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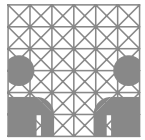

Safety in Physical Human Robot Interaction

using motion planning and prediction

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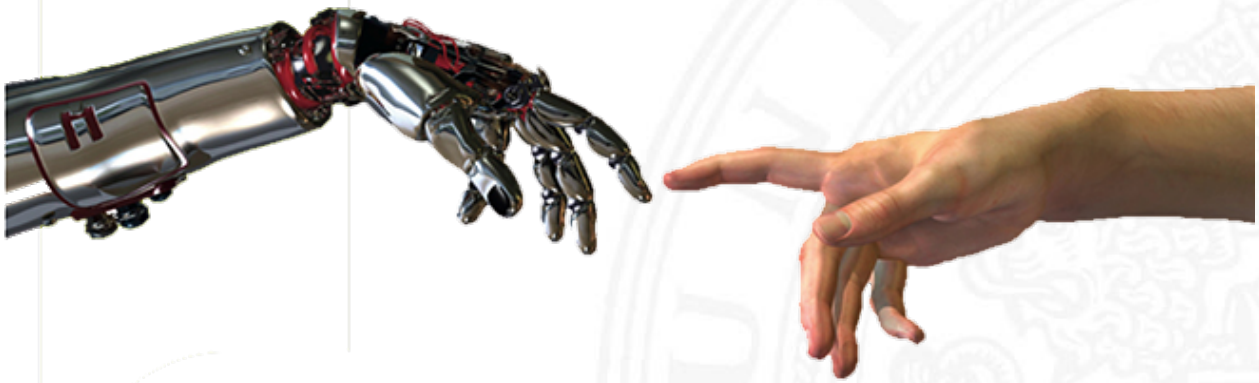
Technical Aspects of Multimodal Systems

26. November 2018

Outline

- Human-robot interaction — collaboration, communication, and cooperation between humans and robots — is a rapidly growing area of robotics research.
- Robotics have long foreseen humans and robots existing side by side (reality is quite different)
- We need the next generation of robots to interact with people directly (at the cognitive level)



Source: http://metropolis.scienze.univr.it/altair/events/ias13tutorial/

Introduction (cont.)

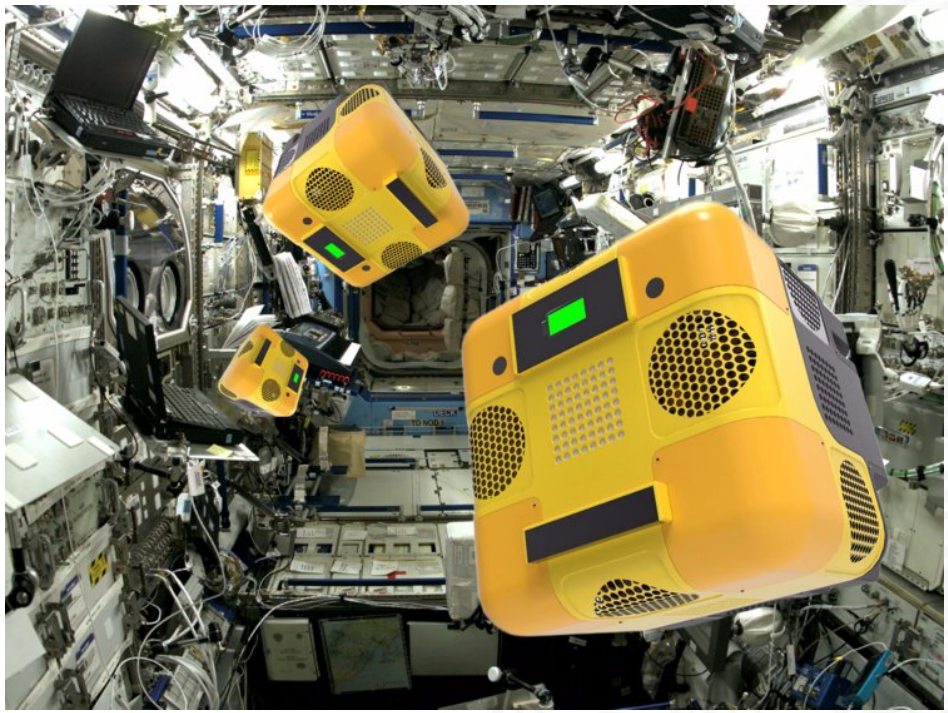
- Robots physically embody the link between perception and action (unlike computers)
- the segregation paradigm fails in cases where the human and the robot must share the physical environment.

