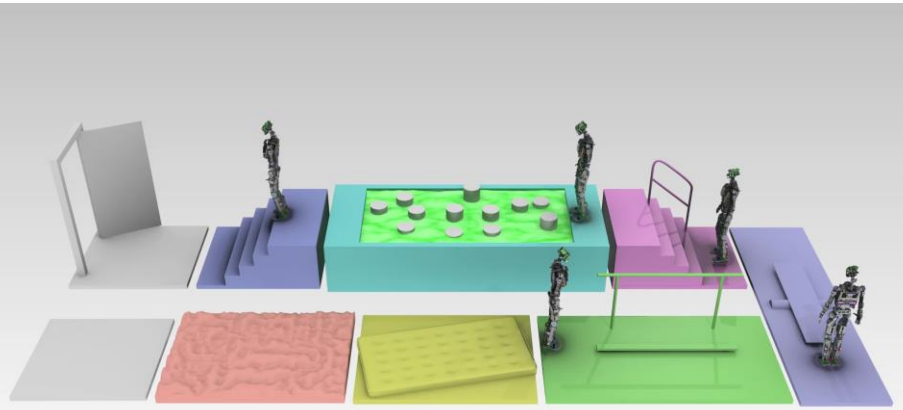
KIT whole-body human motion database

https://motion-database.humanoids.kit.edu/

The KIT whole-body human motion database





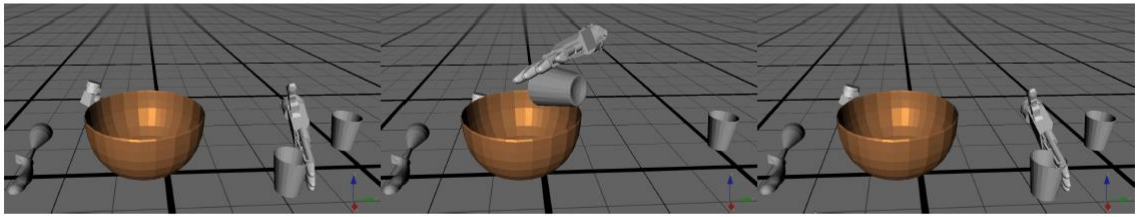


Learning from human observation

- Hierarchical action segmentation which considers motion and relevant objects
  - Semantic segmentation based on object-hand and object-object relation
  - Motion segmentation based on trajectory characteristics (motion dynamics)

Human Demonstration

Converted Demonstration

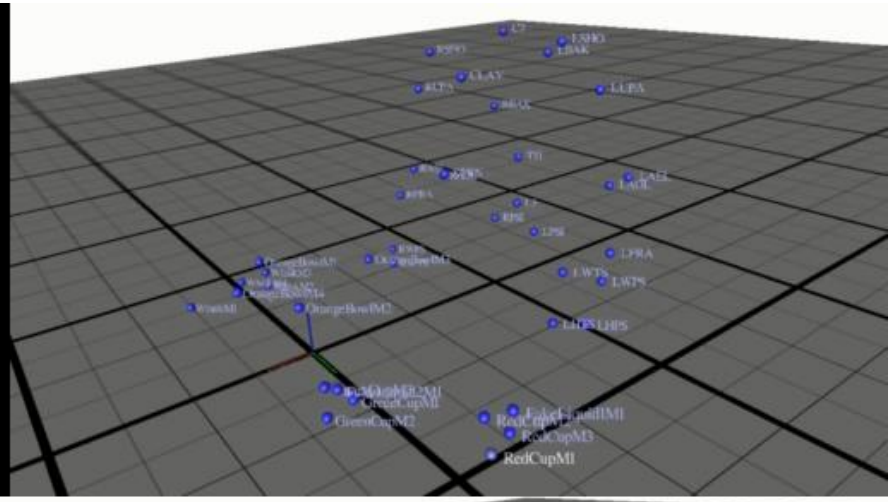


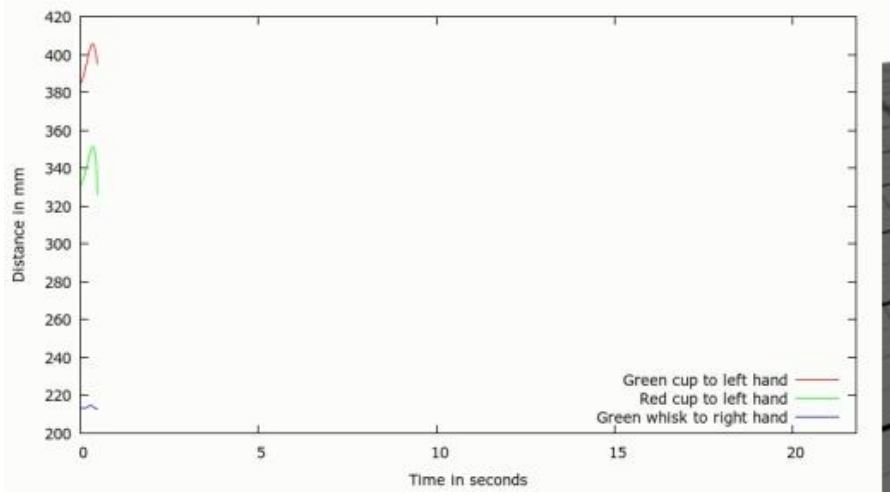
Hierarchical Segmentation

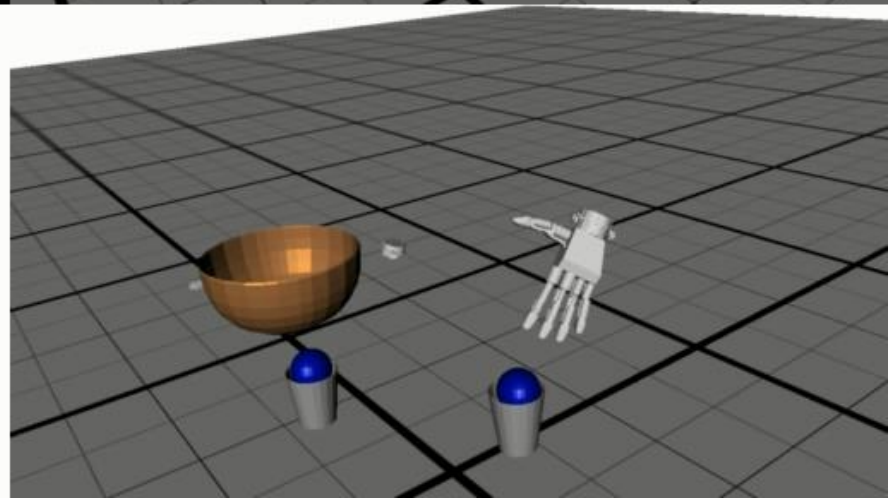
No contact	Cup in left hand			No contact
Grasp	Lift	Pour	Place	Retreat

