On embedded actions for humanoid robots: the status of locomotion.

J.P. Laumond

LAAS-CNRS

The anthropomorphic body structure

- A humanoid robot is both:
- Redundant: 30 dof to grasp
- Underactuaded: the same 30 dof to walk

The anthropomorphic body structure

- A humanoid robot is both:
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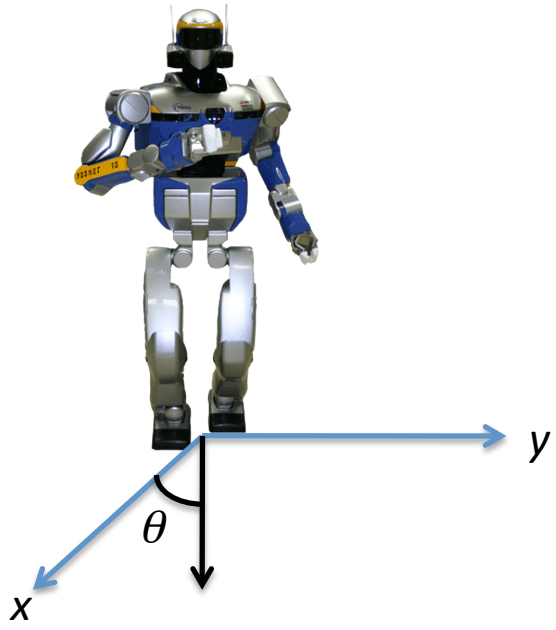
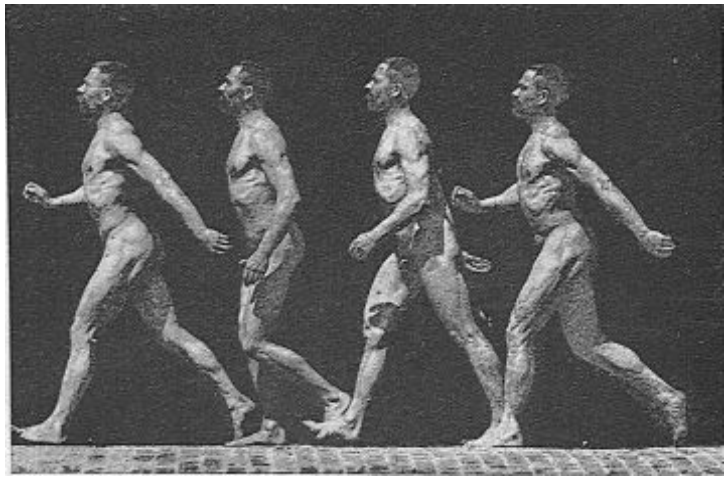
- Underactuaded: the same 30 dof to walk
  (i.e. to control of x, y, θ)
- The robotics perspective:
  Locomotion as a mechanical problem



The embedded action

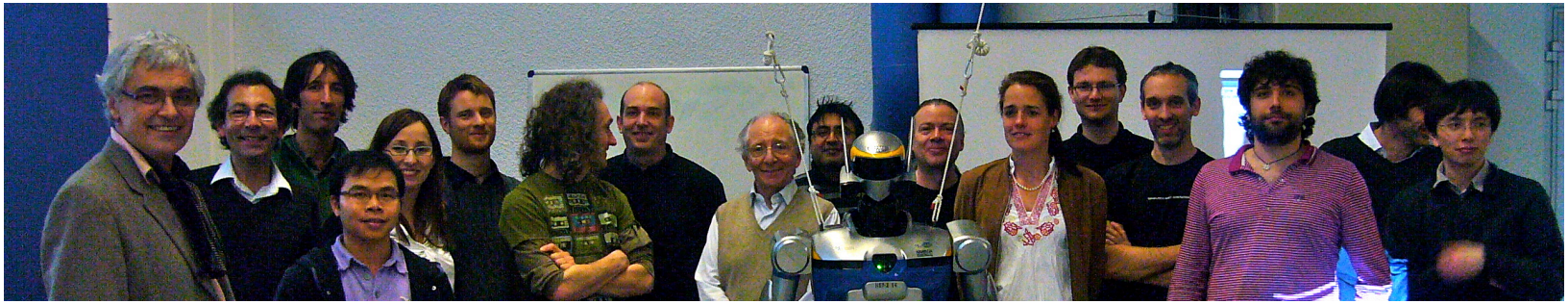
- Action modeling:
- What do you move for?
- What control synergies?
- The life science perspective:
  Locomotion as a cognitive process

