

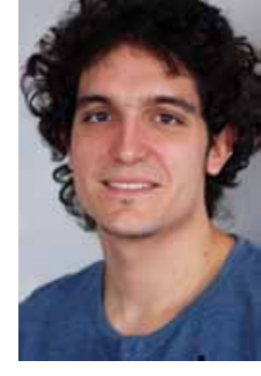
Design Concepts for Physical Human-Robot Cooperation



Alexander Mörtl
moertl@tum.de



Martin Lawitzky
ml@tum.de



José Ramón Medina
medina@tum.de



Dongheui Lee
dhlee@tum.de

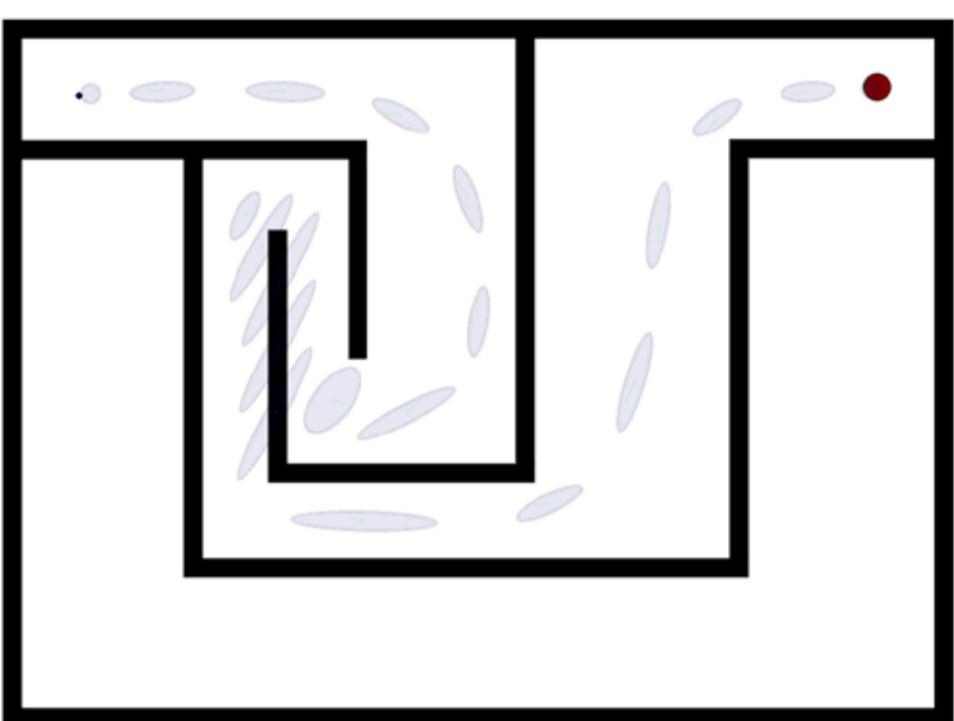


Sandra Hirche
hirche@tum.de

Complementary Strengths of Learning and Planning

- Challenge: Motion generation for goal-directed robotic assistance
- Proposed methods:

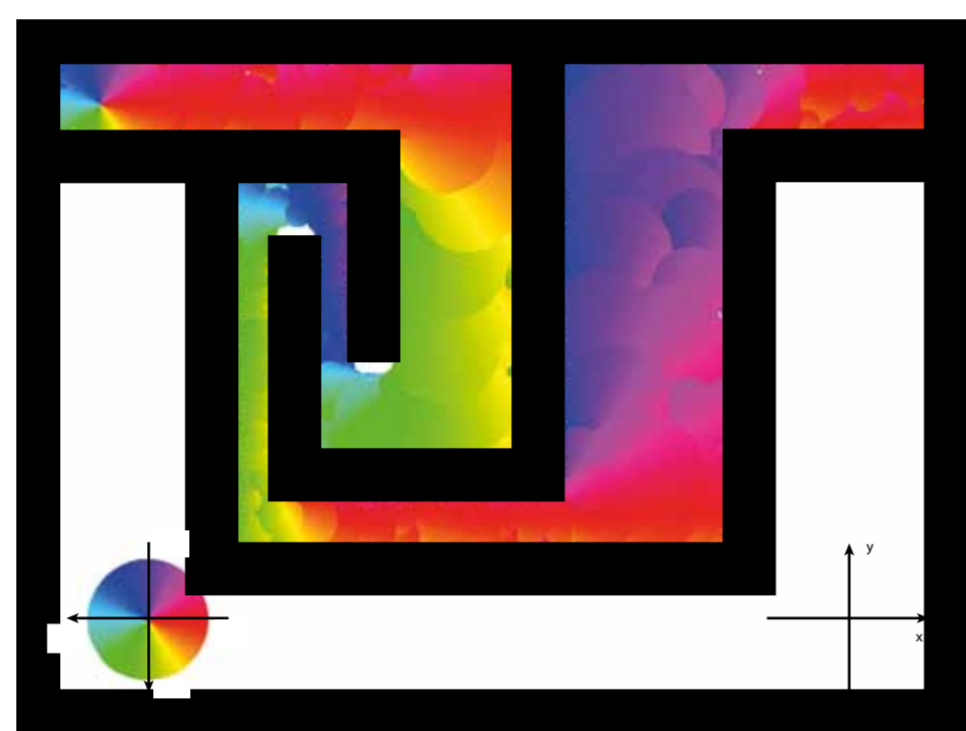
1) Motion reproduction from demonstration