XPERIENCE.ORG

Hierarchical action segmentation



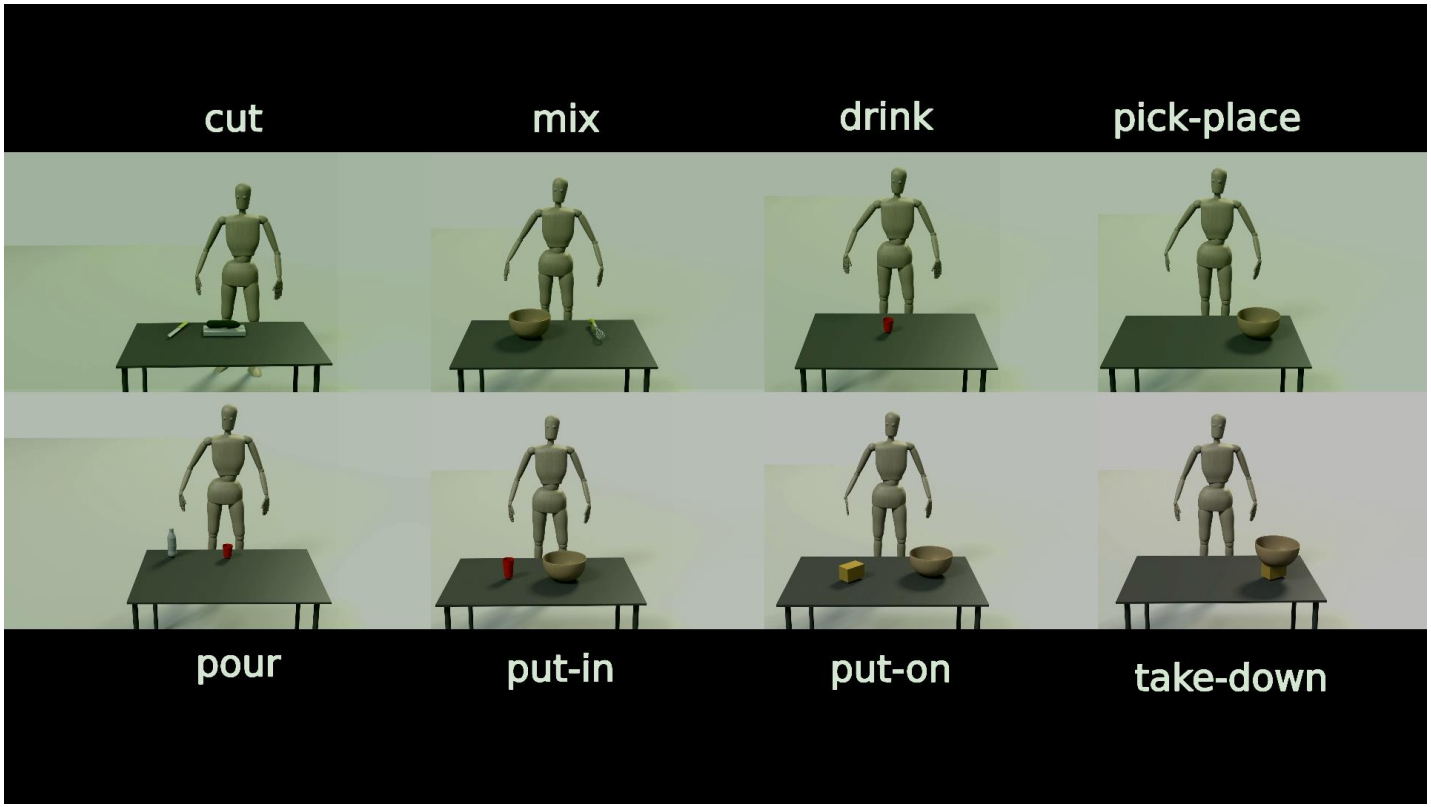


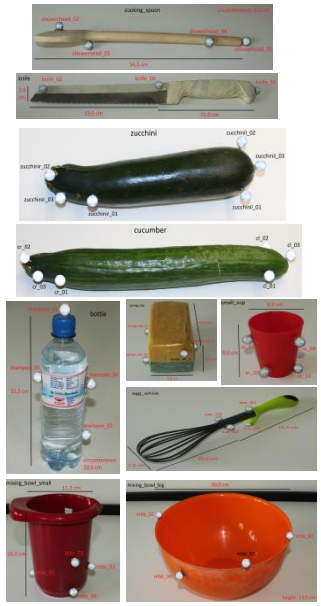


Learning from observation – prepare the dough

Examples of manipulation actions

- Dataset:
  - Vision data
  - Marker data (VICON) of humans and objects