- Locanthrope: a French ANR project



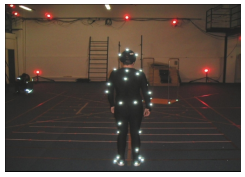
Understand the computational foundations of human locomotion

Locanthrope: a pluridisciplinary perspective



- Robotics (LAAS-CNRS, J.P. Laumond)
- Neurosciences (LPPA, A. Berthoz)
- Computer Graphics (INRIA, J. Pettré)
- Biomechanics (M2S, A. Crétual)

Models



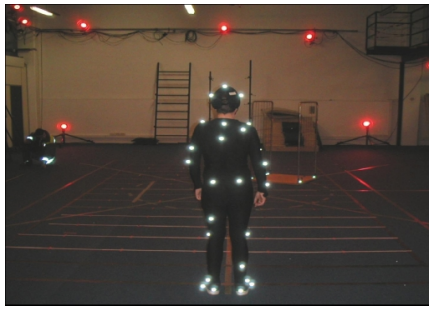
Algorithms

Computer Animation

Human-robot interaction

Humanoid Robotics

Locanthrope



- K. Mombaur, A. Truong , J.P. Laumond
  From human to humanoid locomotion:
  an inverse optimal control approach,
  Autonomous Robots, Vol. 28, 3, 2010.


- M. Sreenivasa, P. Souères, J.P. Laumond
  On using human movement invariants to generate
  target-driven anthropomorphic locomotion,
  IEEE/RAS-EMBS BioROb, 2010.

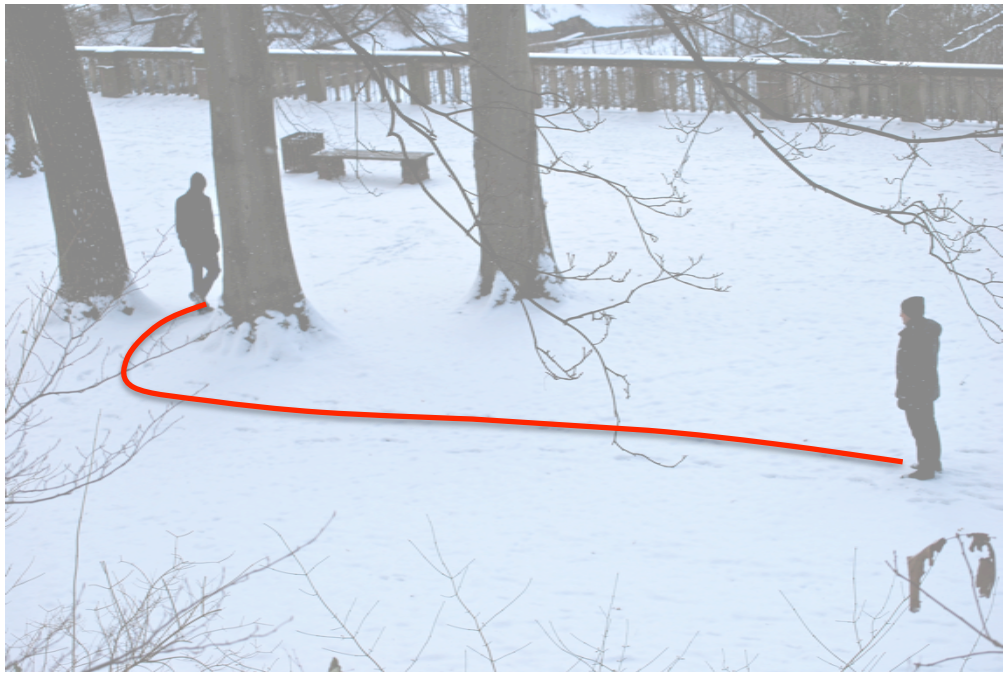
(Best Paper Award)


- O. Kanoun, E. Yoshida, J.P. Laumond
  An optimization formulation for footsteps planning,
  IEEE RAS Humanoids, 2009 *(to appear in IJRR)*