Robot accidents are not limited to normal operating conditions

but instead during programming, program touch-up or refinement, maintenance, repair, testing, setup, or adjustment.

Physical Human Robot Interaction

- In pHRI, humans and robots share the same workspace (occasional or intentional contact)
- Many applications: co-workers in factories, in-home robot helpers, robotic assistants for astronauts on-board the ISS etc.
- Success of HRI depends on safety being a top priority.



Source: https://www.businessinsider.de/astrobee-cube-robot-space-station-2017-3?r=UKIR=T

Isaac Asimov's three "Laws of Robotics", Law No. 01

A robot may not injure a human being or, through inaction, allow a human being to come to harm.

- **Physical Safety:** avoid physical discomfort or injury.
- **Psychological Safety:** avoid stress, discomfort and social inconvenience.

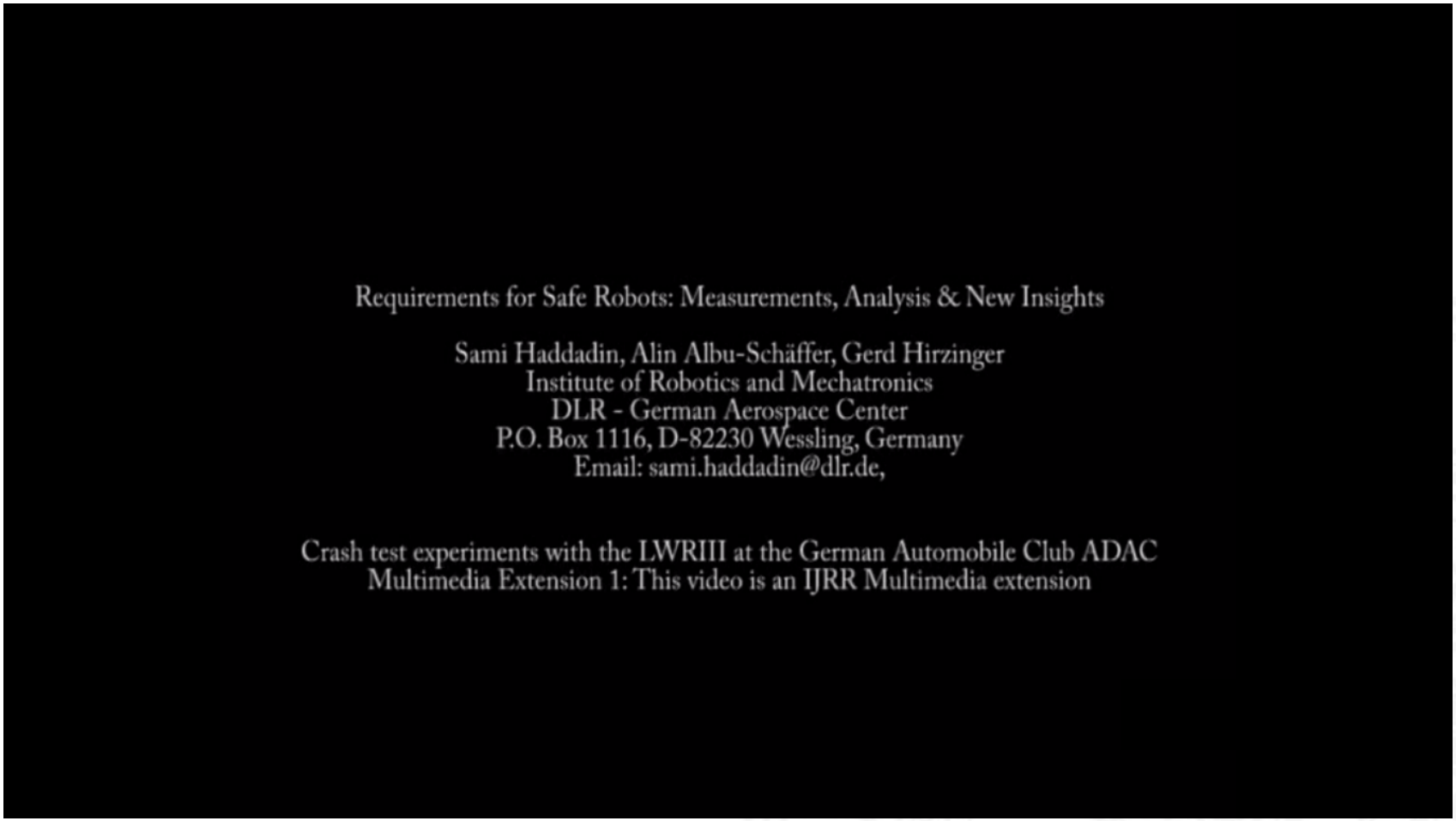
Safety standards and criteria

- **The ISO:** potential methods of safe collaborative manipulation, ex: speed, power and force limiting.
- **Collision crash dummy tests**
- **Classify pain and injury threshold**
- **Effectiveness of control strategies**
- **Injury prevention criteria.**

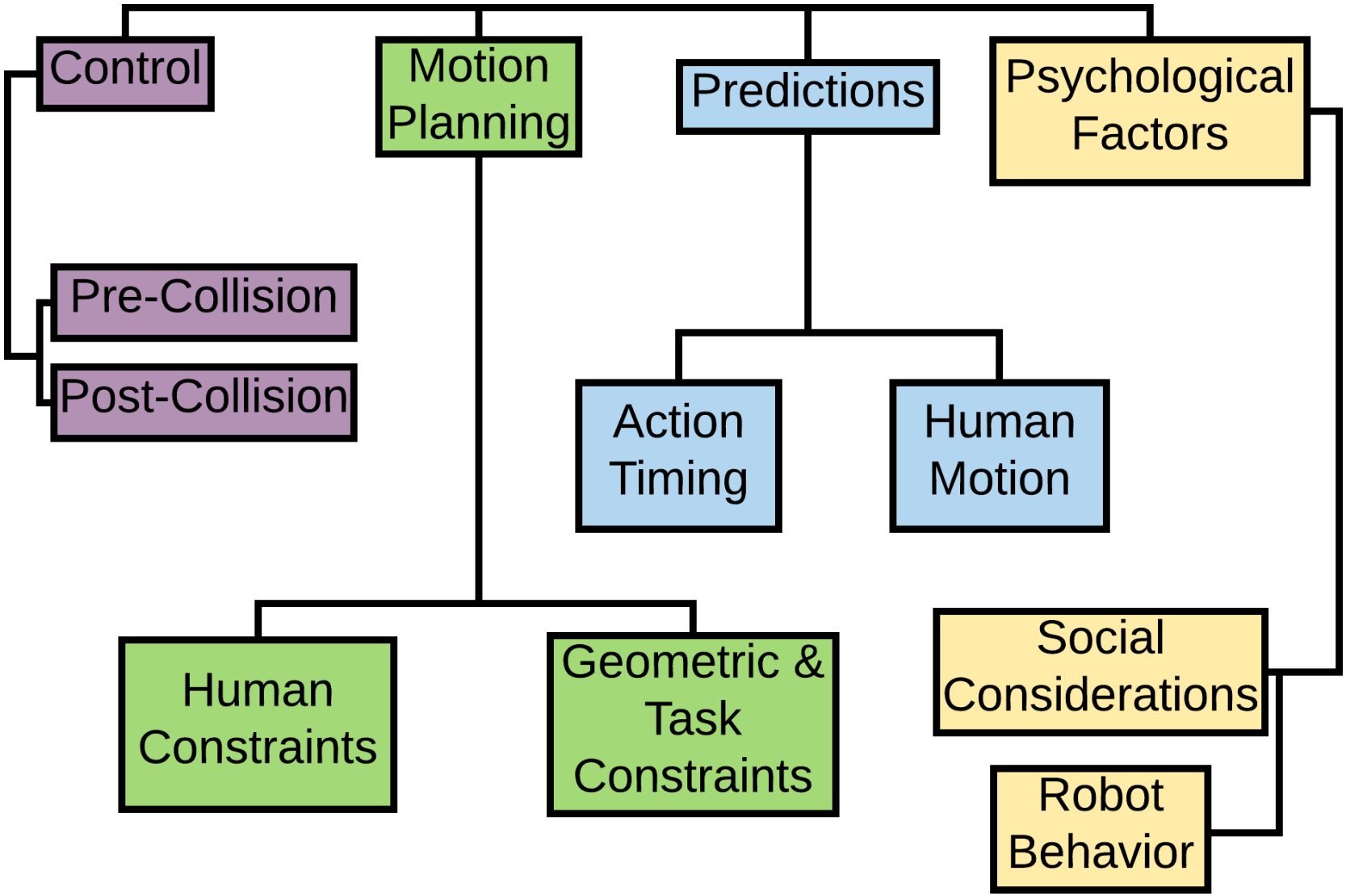
What about a robotic tour guides or assistants for the elderly?