- + No explicit environmental model
- + Implicit dynamical task model
- + Scales to high degrees of freedom
- + User-adaptive

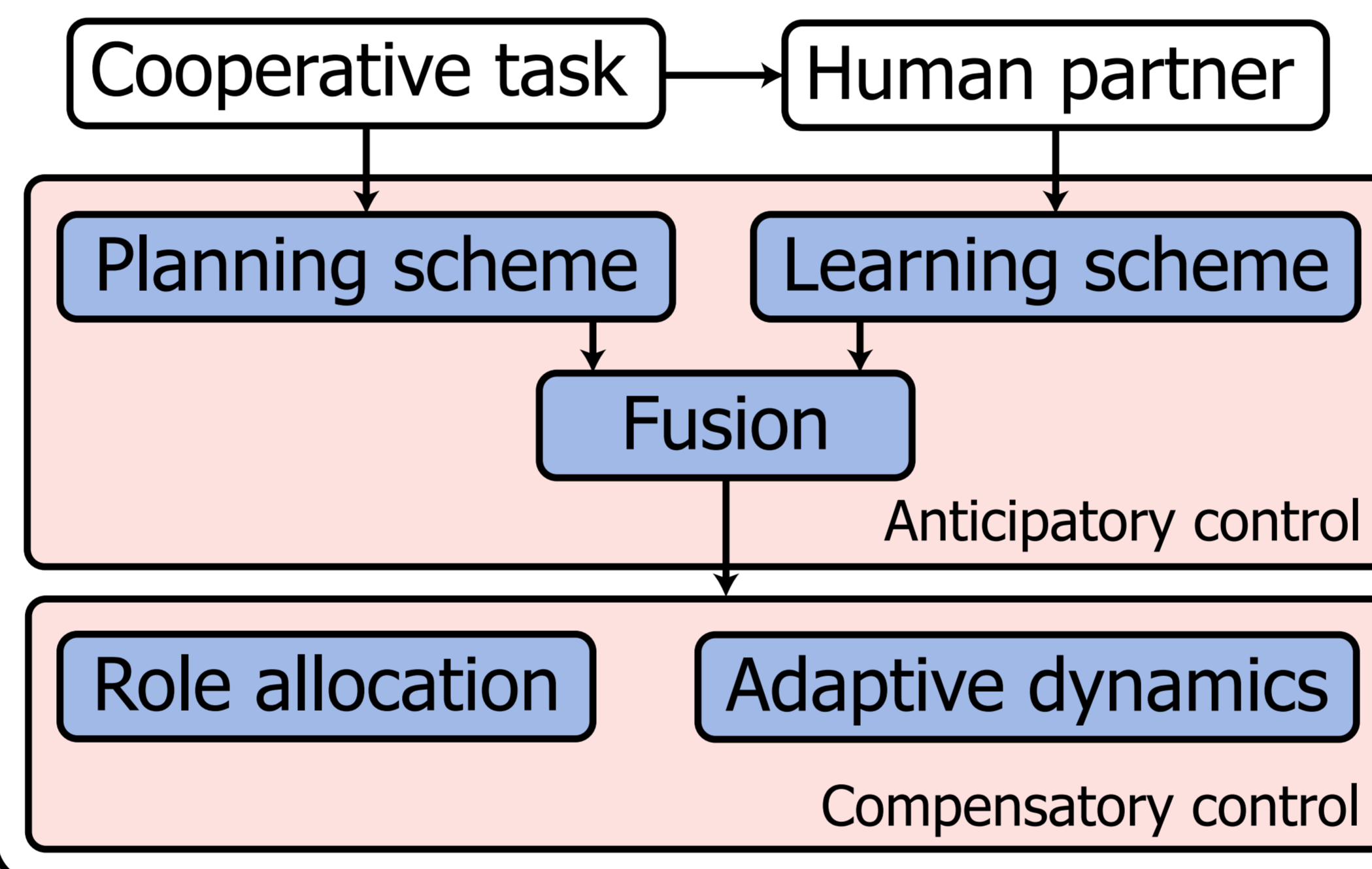
2) Feedback motion planning

- + Plan for entire accessible region
- + Computationally tractable in 6D
- + Short and collision-free paths