On the shape of locomotor paths

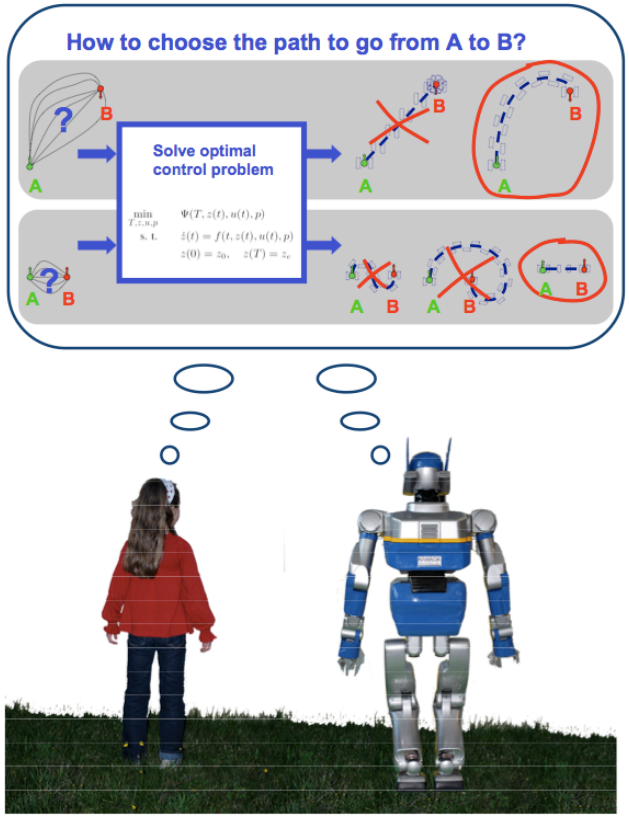
Heidelberg, Dec. 1st, 2010

On the shape of locomotor paths



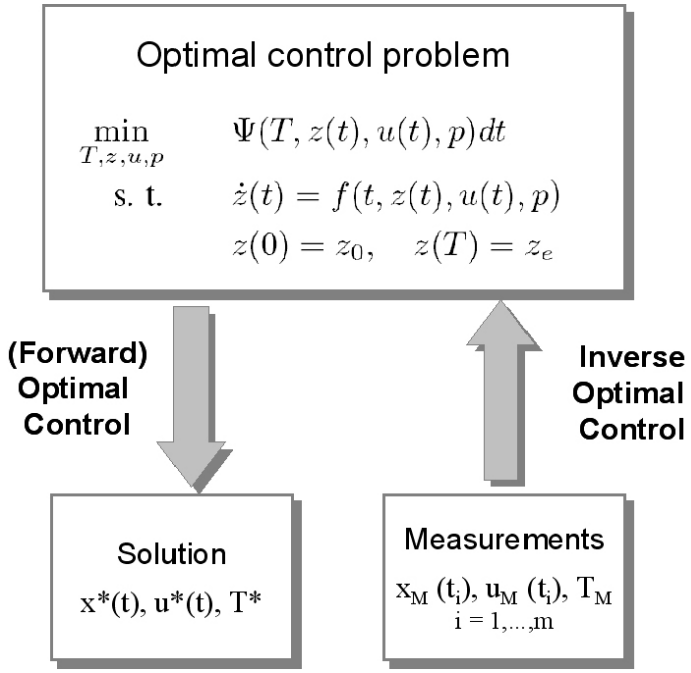
Heidelberg, Dec. 1st, 2010

- An inverse optimal control problem



K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

An inverse optimal control problem



K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

On the shape of locomotor paths

- An inverse optimal control problem

- Observation
- Control model
- Cost function basis

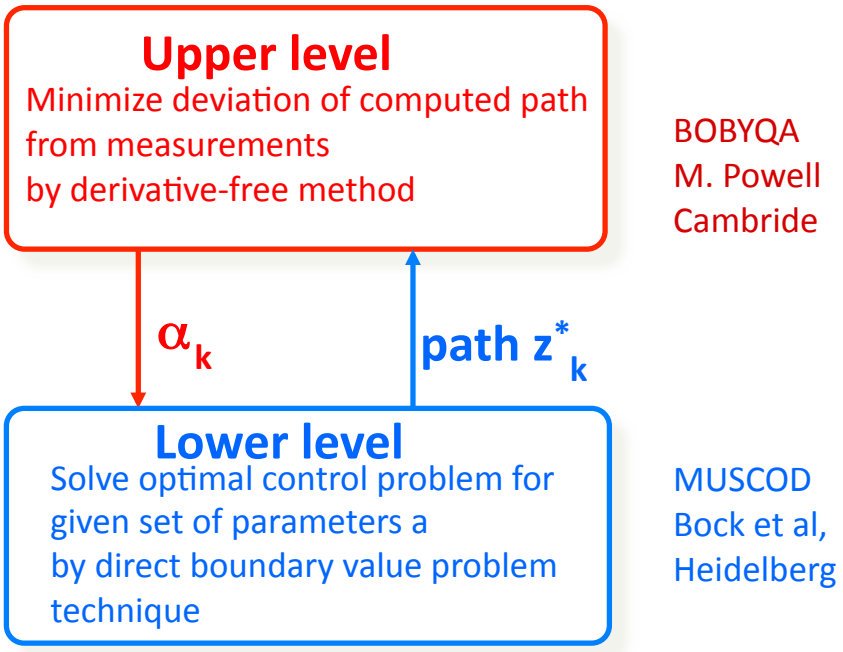
K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

