
Humanoid Motion: Between Reactive Planning and Extensive Control

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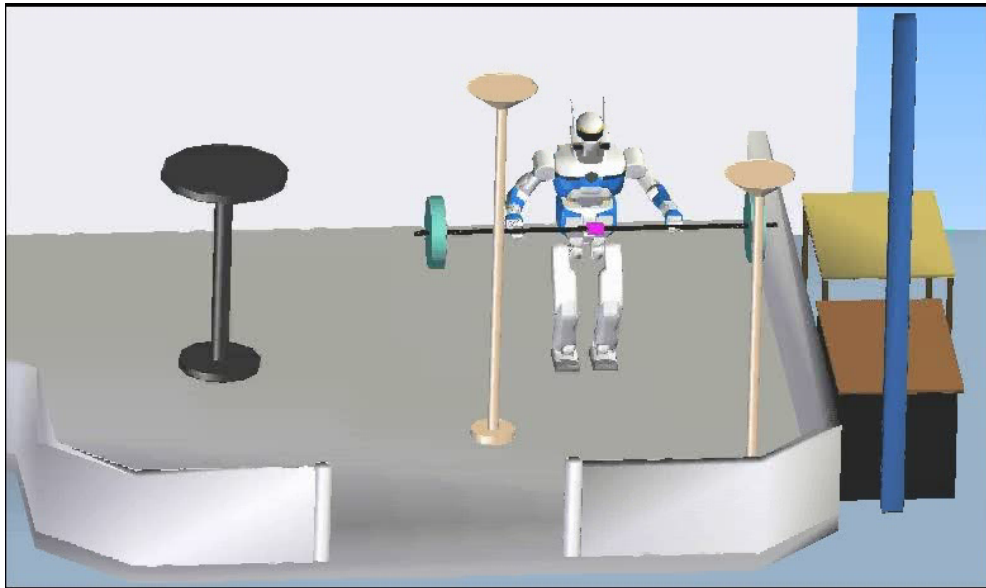
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What's next on humanoid motion...?

- To bring it in various places
 - Reactiveness
 - Robustness
 - Reliability (hardware/software)
- Focus: whole-body **motion** reactivity
 - Make planning more **reactive**
 - Make control more **extensive**
 - Combine planning and control
 - Know itself and update its world

Motion update cycle

- Cycle: hours, minutes



- Environment calibration
- Parameter adjustment

[Yoshida, Laumond et al., IEEE TRO 08]

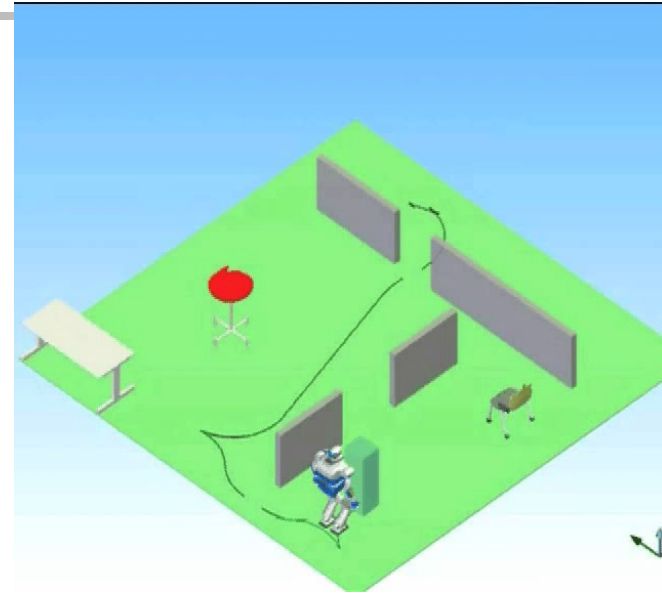
- What if we move obstacles...?



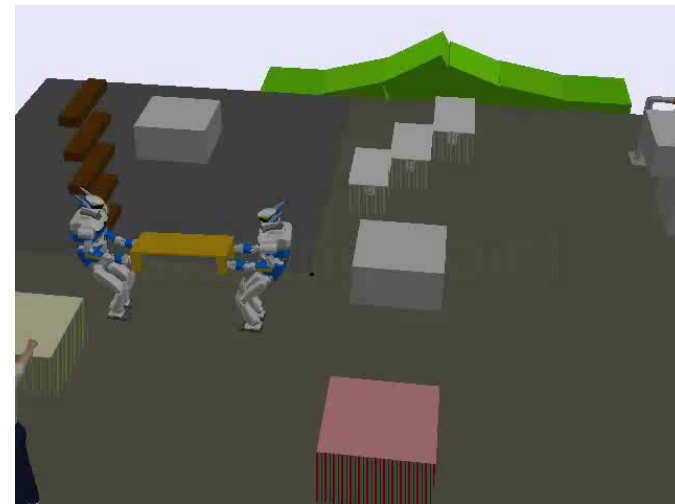
Cycle: hours, minutes



[Yoshida, Laumond et al., Auton. Robots, 10]