Although many of the principles would likely transfer to other types of robots and applications, the standards' scope is still too narrow.

Safety standards and criteria (cont.)

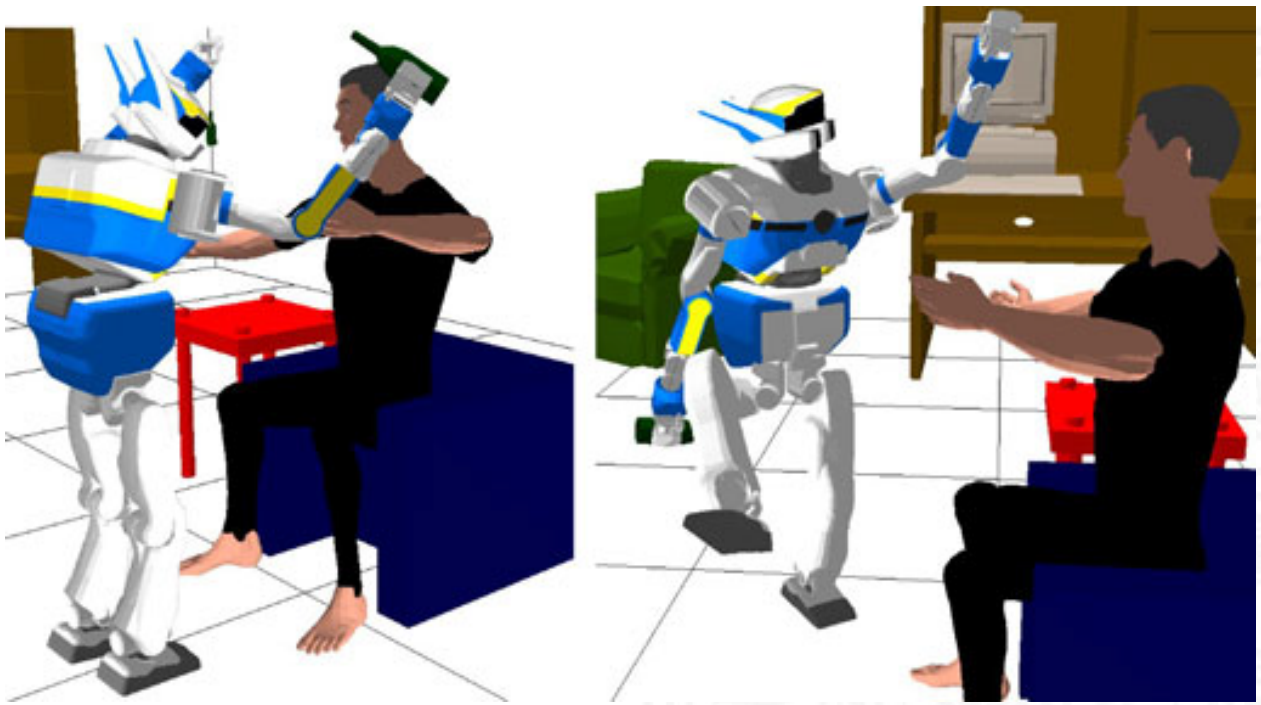


Source: Sami Haddadin, et al. 2009


Control
Motion Planning
Predictions
Psychological Factors
Pre-Collision