An inverse optimal control problem

$$
\begin{aligned}
\dot{x} &= cos\phi\, v_{tan} - \sin\phi\, v_{orth} \\
\dot{y} &= sin\phi\, v_{tan} + \cos\phi\, v_{orth} \\
\dot{\phi} &= \omega \\
\dot{v}_{tan} &= u_1 \\
\dot{\omega} &= u_2 \\
\dot{v}_{orth} &= u_3
\end{aligned}
$$

$$
\int_0^T [\alpha_0 + \alpha_1 u_1(t)^2 + \alpha_2 u_2(t)^2 + \alpha_3 u_3(t)^2 + \alpha_4 \Psi(z(t), z_e)^2] dt
$$

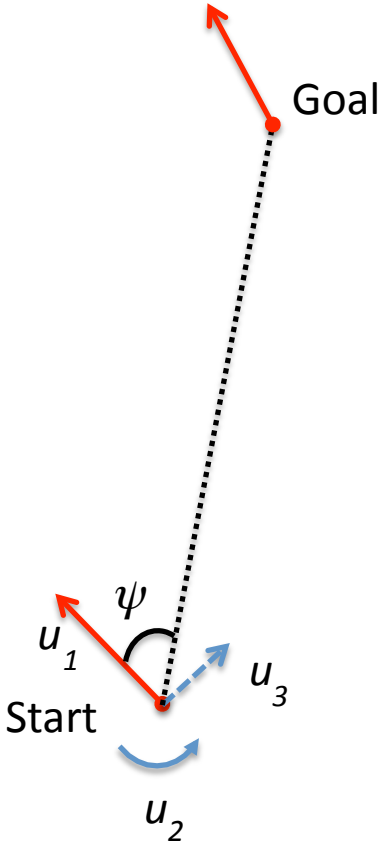
- Observation
- Control model
- Cost function basis α_k



- Numerical optimization algorithm

K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

- The locomotor paths minimize:



$$\Phi(T, x(t), u(t), p)$$
$$= T + 1.2\int_0^T u_1^2 dt + 1.7\int_0^T u_2^2 dt + 0.7\int_0^T u_3^2 dt$$
$$+ 5.2\int_0^T \Psi(z(t), z_e)^2 dt$$

K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

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K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

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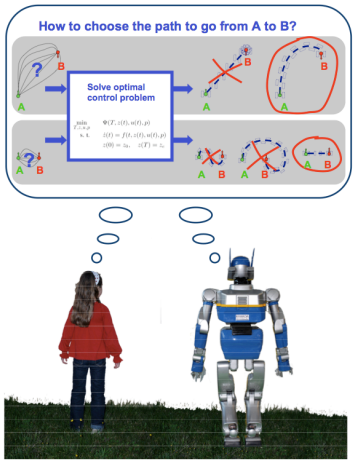
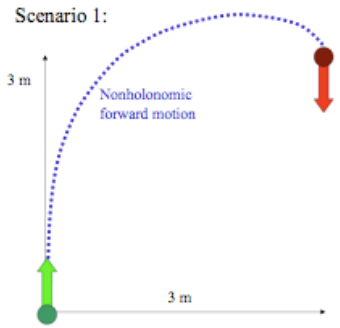
Interpretation

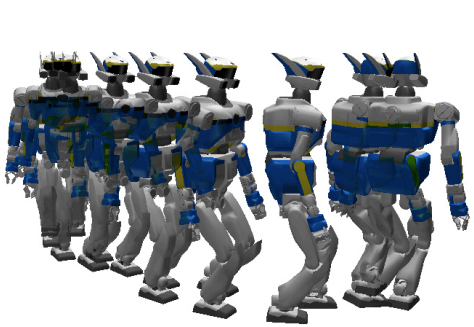
- 0.7 << 1.2 : Prefer the ***nonholonomic behavior***
- Minimize the bearing angle ψ : ***see the goal asap !***