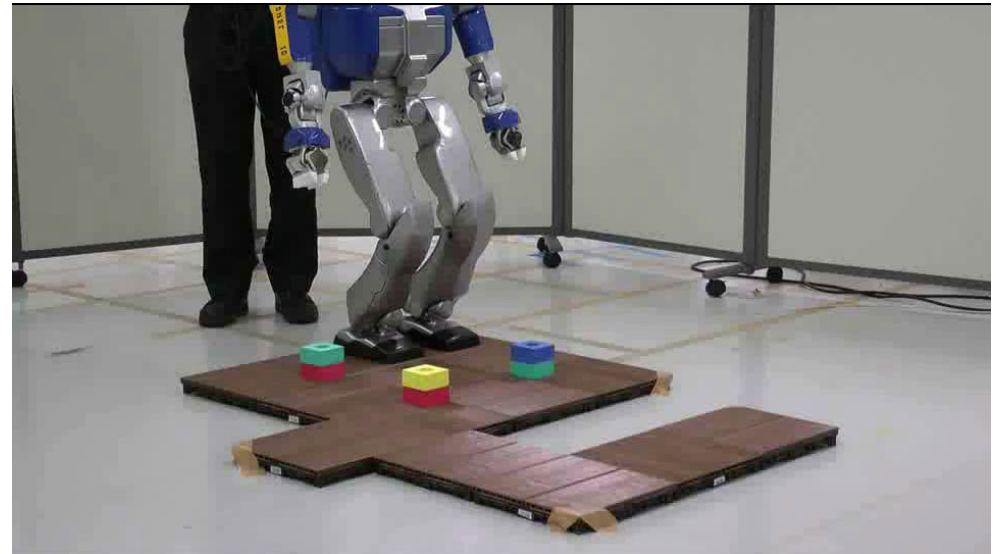
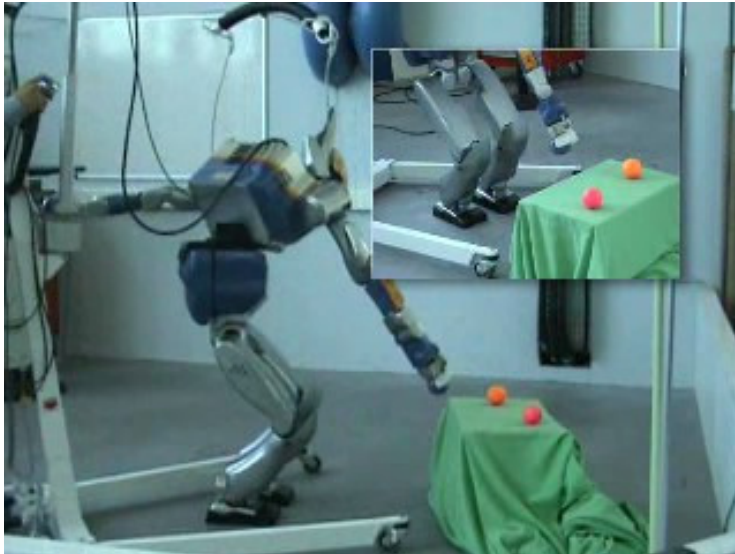
[Lengagne, et al Humanoids 10, MA-I.3]



[Bouyarmane and Kheddar, Humanoids 10, MA-I.2]

Motion update cycle

- Cycle: seconds – one step further
 - Can integrate online sensing



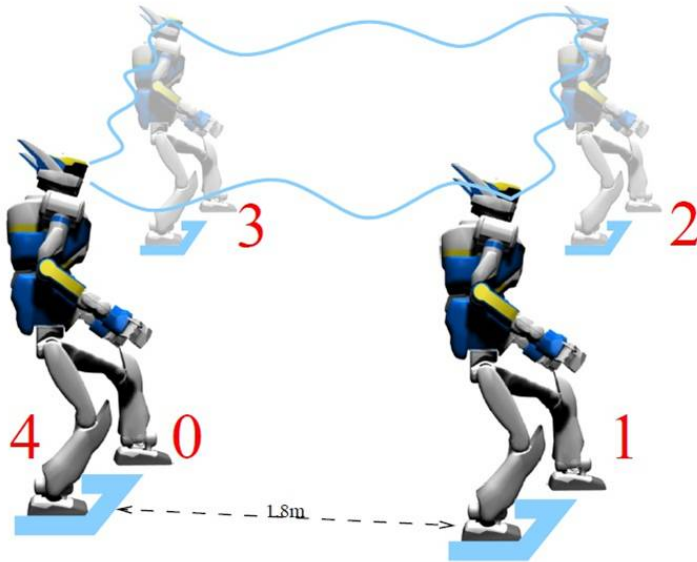
[Yoshida, Kanoun et al., Humanoids 07]

[Perrin, Stasse, et al, ICRA 11 submitted]
Project ANR “R-Blink”