Post-Collision
Action Timing
Human Motion
Human Constraints
Geometric & Task Constraints
Social Considerations
Robot Behavior

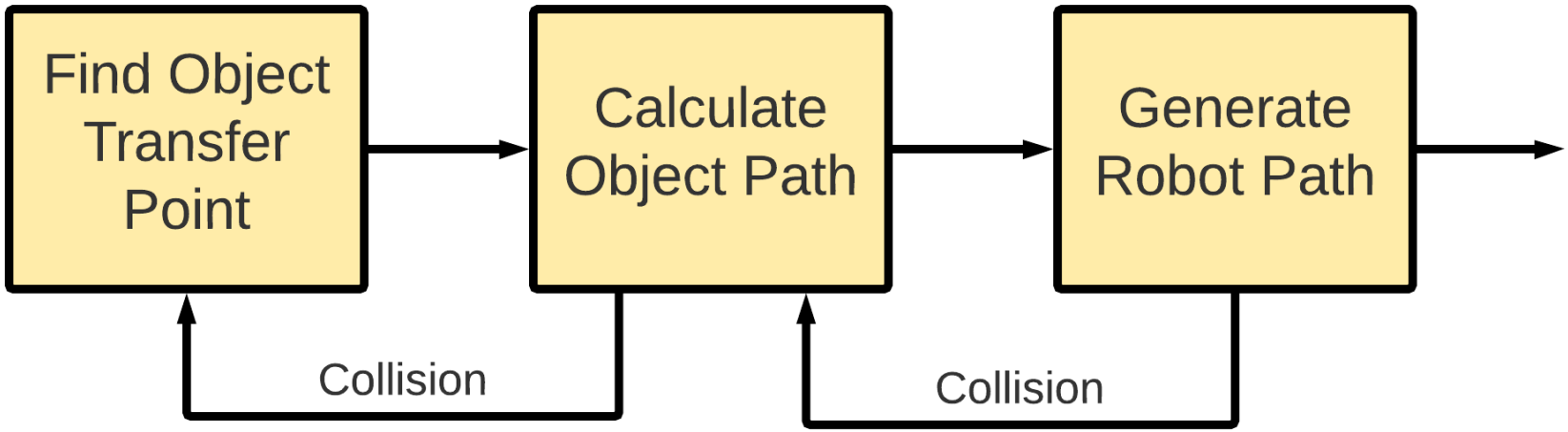
Human Aware Manipulation Planner

- A motion planner for human-robot object transfer.
- Design considerations: legibility, the safety and physical comfort.