- + Reactive to user-induced deviation



- Fusion for the best of both worlds

Assistance Concept for pHRI



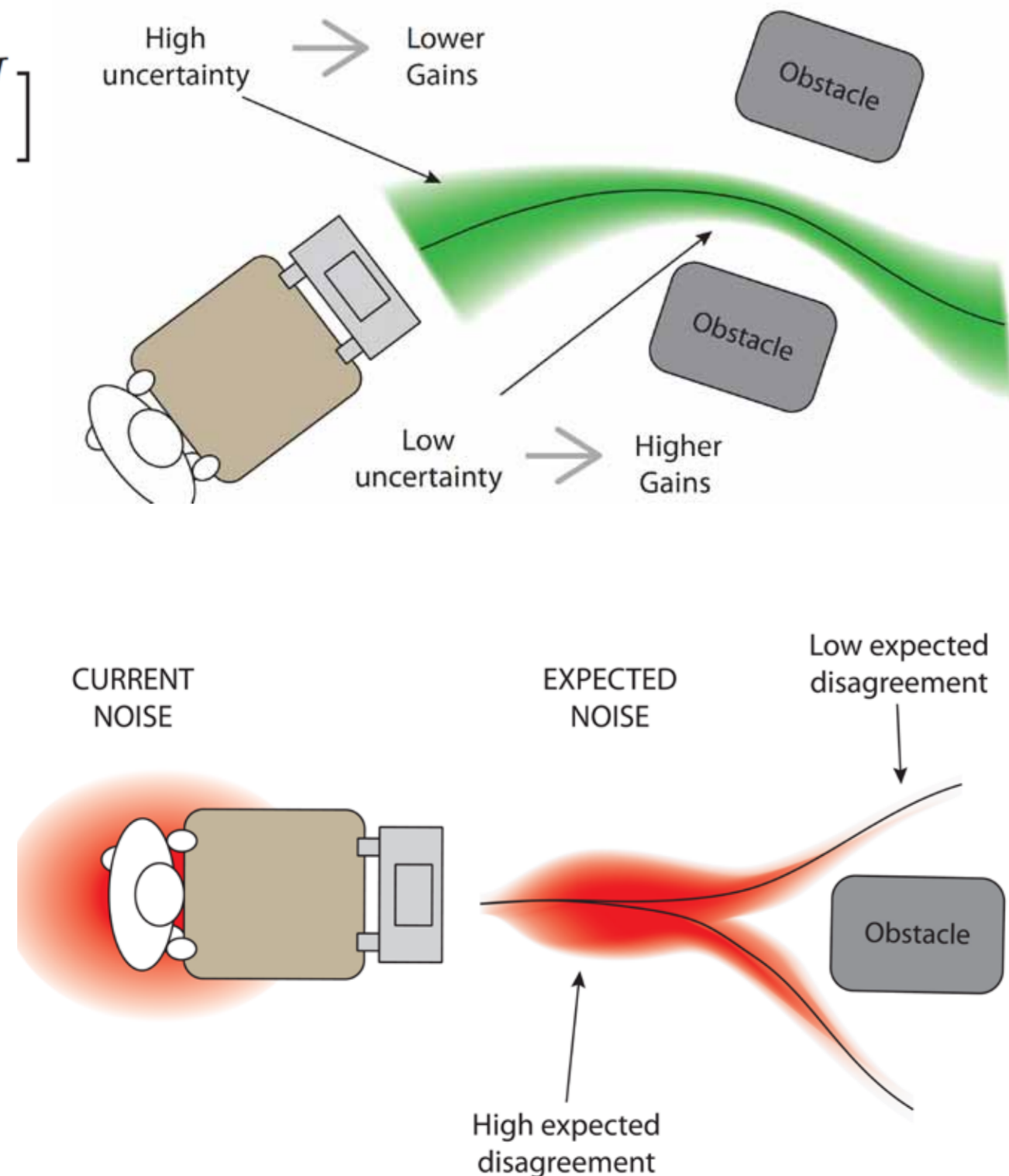
Disagreement-Aware Assistance

- Understanding human sensorimotor behavior as a source of variability
- Novel control concept based on risk-sensitive optimal feedback control with cost function