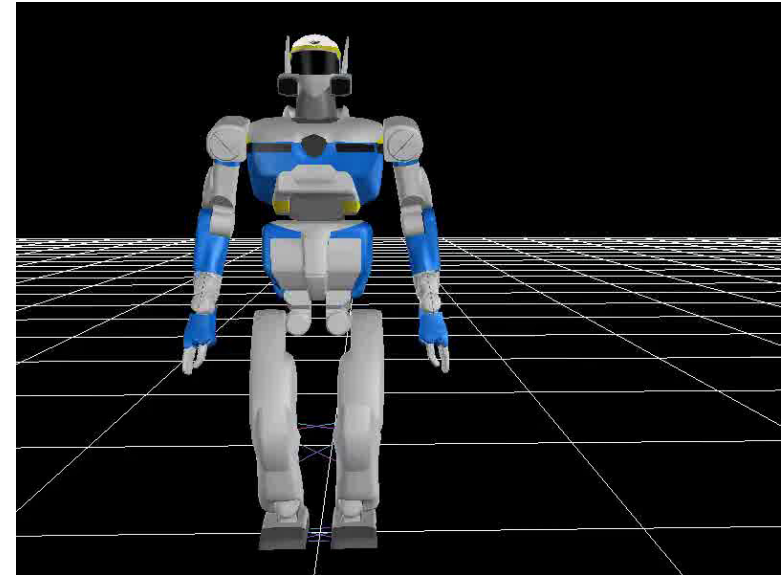
- Whole-body generalized IK
- Feasible dynamic walking learned before planning

Motion update cycle

- Cycle: msec – local control, but longer range



[Dune et al., IROS 10]



[Kanehiro et al., IROS 10]

- Visual feedback for walking

- Online generation of feasible walking pattern

Motion update cycle

- Days, months
- Really need reactiveness



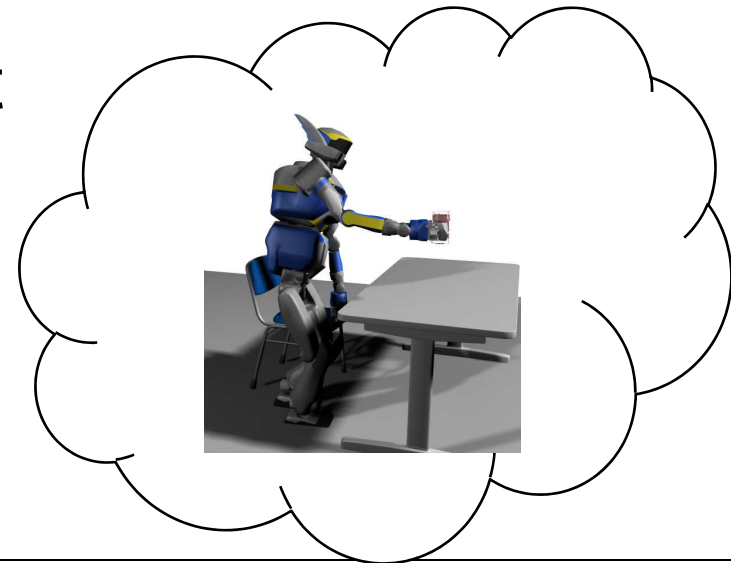
Planning and control

- Motion planning → more reactive
 - Accelerated: parallelization, cloud computing...
- Local Control → more extensive
 - Now for longer range
 - No more planning?
- How does humanoid benefit from them both?
 - Not one or the other
 - Combine them complementarily for motion reactiveness