Source: Dehais, F., et al. 2011

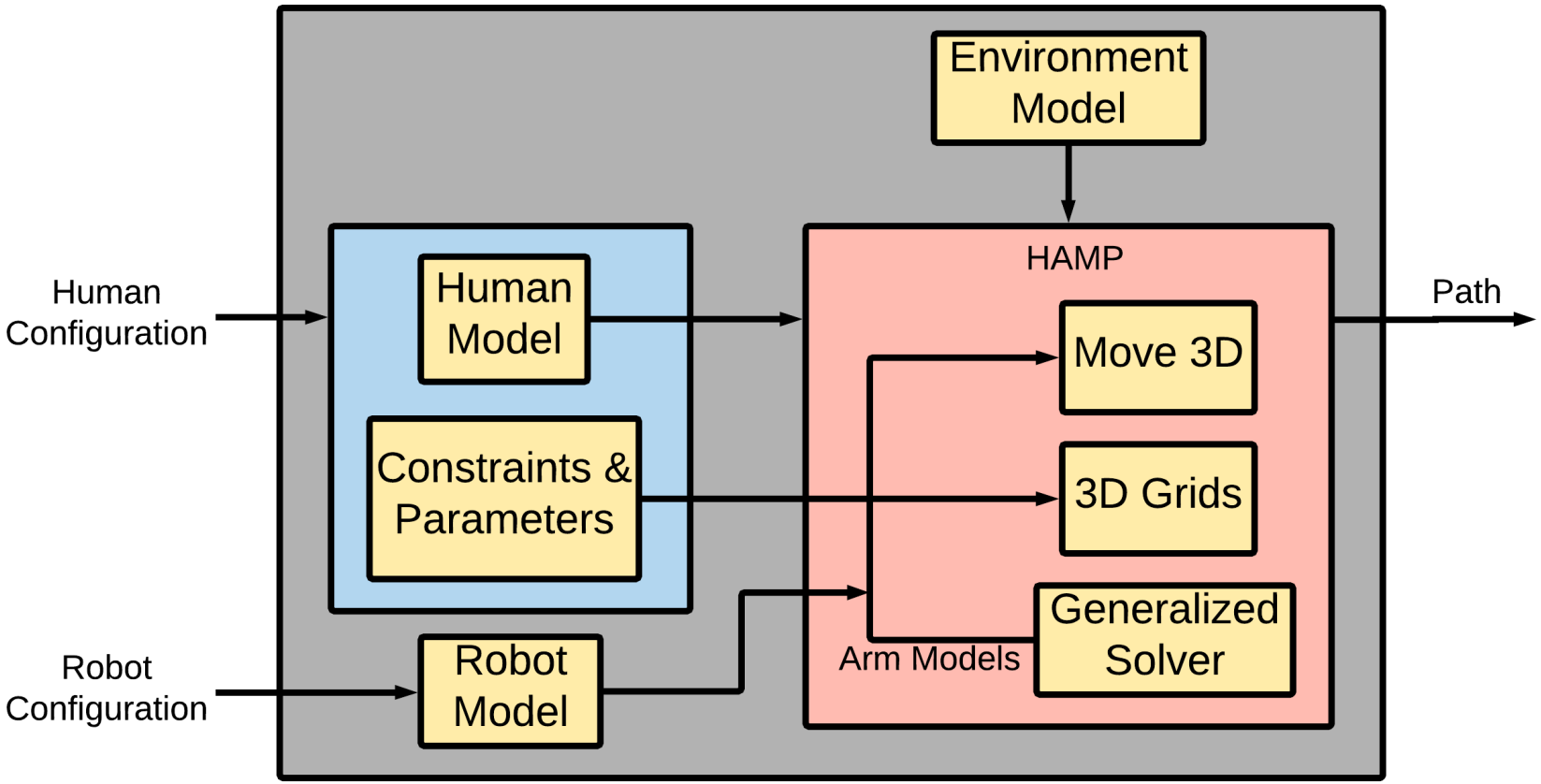
Human Aware Manipulation Planner (cont.)