$$\gamma(\theta) = -2\theta^{-1} \ln \mathbb{E}[\exp^{-\frac{1}{2}\theta J}]$$

- Observation of past and current process noise interpreted as disagreement

- Intuitive assistance behavior considering prediction uncertainties of the task model and process noise

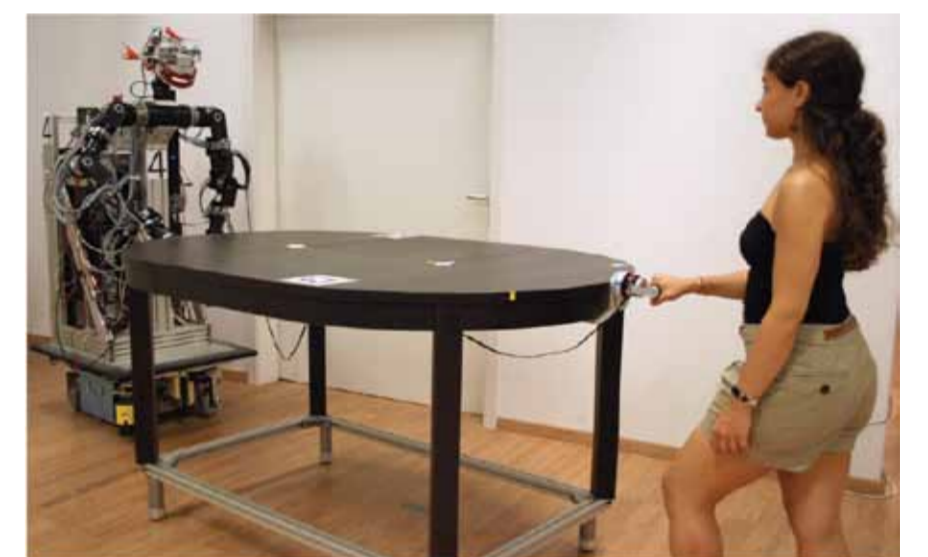
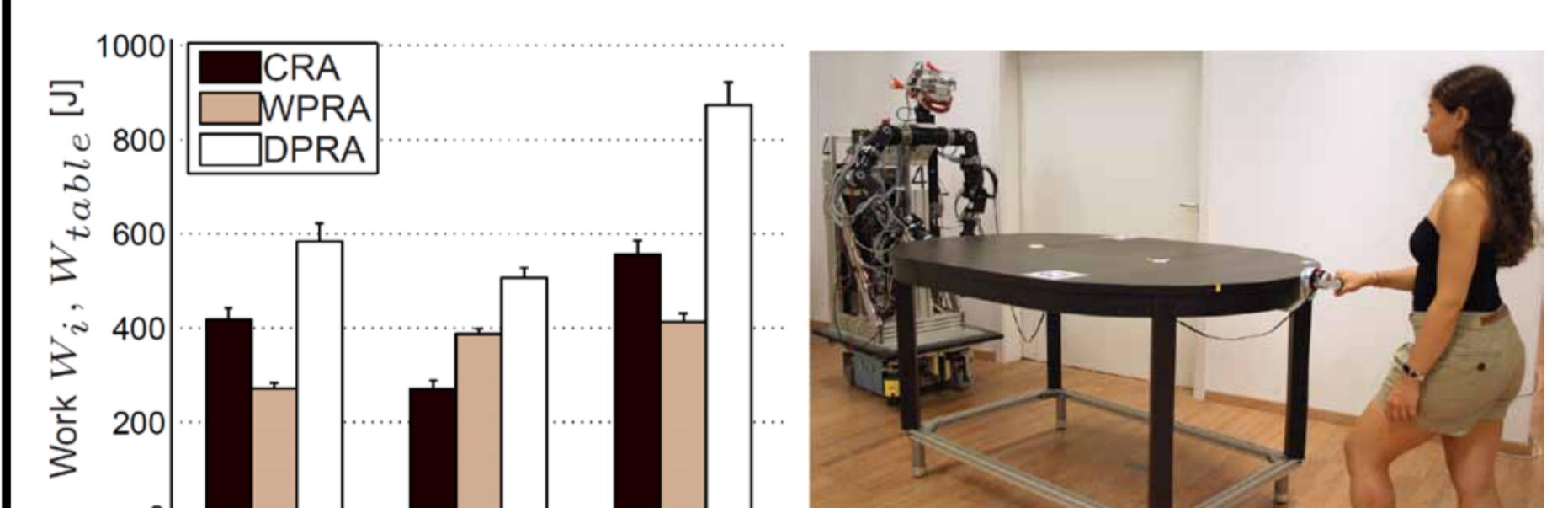
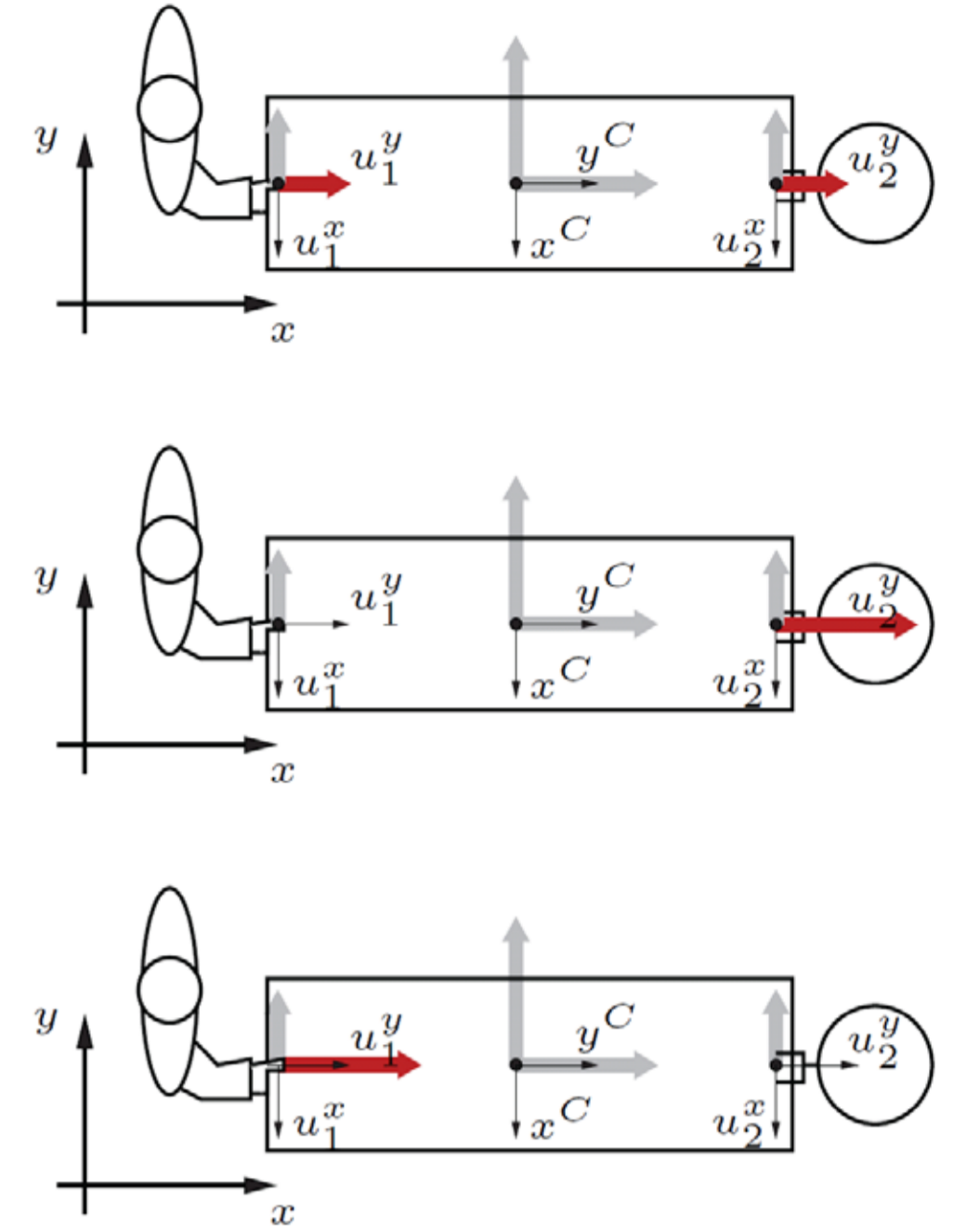