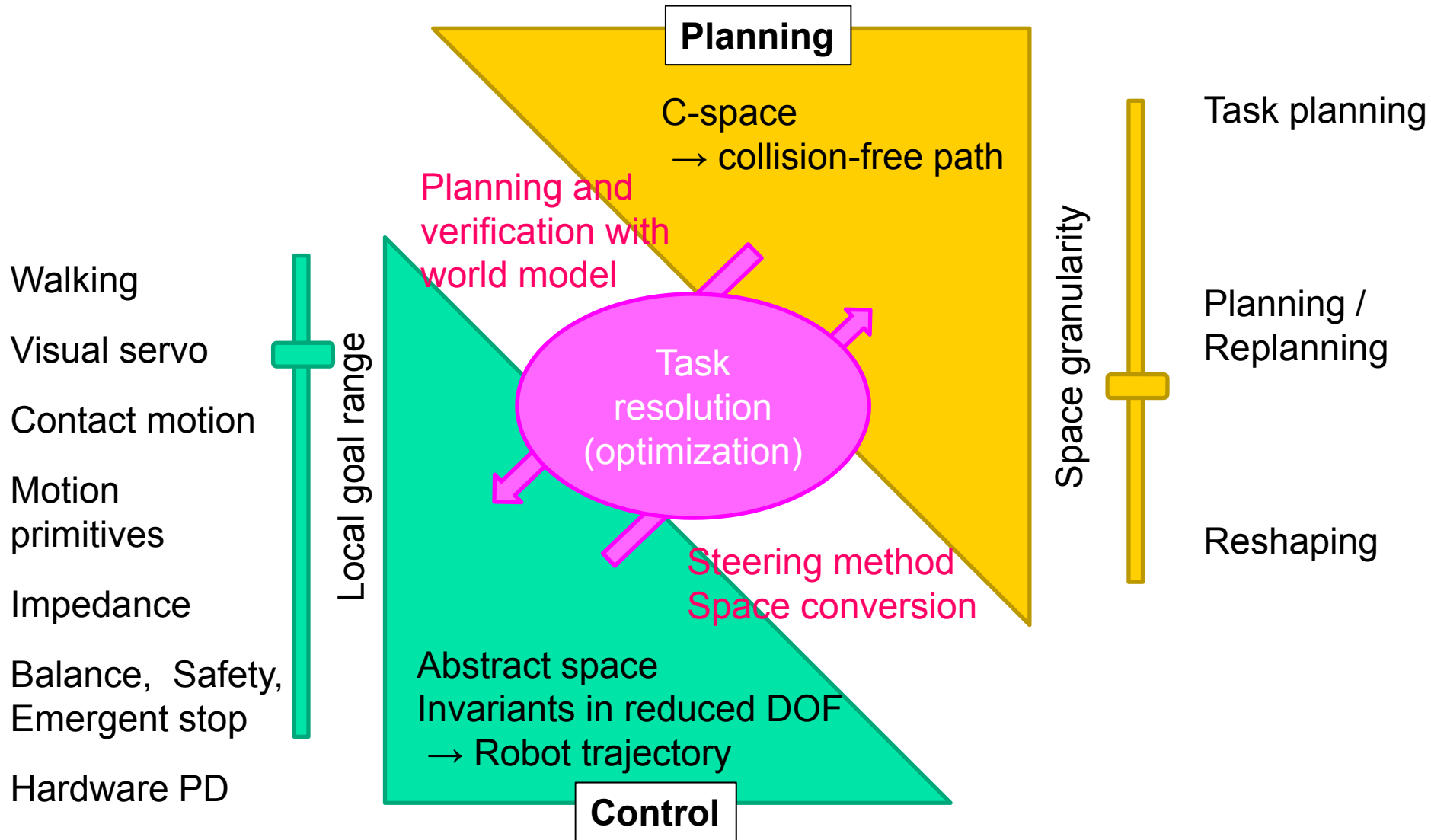
Planning and execution time

- Execution time (current state)
 - Controller with real robot
 - Hard time constraint