Original Contribution: Dehais, F., et al. 2011. Diagram created with lucidchart.com

- 3 cost function factors (distance, visibility and arm comfort)
- Failure: the OTP is in collision, or a constrained space.
- **A force detection module**
- **A Reaching gesture detected module**

Human Aware Manipulation Planner (cont.)



Original Contribution: Dehais, F., et al. 2011. Diagram created with lucidchart.com

Human Aware Manipulation Planner (cont.)

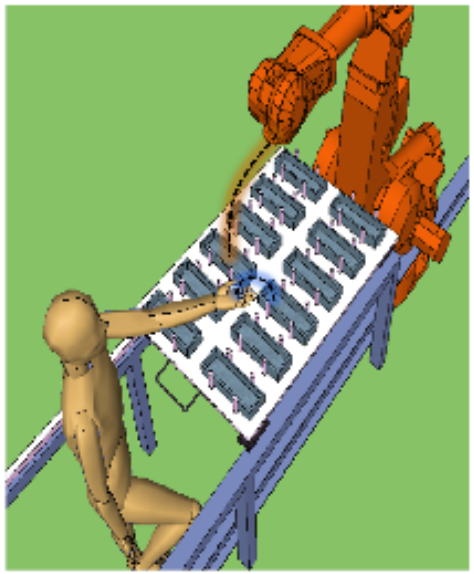
Source: Dehais, F., et al. 2011

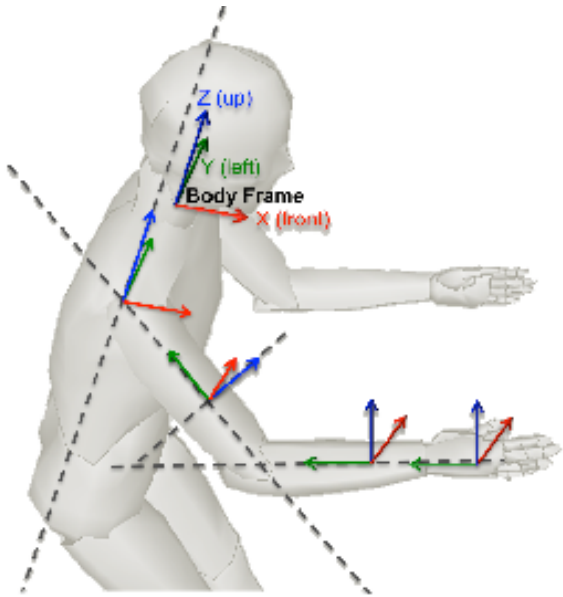
Human Aware Manipulation Planner (cont.)

✓ Human aware model	X Assumes a robot fixed base
✓ Allows robot to take initiative	X May not be world applicable
✓ Integrated into an architecture	X No mutual attention of object