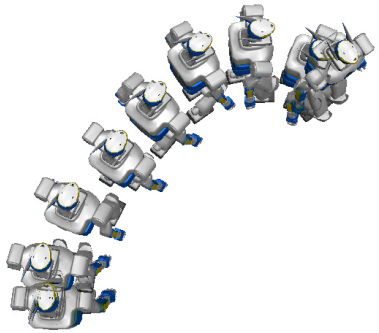
K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

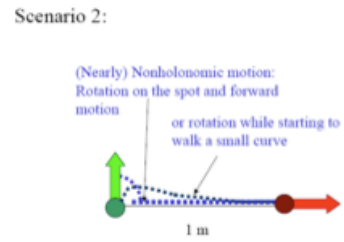
A unified control

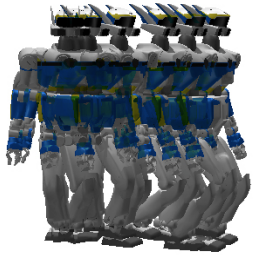


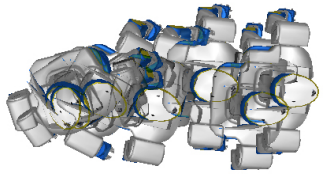


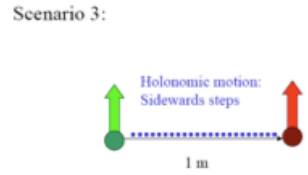


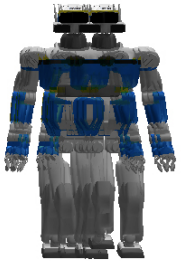


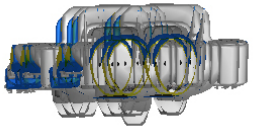








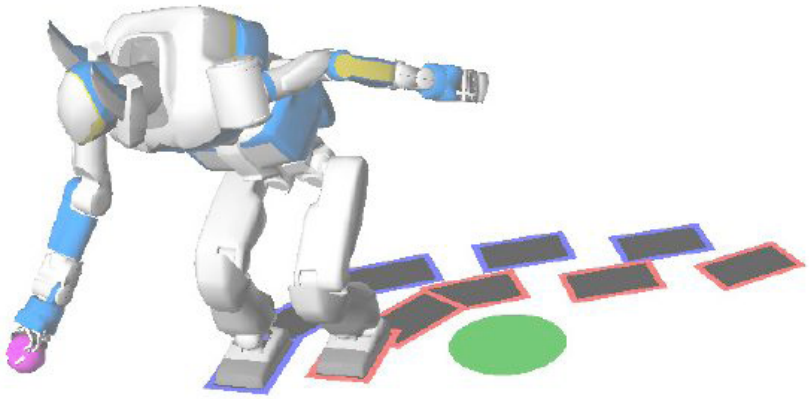




K. Mombaur, A. Truong , J.P. Laumond, *Autonomous Robots, Vol. 28, 3, 2010.*

Walking to grasp

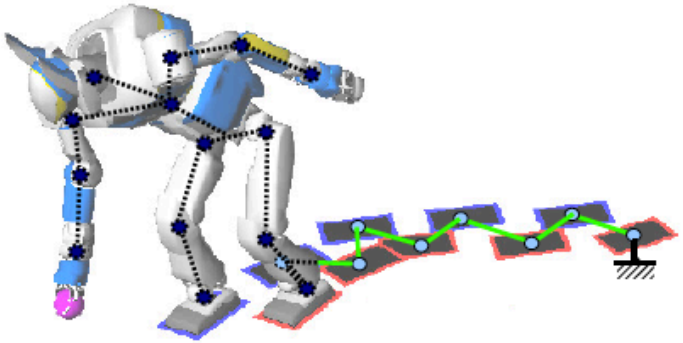
- How to fuse [walk to] and [grasp]?

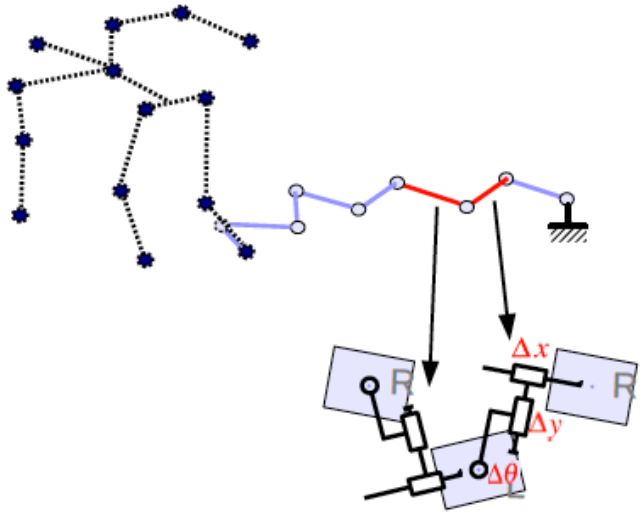


Whole body grasping and stepping

Walking to grasp

- Modeling underactuaction with virtual redundancy





virtual manipulator = robot kinematic tree + virtual kinematic chain of footprints