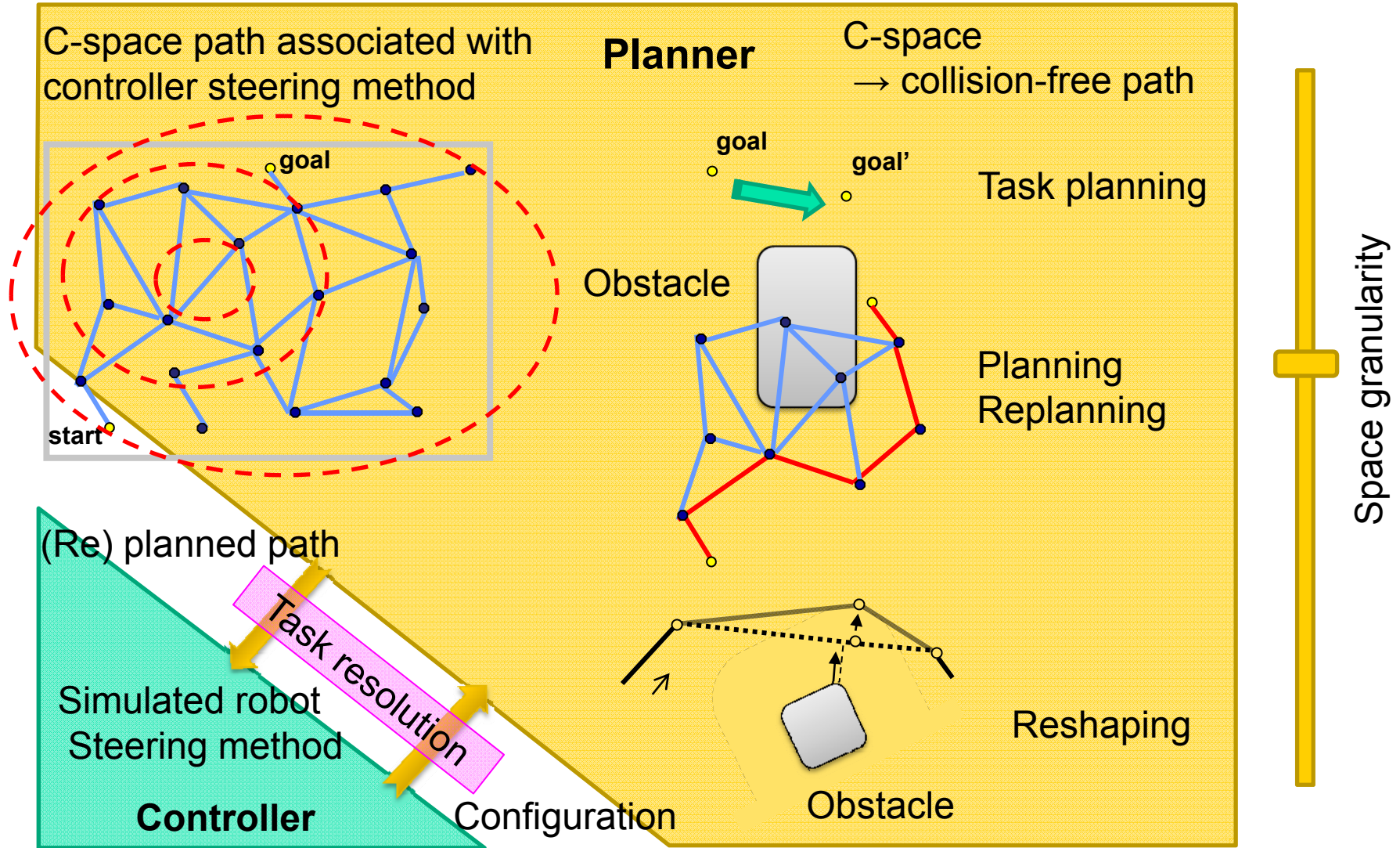
- Planning time (virtual)
 - Controller with simulated robot in world model
 - Controller as steering method