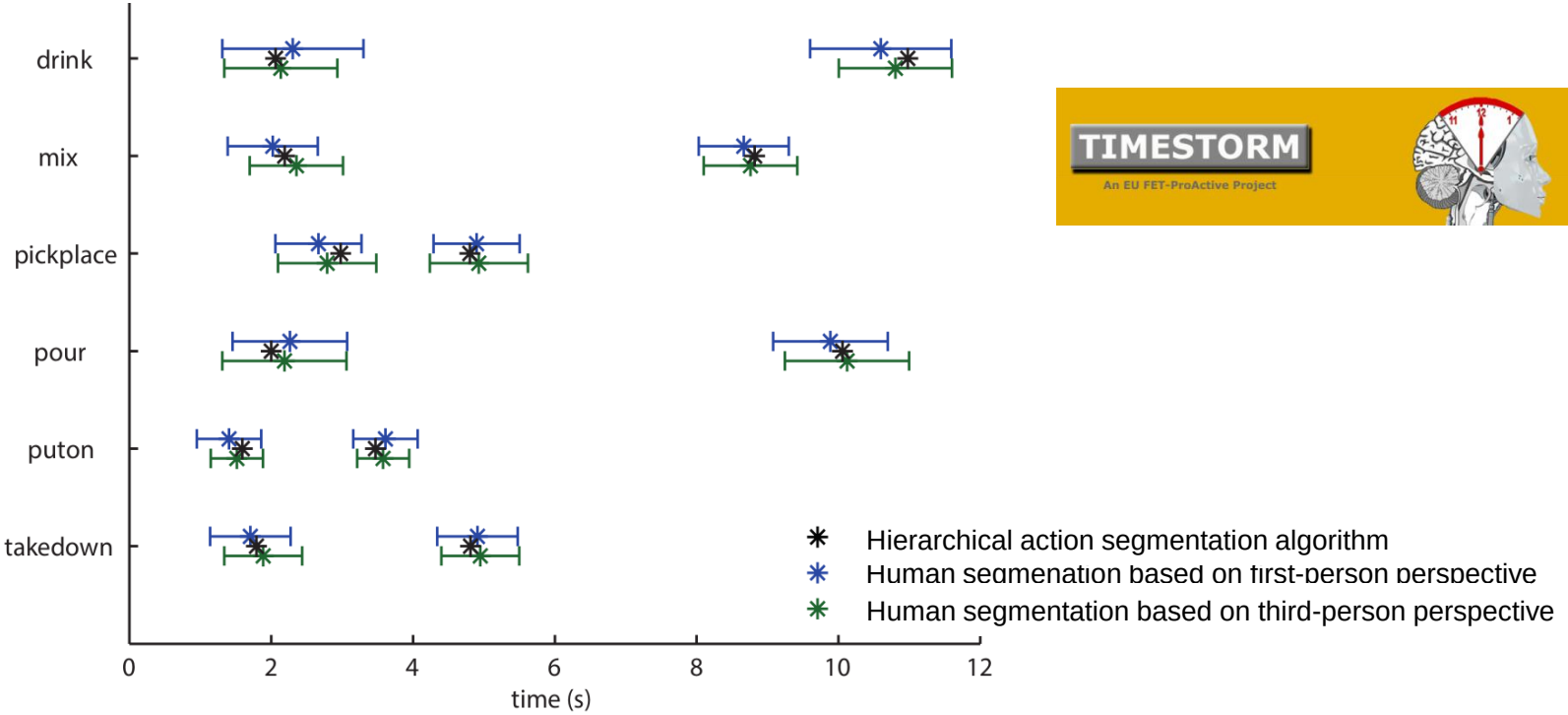




10 Different Objects

Grounding with psychological experiments

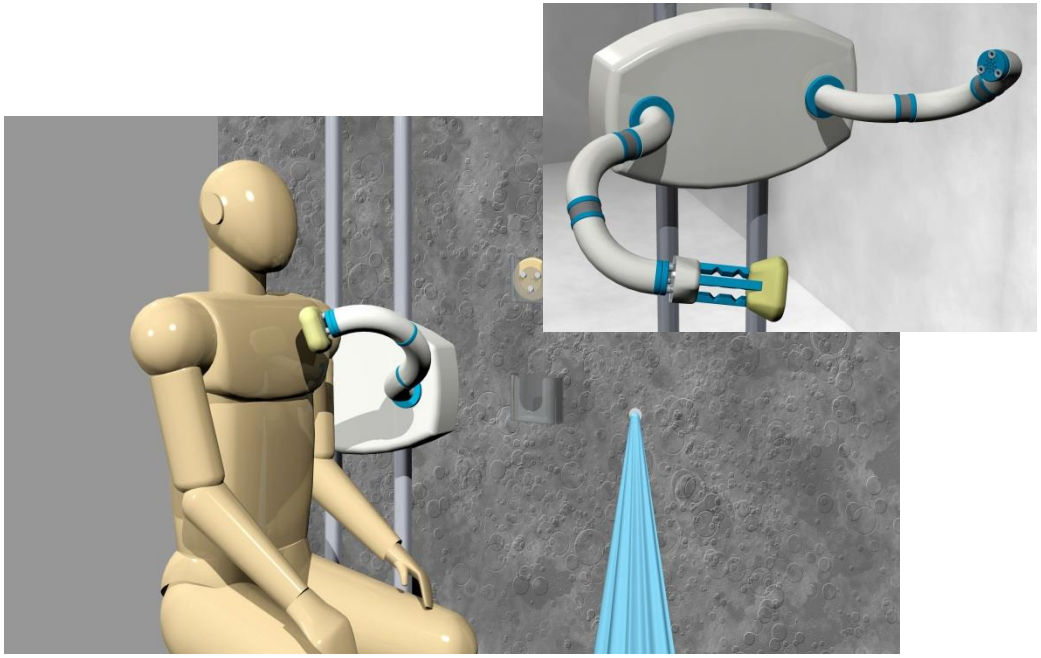
- Psychological experiments related to the “Perception of Time” in humans support our action segmentation approach