Predicting Human Reaching Motion

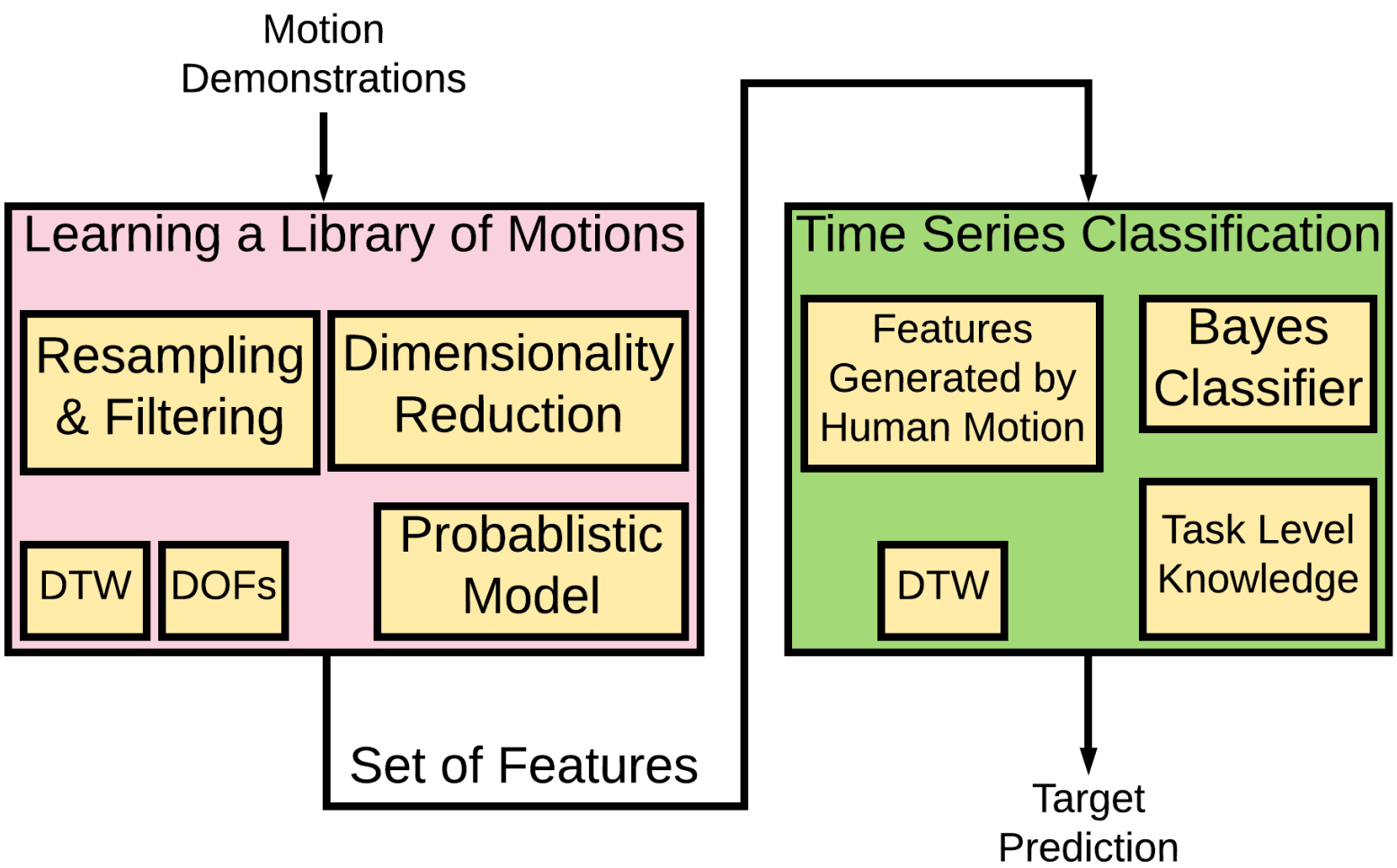
- A data-driven approach that combines anticipatory knowledge of both human motions and subsequent action steps.
- Predicts in real-time the intended target of a human performing a reaching motion.





Source: Pérez-D'ArpinoFast, et al. 2015

Predicting Human Reaching Motion (cont.)



Original Contribution: Pérez-D'ArpinoFast, et al. 2015. Diagram created with lucidchart.com

Predicting Human Reaching Motion (cont.)

Pérez-D'ArpinoFast, et al. 2015

Predicting Human Reaching Motion (cont.)

✓ Real time predictions	X Requires offline phase
✓ Validated performance	X Computationally expensive

Conclusion

- Safety in pHRI is not just one technique but a research area that involves many topics such as: planning, navigation and collision avoidance.
- Standards are still under development.

Control	✓ Simple	**X** Not sufficient
Motion Planning	✓ Proactive	**X** Practical limits
Prediction	✓ More efficient	**X** Depends on accuracy

- Feasibility and Scalability.
- What's next? investigate other methods?

Thank you for listening!

References

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