Whole body grasping and stepping

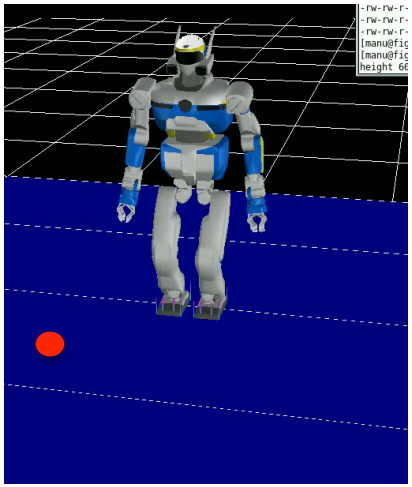
O. Kanoun, E. Yoshida, J.P. Laumond, IEEE RAS Humanoids 2009, to appear in IJRR

Walking to grasp

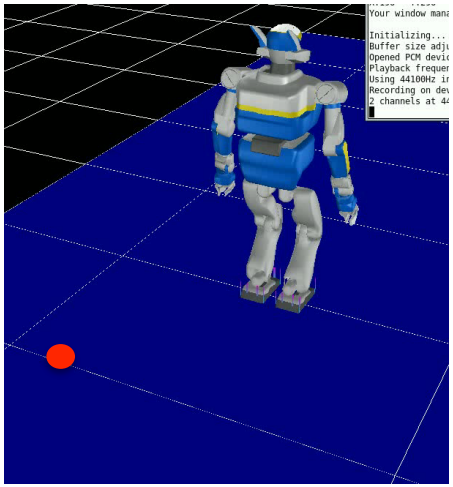
- Modeling underactuaction with virtual redundancy

O. Kanoun, E. Yoshida, J.P. Laumond, IEEE RAS Humanoids 2009, to appear in IJRR

- Walking to grasp



Grasp in front

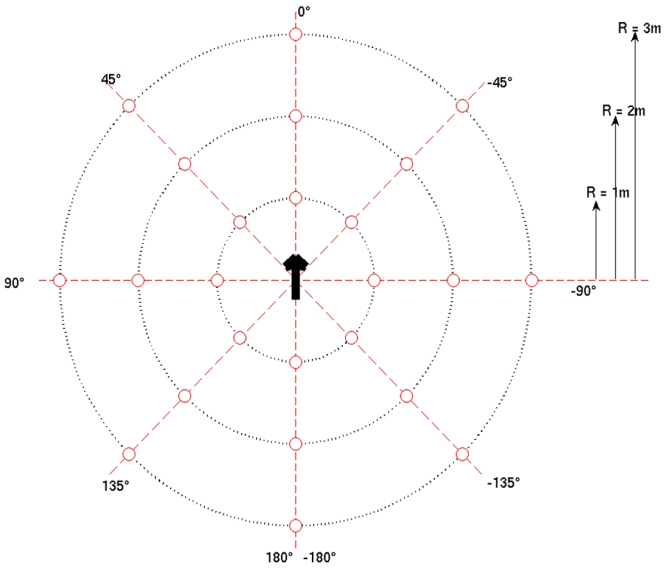


Grasp behind

Whole body grasping and stepping:
the limits of numerical optimization.

Walking to grasp

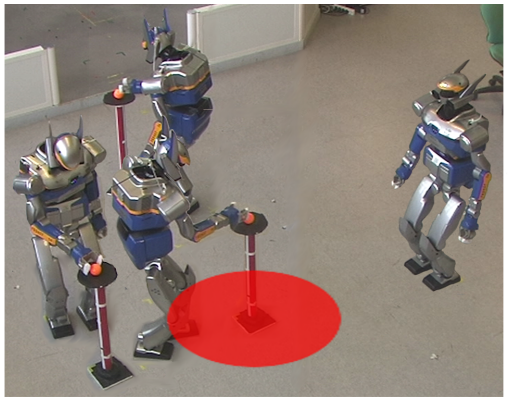
14 participants
(8 male, 6 female)