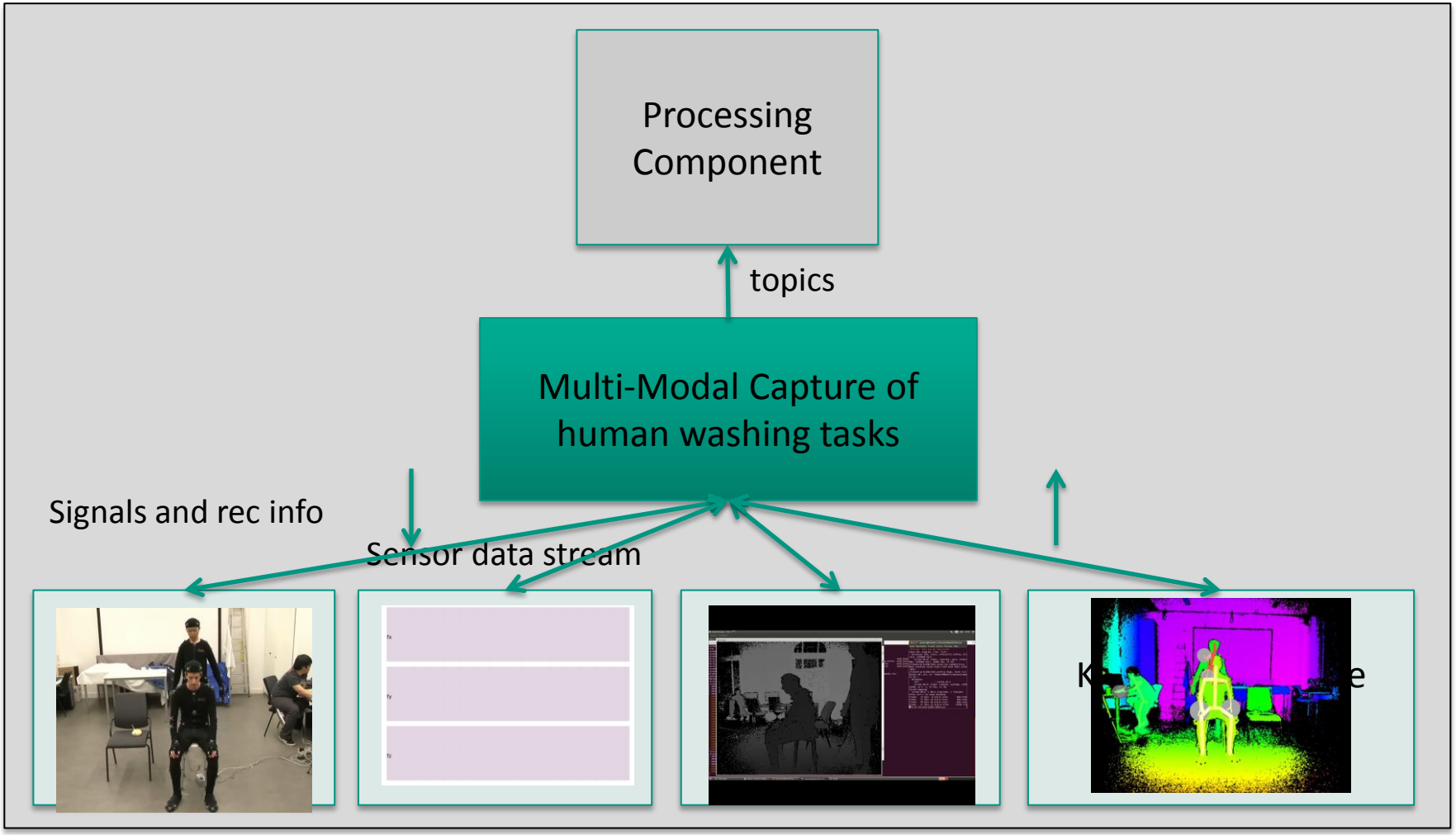
In collaboration with the University of Groningen (Hedderik van Rijn, Experimental Psychology & Statistical Methods and Psychometrics) in the context of the EU FET-ProActive Project TimeStorm (www.timestorm.eu)

What‘s next?

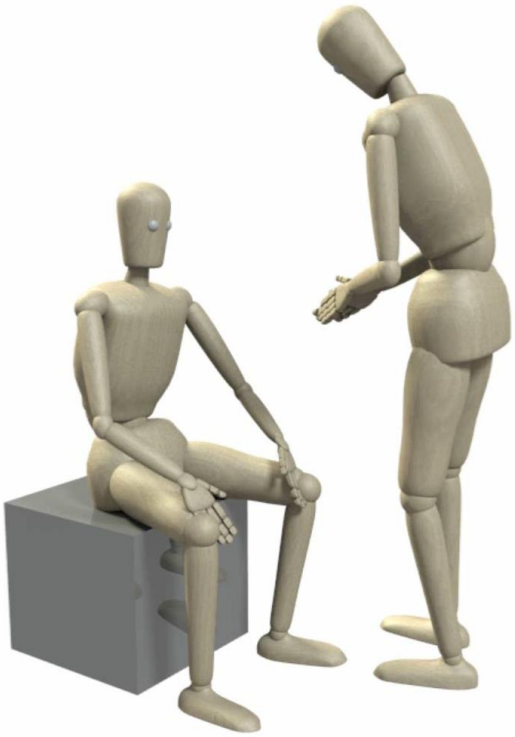
- I-SUPPORT: ICT Supported Bath Robot
- Deliver a service robotics system in the bathroom environment that is absolutely safe and reliable from all end user, operational and industrial perspectives



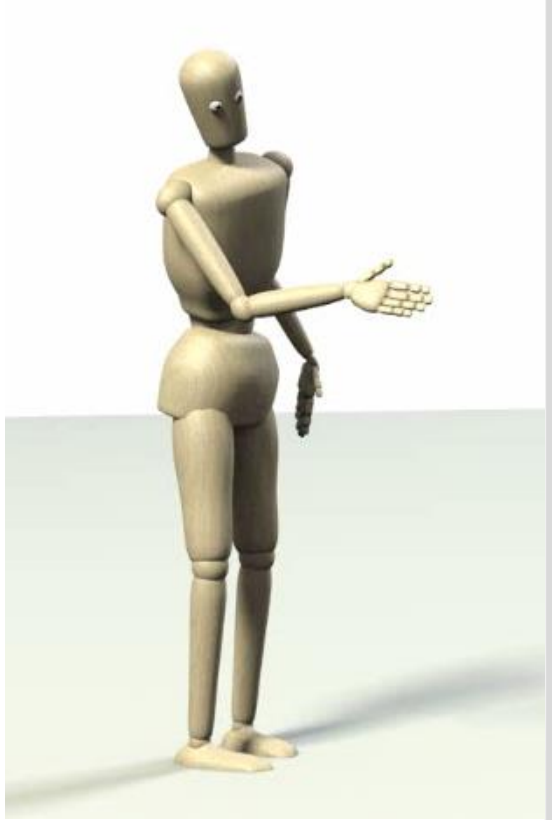
Learning motor skills for “SOFT” bathing robot