Dynamic Allocation of Roles

- Humans dynamically negotiate the effort distribution
- Effort sharing by geometrical wrench decomposition

$$\tilde{\mathbf{u}} = \mathbf{G}^+ \hat{\mathbf{u}}_c + \sum_{j=1}^{\text{nullity}(\mathbf{G})} \lambda_j \text{Ker}_j(\mathbf{G})$$

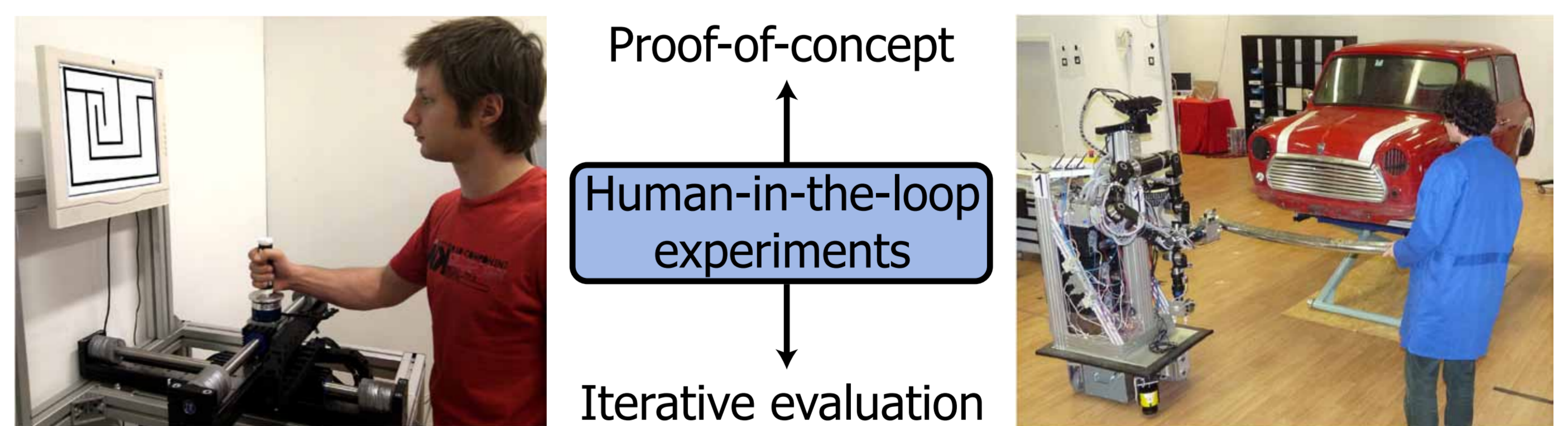
- Dynamic role changes by interpreting human feedback as agreement and varying λ_j
- Weighted pro-active (WPRA), discrete (DPRA) and constant (CRA) role allocation scheme evaluated in a large-scale HR-study¹
- Role schemes affect cooperation, yielding a trade-off between subjective acceptance (CRA best) and objective performance criteria (WPRA best)



¹Joint work with Kucukyilmaz / Basdogan (KOC Univ.)

Rapid Prototyping Environment

- Development of pHRI-capable robots requires robust, flexible and safe experimental systems



- VR-system for 2-DoF visuo-haptic rendering (left)
- 6-DoF mobile manipulator for realistic full-body kinesthetic interaction (right)
- Driven by modular real-time software architecture

Selected publications:

- M. Lawitzky, J. Medina, D. Lee and S. Hirche, Feedback Motion Planning and Learning from Demonstration in Physical Robotic Assistance: Differences and Synergies, in Proc. IEEE/RSJ IROS, 2012
- J. Medina, T. Lorenz, D. Lee and S. Hirche, Disagreement-Aware Physical Assistance Through Risk-Sensitive Optimal Feedback Control, in Proc. IEEE/RSJ IROS, 2012
- A. Mörtl, M. Lawitzky, A. Kucukyilmaz, M. Sezgin, C. Basdogan and S. Hirche, The Role of Roles: Physical Cooperation between Humans and Robots, Int. J. Robot. Res., 2012



TECHNISCHE UNIVERSITÄT MÜNCHEN

LEHRSTUHL FÜR STEUERUNGS- UND REGELUNGSTECHNIK

ORDINARIUS: UNIV.-PROF. DR.-ING./UNIV. TOKIO MARTIN BUSS

EXTRAORDINARIA: UNIV.-PROF. DR.-ING. SANDRA HIRCHE