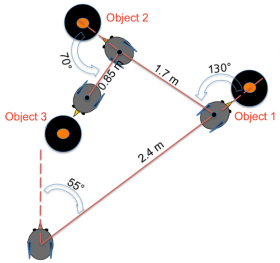


Looking at human motion invariants

M. Sreenivasa, P. Souères, J.P. Laumond, IEEE BioRob 2010 *(Best Conference Paper)*

- Walking to grasp

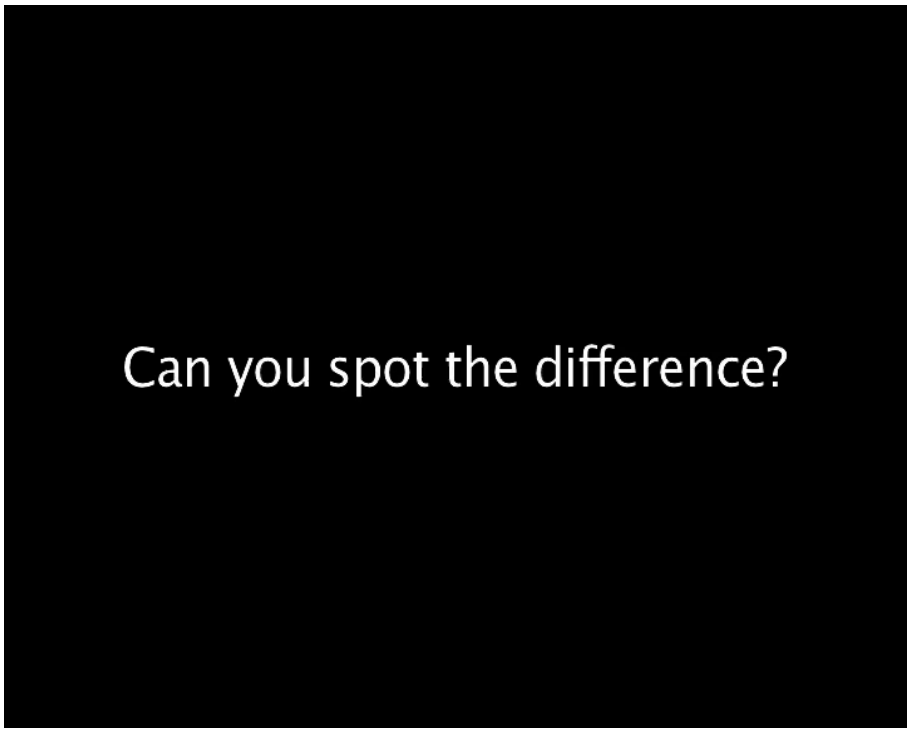




M. Sreenivasa, P. Souères, J.P. Laumond, IEEE BioRob 2010 *(Best Conference Paper)*

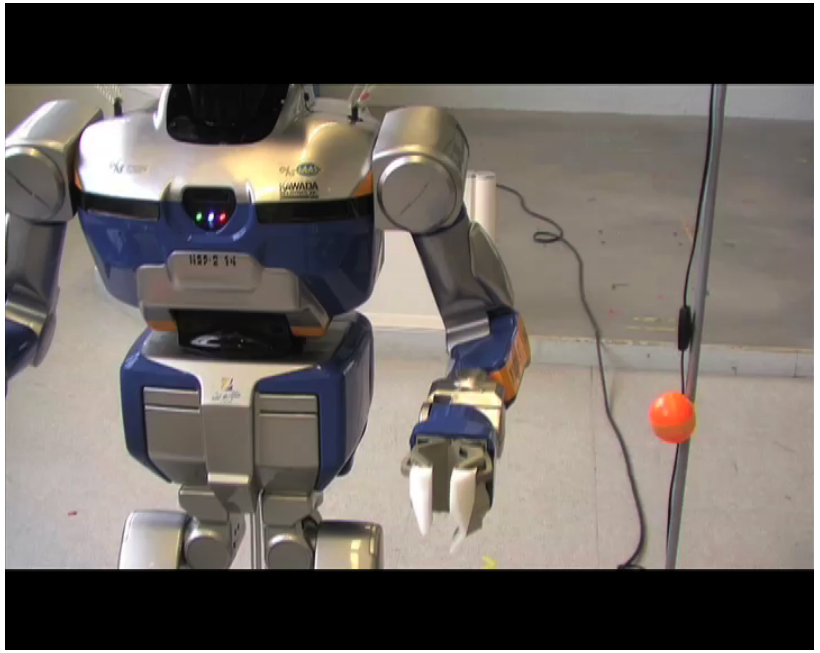
- Action recognition

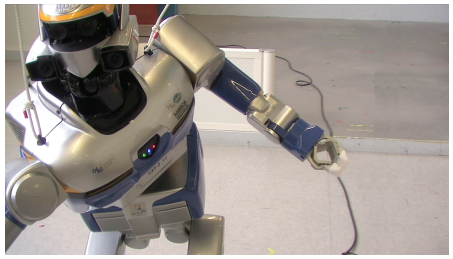
Action recognition

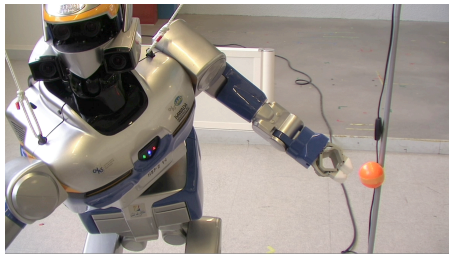


S. Hak, N. Mansard, O. Stasse, IEEE RAS Humanoids, 2010