Mapping



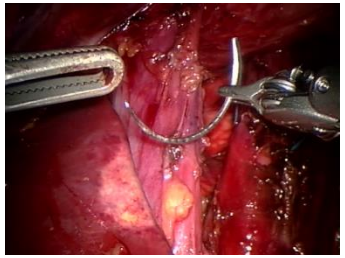
Wash arm action

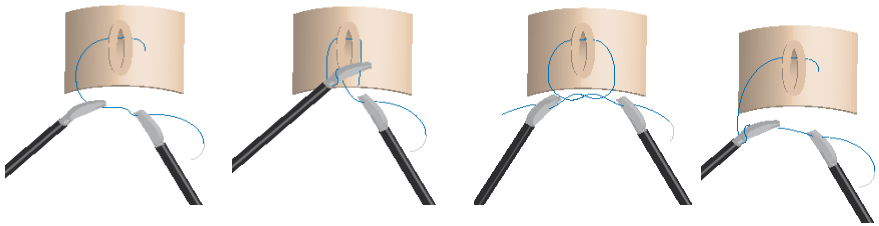


Wash back action

What's next?

- Modelling surgical skills
  - Semantic segmentation of surgical demonstrations
  - Alphabet of surgical skills and "language of surgery"
  - Prediction of the next action or next operation phase
  - Intraoperative assistance through predictive interfaces control





ARMAR-IV: Mechano-Informatics

- Torque controlled
- 3 on-board embedded PCs
- 76 Microcontroller
- 6 CAN Buses

- 63 DOF
  - 41 electrically-driven
  - 22 pneumatically-driven (Hand)

- 238 Sensors
  - 4 Cameras
  - 6 Microphones
  - 4 6D-force-torque sensors
  - 2 IMUs
  - 128 position (incremental and absolute), torque and temperature sensors in arm, leg and hip joints
  - 18 position (incremental and absolute) sensors in head joints
  - 14 load cells in the feet
  - 22 encoders in hand joints
  - 20 pressure sensors in hand actuators
  - …