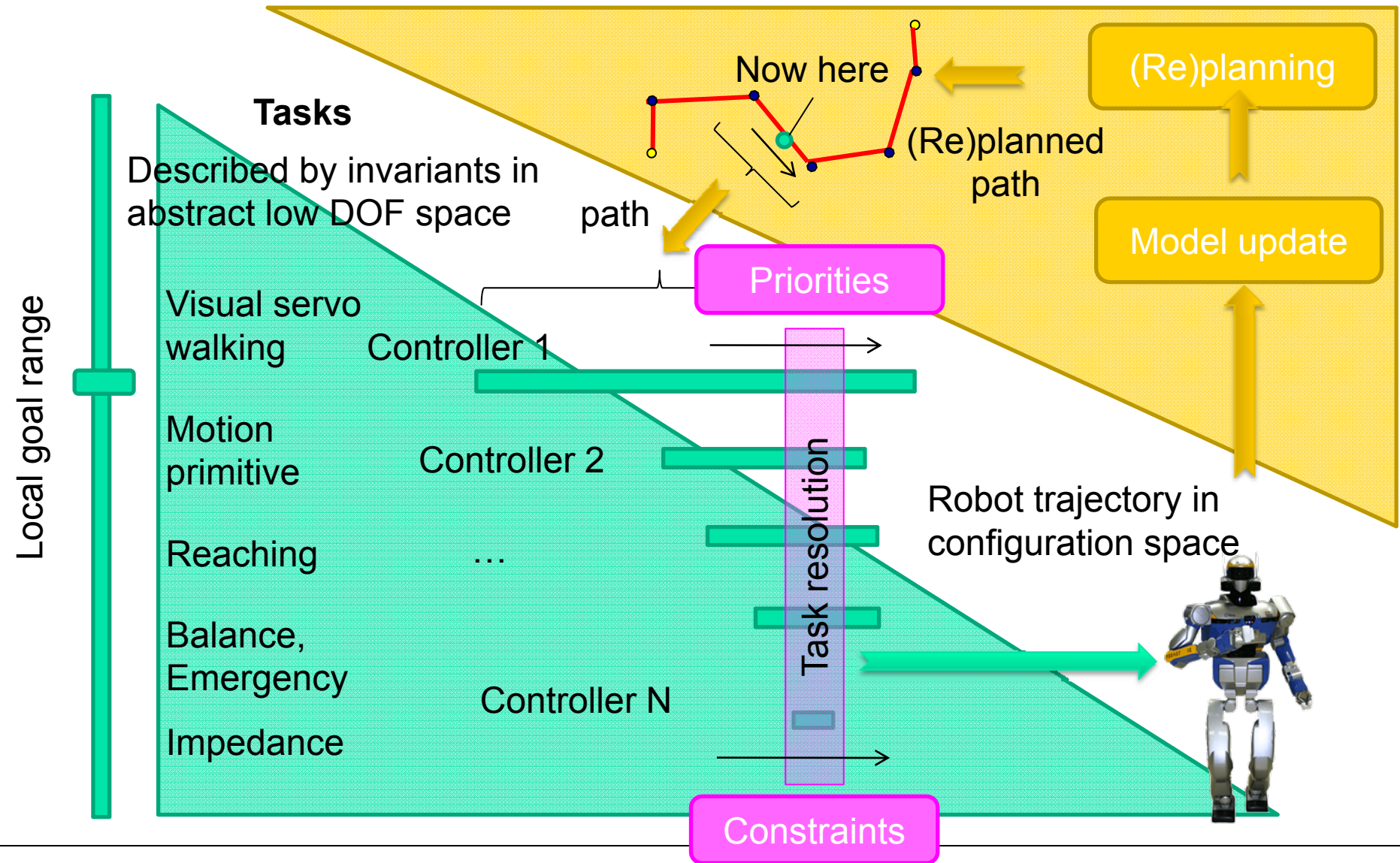
Frontier for planning and control



Reactive planning

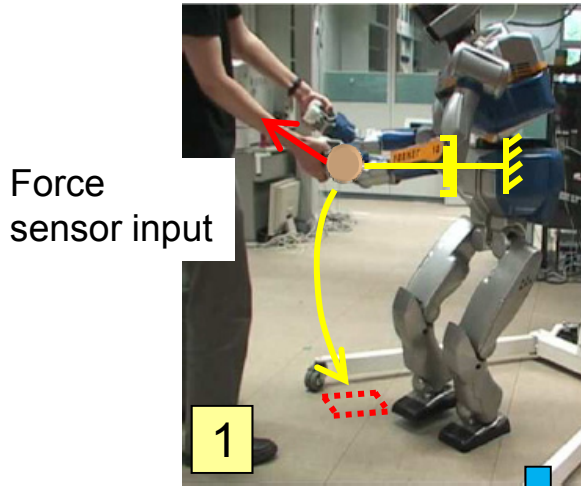


Extensive Controller



Example of task resolution

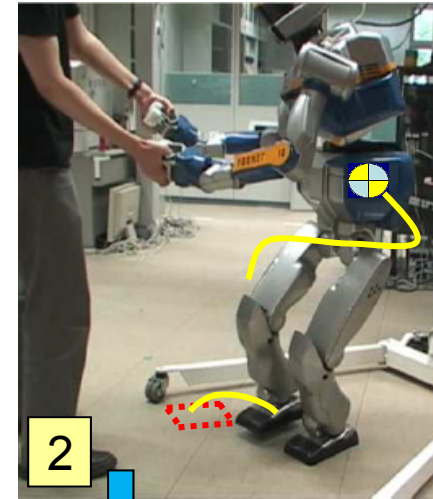
[EU FP6 Robot@CWE]



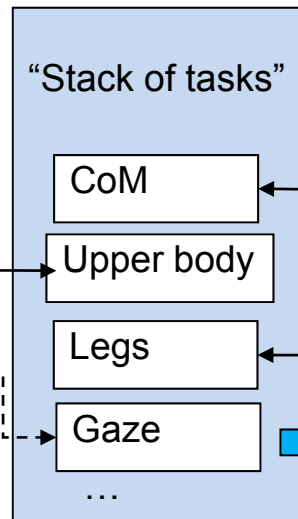
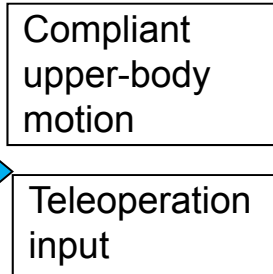
Force input and footstep planning

Real-time walking pattern generation:

Stability and foot motion



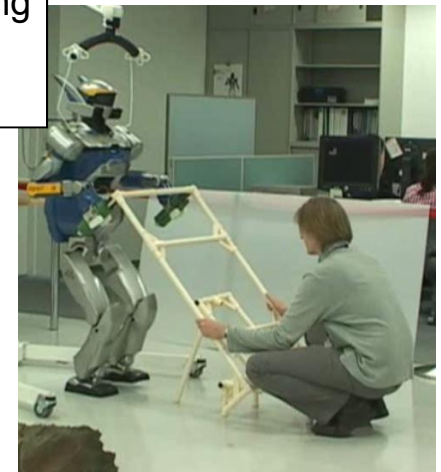
Teleoperator



Optimization Constraints

Fast walking pattern generation

Real-time whole-body motion



Example of reactive planning

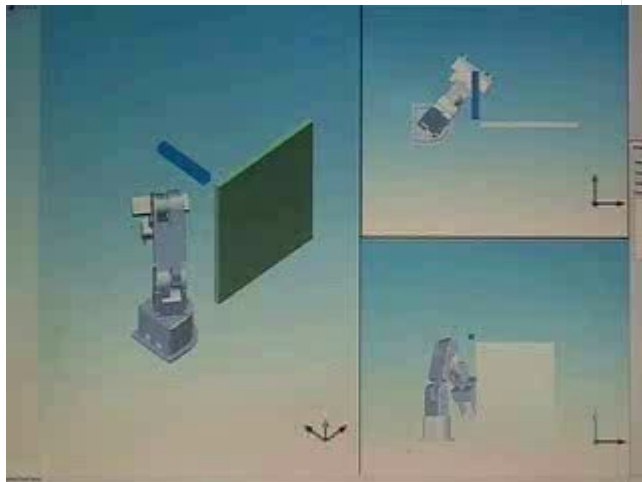
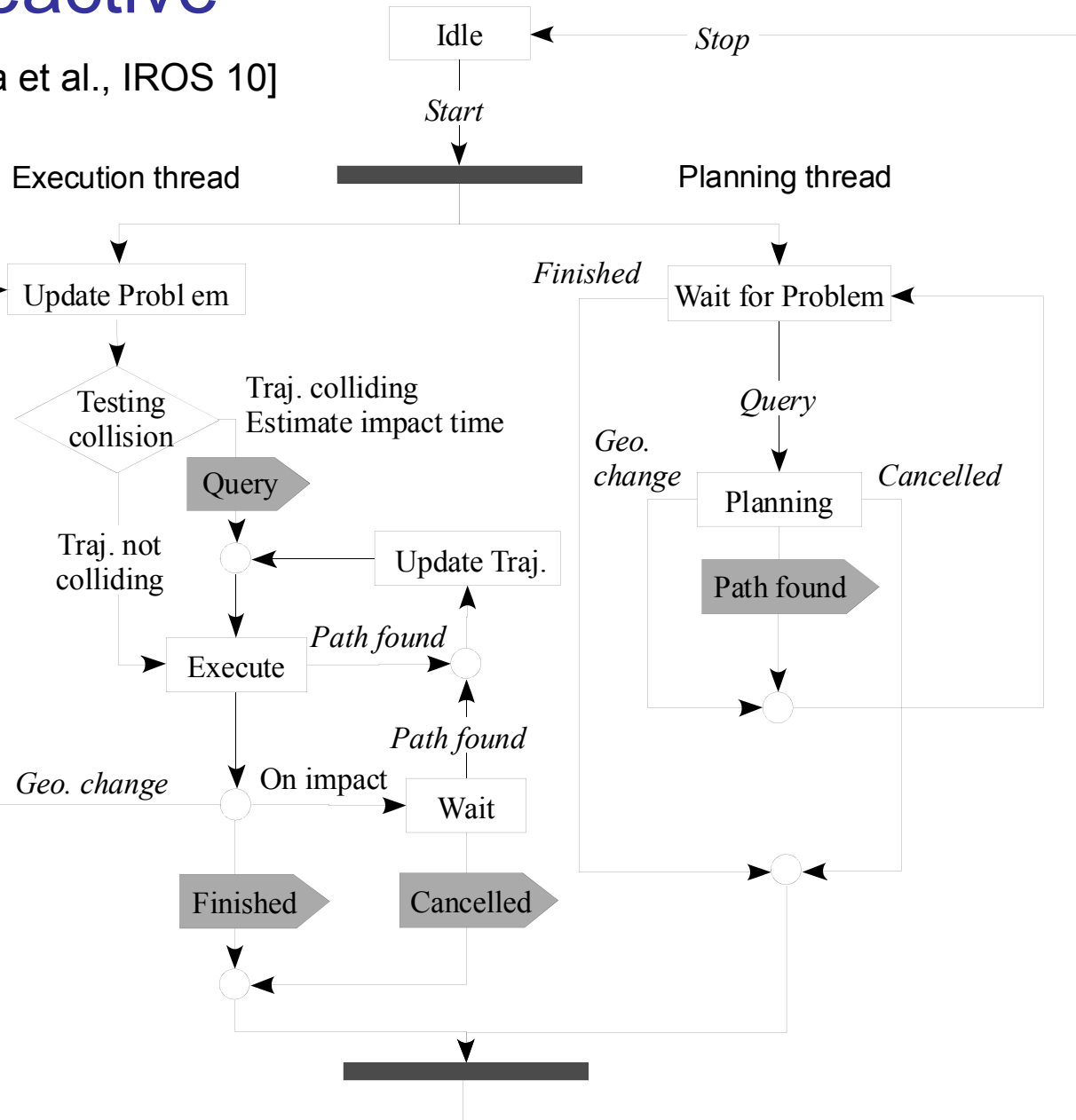
[Yoshida et al., IROS 10]

- Parallel

- Execution
- Planning

- Signals (➡)