Action recognition







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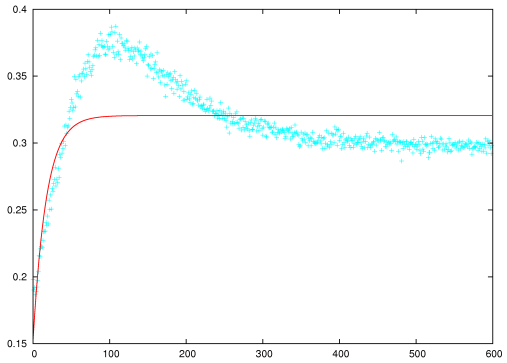
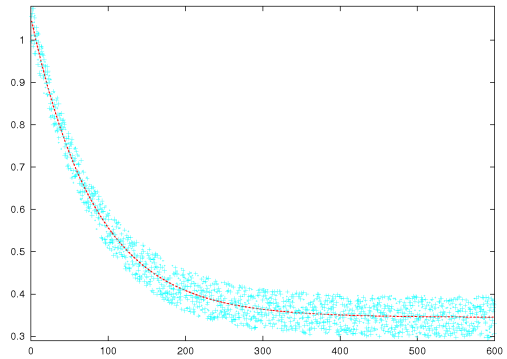
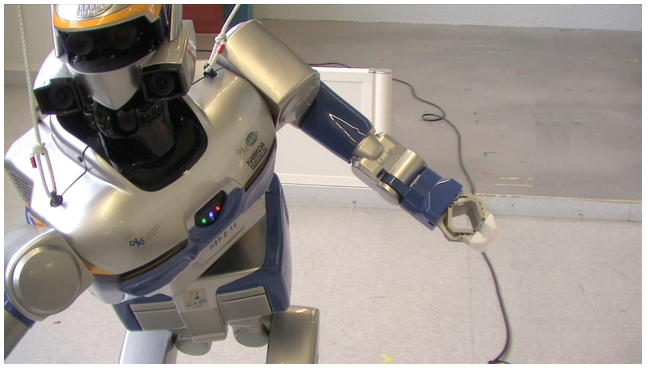
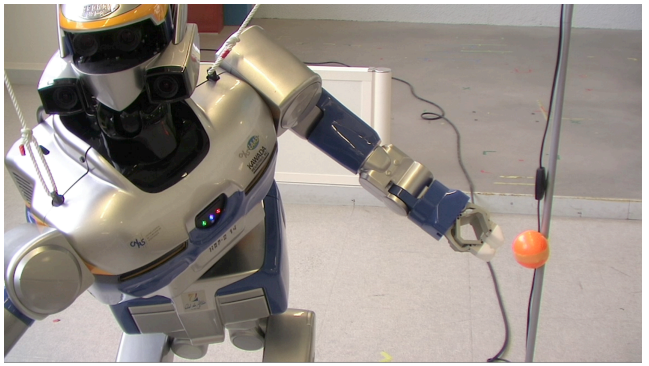
Action recognition









S. Hak, N. Mansard, O. Stasse, IEEE RAS Humanoids, 2010

Conclusion

Conclusion

- A need of a pluridisciplinary research

  - Robotics
  - Neurosciences
  - Mathematics

- The Romeo Project
- 30 SMEs, 12 laboratories

ALDEBARAN Robotics

PROJET ROMEO