More than mechatronics

ARMAR-IV

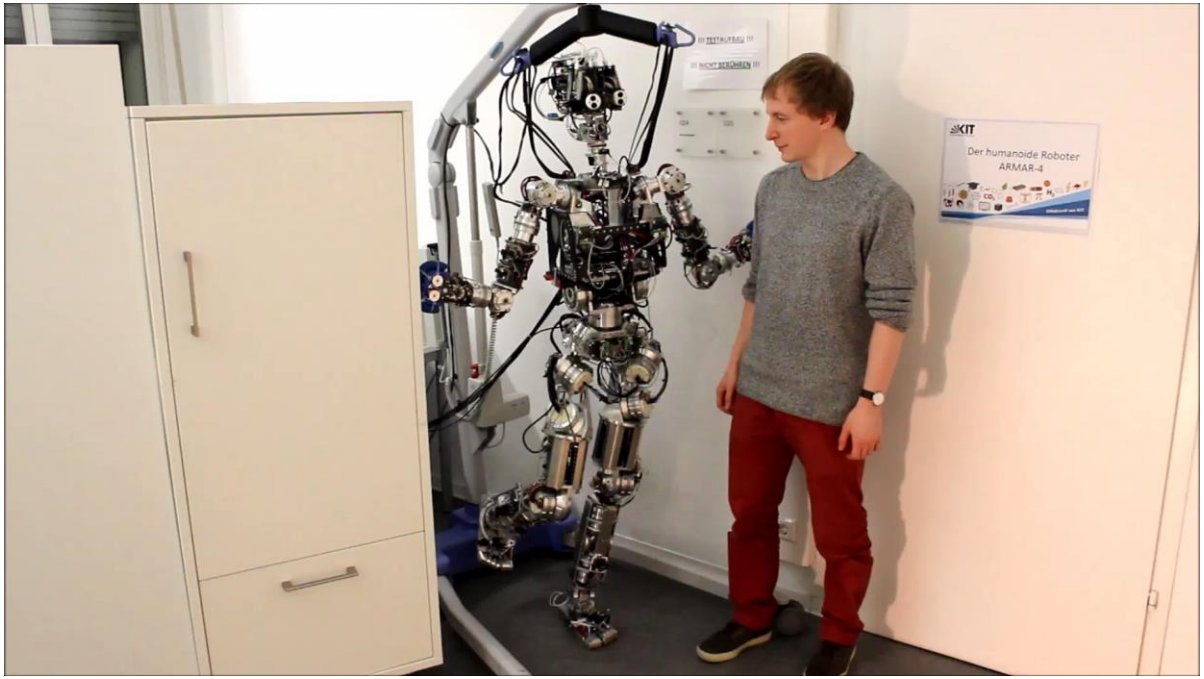
made@KIT

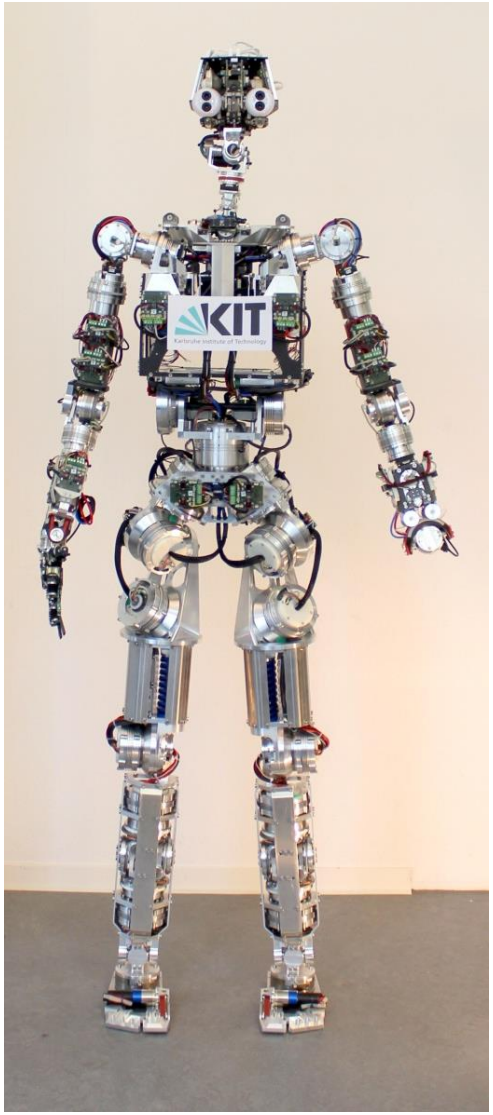
70 kg

170 cm

ARMAR-IV

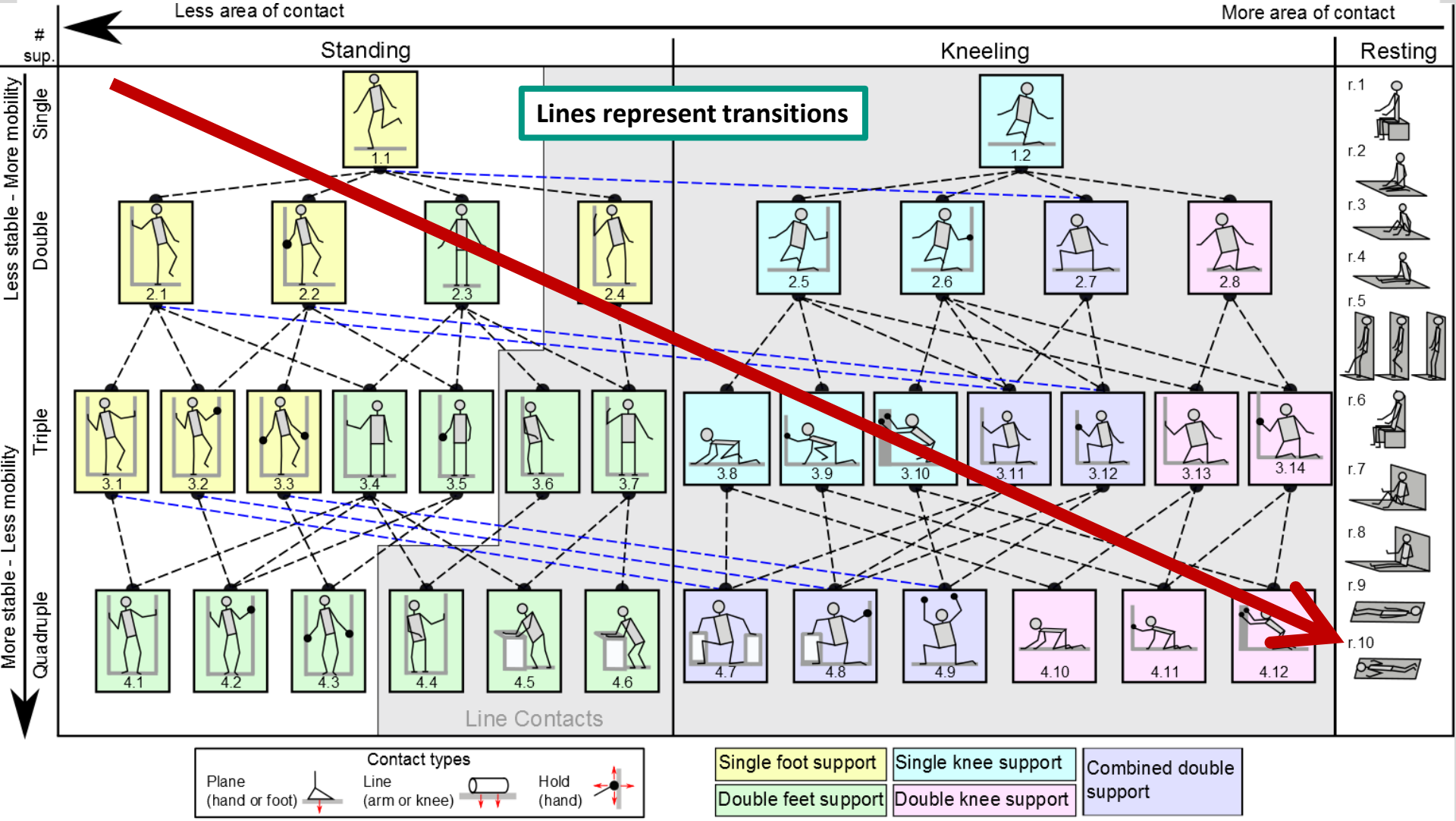
- 63 DOF
- Torque-controlled!





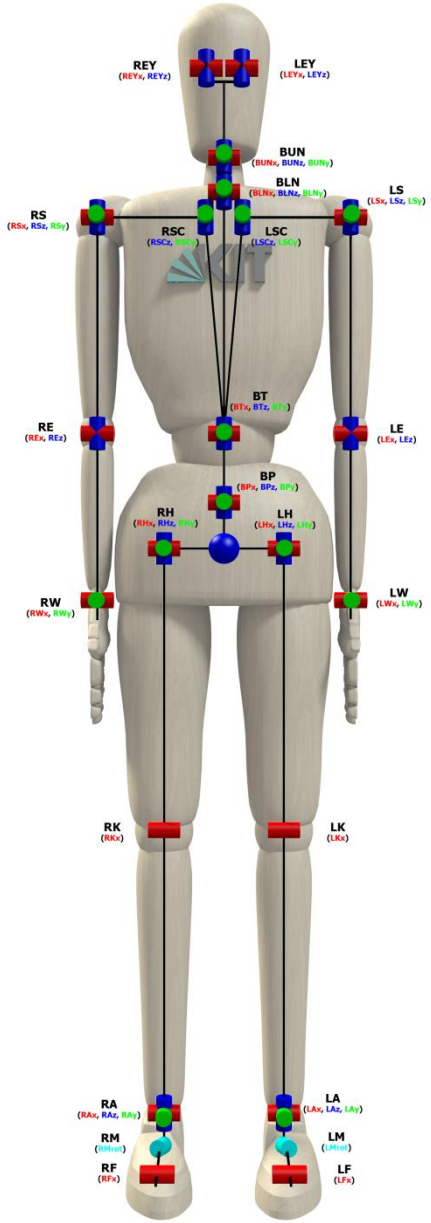
Multi-contact active compliance balancing controller