- Planning request
- Planning finished

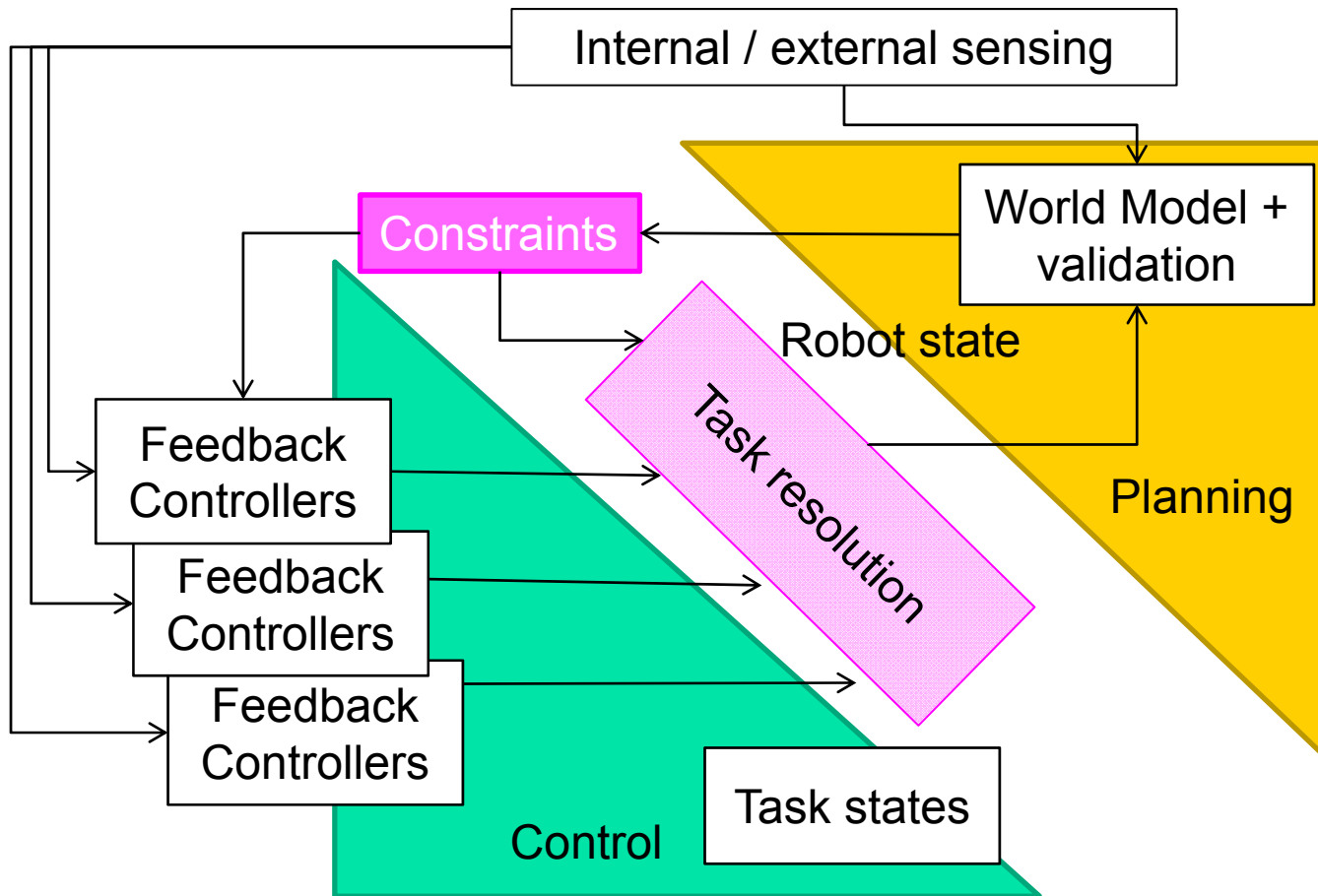


Remaining problem: sensing

- Reactiveness needs updated world model
- Planning
 - Localization
 - Geometric / physical model
- Control
 - Own body dynamics
 - World model as constraints: collision, force
 - Appropriate sensing for different level

Sensing for reactiveness

■ Model level interaction

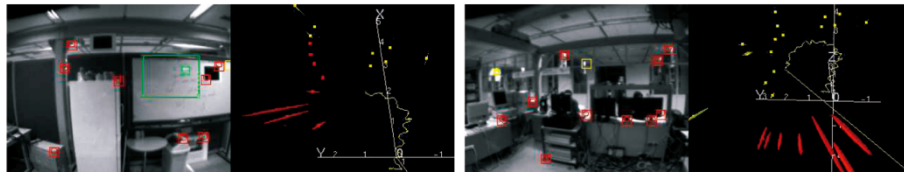


Constraints: world model interpreted with task space: Collision, force...

Need to provide appropriate sensed states to controller / planner...

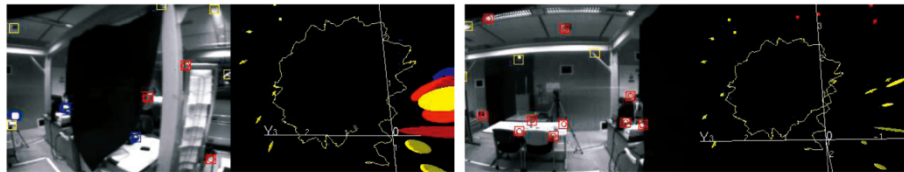
Continuous world model update

- Local update and interpolation
- Sensor fusion
- Virtual/Mixed/Augmented reality
- Human interactions
- Uncertainty



(a)

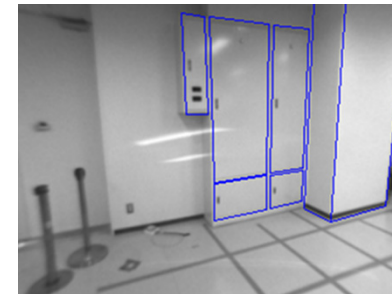
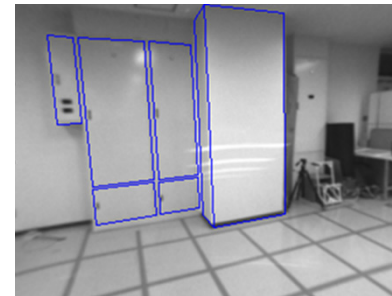
(b)



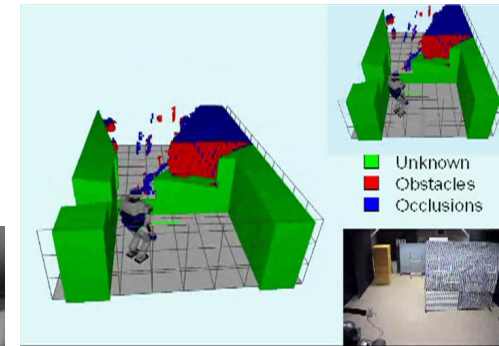
(c)

(d)

[Davison, Stasse, 07]



[Dune et al. 10]



[Saidi et al. 07]



[EC FP7
Robot@CWE]

Perspective

- Extensive controller is a good direction
- There is still something to plan
- They go together with task resolution
- Importance of sensing for reactiveness