Taxonomy of whole-body poses



Validation of the taxonomy

- Analyses of different human loco-manipulation tasks with supports
- Reference model of the human body (Master Motor Map: MMM) with 104 DOF
- Motion capture data mapped to reference model of the human body (MMM)
- Automatic segmentation to detect support poses and transitions
- Automatic generation of a taxonomy of the poses and their transitions in der motion data



Analysis of pose transitions

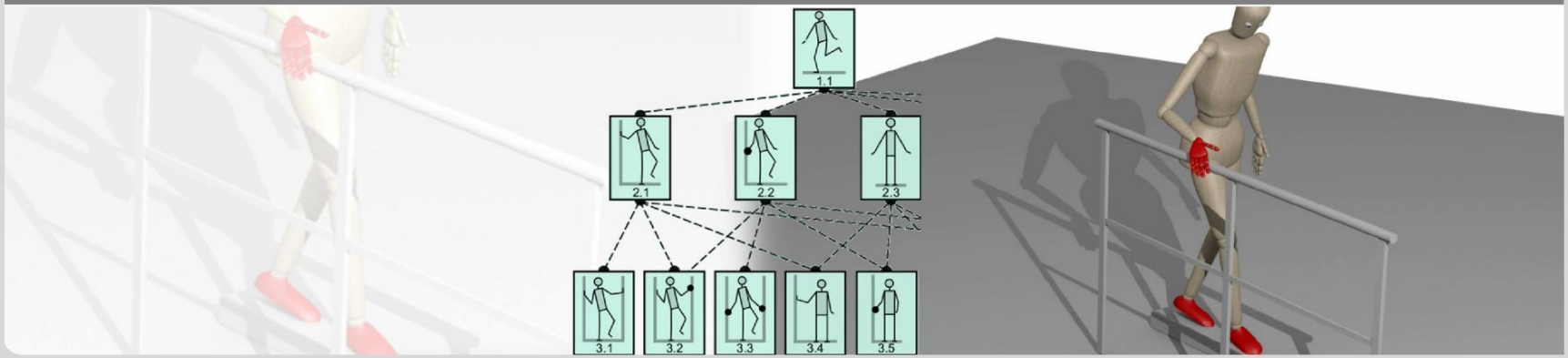
Karlsruhe Institute of Technology

Karlsruhe Institute of Technology

Analyzing Whole-Body Pose Transitions in Loco-Manipulation Tasks

Christian Mandery, Júlia Borràs, Mirjam Jöchner, Tamim Asfour

Institute for Anthropomatics and Robotics (IAR), High Performance Humanoid Technologies (H²T)



KIT – University of the State of Baden-Wuerttemberg and
National Research Center of the Helmholtz Association

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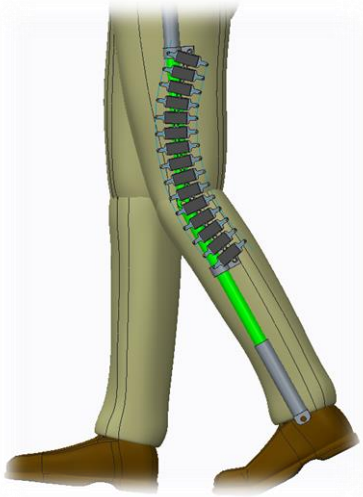
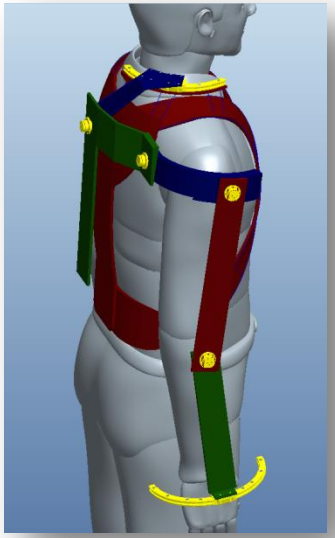
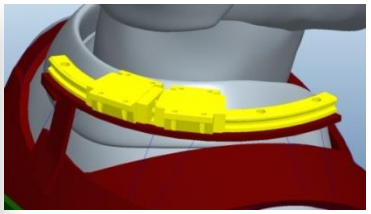
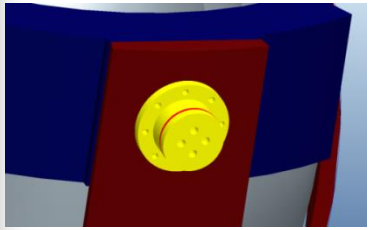
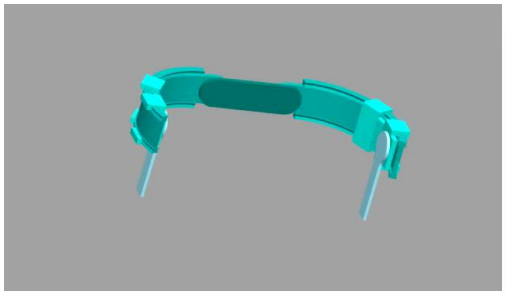
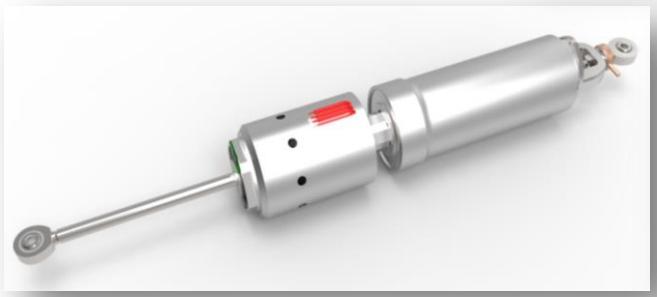
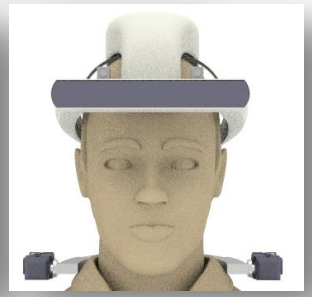
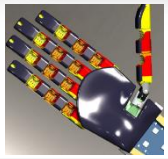
ARMAR-5: Wearable Humanoid



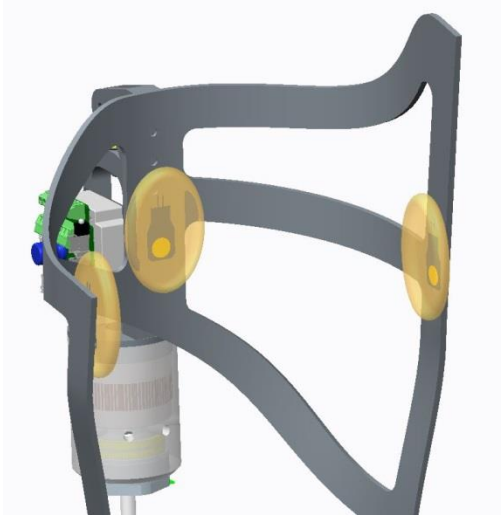

- Maximal „axial“ force 2900 N
- Force at nominal motor torque 930 N
- Speed 300 mm/sec



ARMAR-5: Interface to the human body

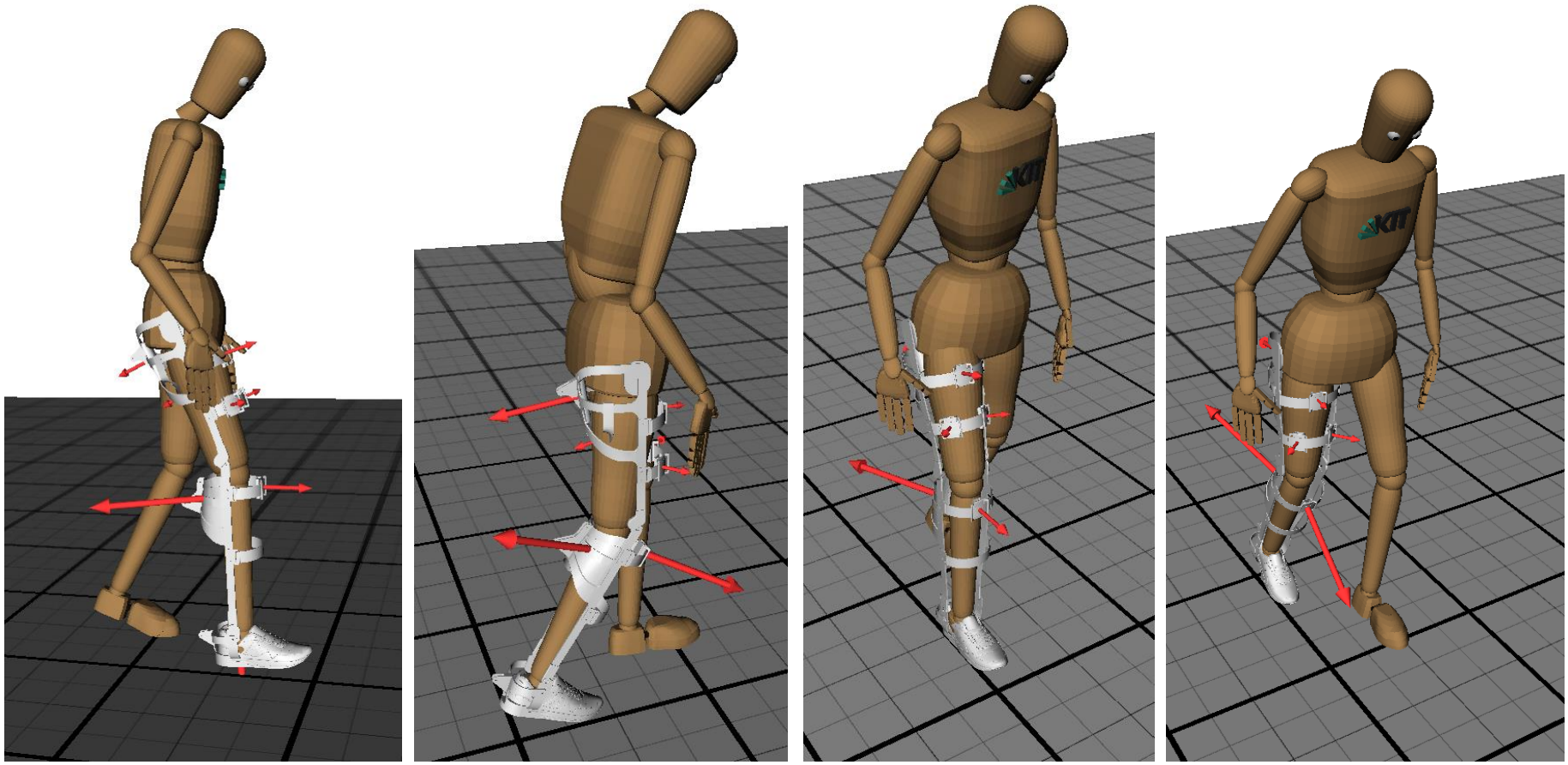
Force sensor suit

- Non-invasive, EMG-free Interface to the human body
- Learn interaction force pattern between human and suit and use them for prediction **“feel the muscle activation”**



- EMG unreliable
- EMG can be used to train a classifier as well as to study correlations between EMG pattern and force pattern

ARMAR-5: Interface to the human body



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- German Research Foundation (DFG)
  - SFB 588 www.sfb588.uni-karlsruhe.de (2001 - 2012)
  - SPP 1527 autonomous-learning.org (2010 -)
  - SFB/TR 89 www.invasic.de (2009 -)

- European Union
  - SecondHands www.secondhands.eu (2015-2019)
  - TimeStorm www.timestrom.eu (2015-2018)
  - I-Support www.i-support.eu (2015-2017)
  - Walk-Man www.walk-man.eu (2013-2017)
  - KoroiBot www.koroibot.eu (2013-2016)
  - Xperience www.xperience.org (2012-2015)
  - GRASP www.grasp-project.eu (2008-2012)
  - PACO-PLUS www.paco-plus.org (2006-2011)

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Thanks for your attention