Imitation System for a Social Robot: Testing the quality of the HMC system

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Project Goals

Platform

Visual Perception System

Dynamic joint control

Testing the quality of the HMC

Behaviour-based control

Project Goal

- Develop a **social robot**, that

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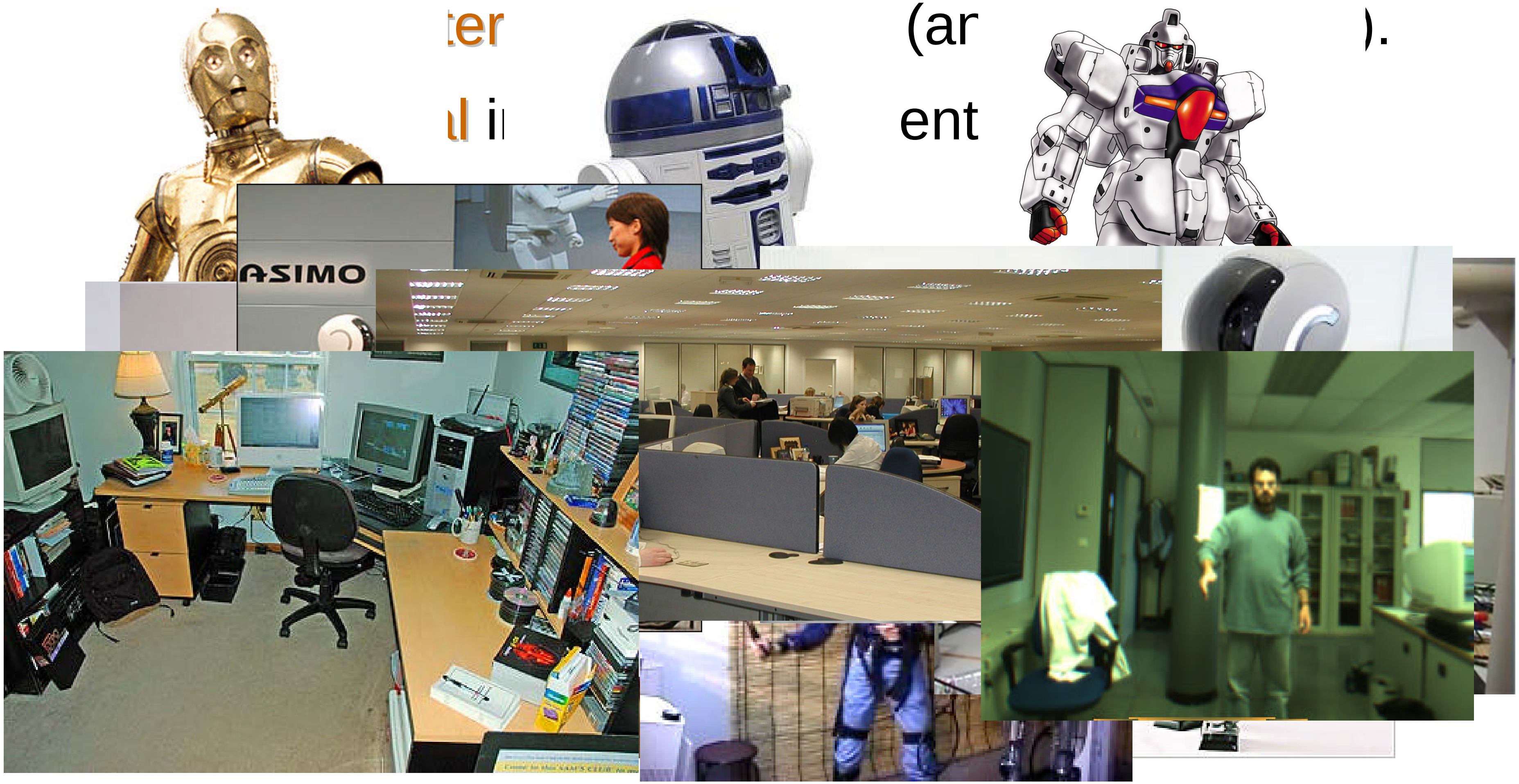
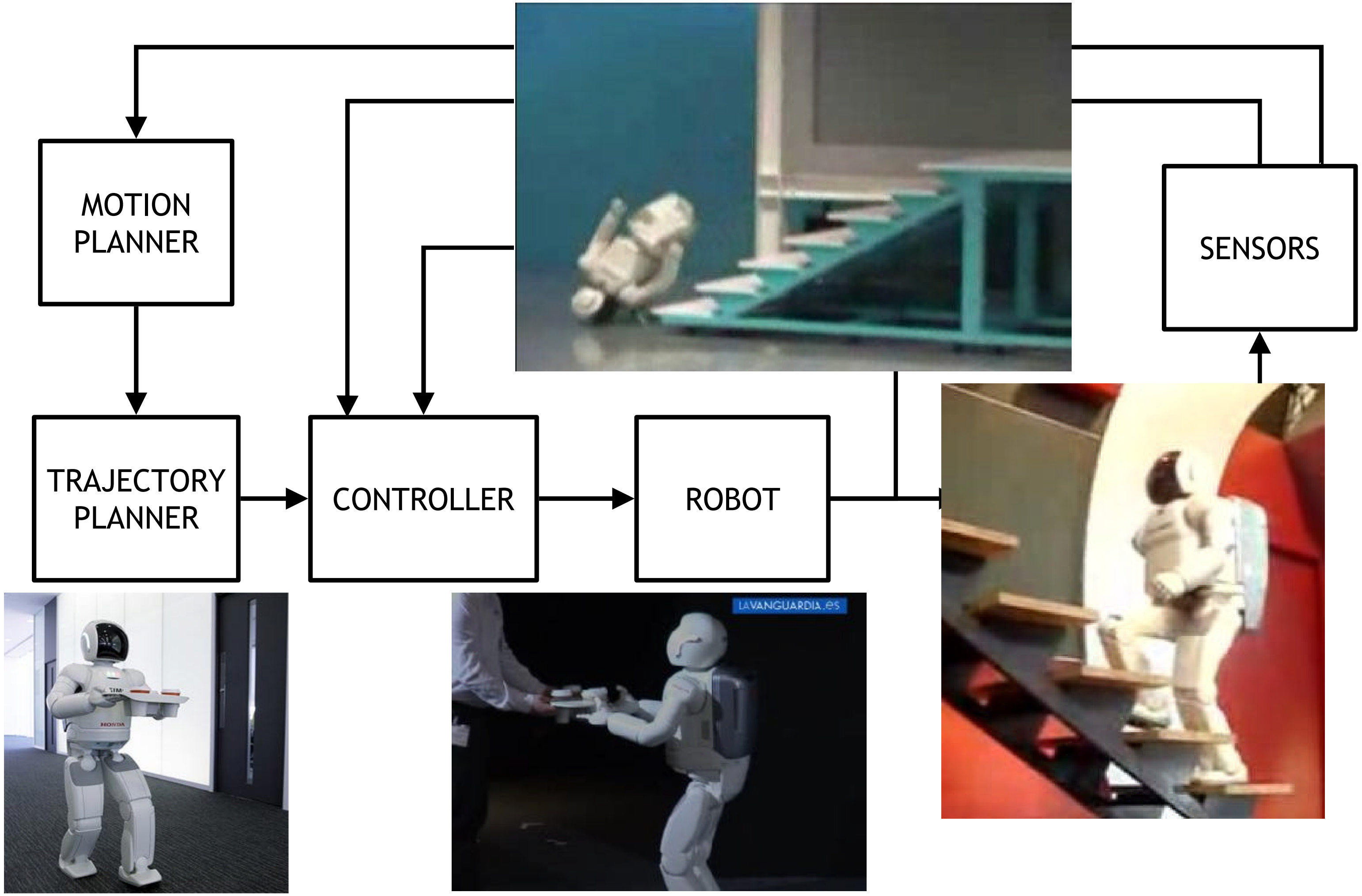
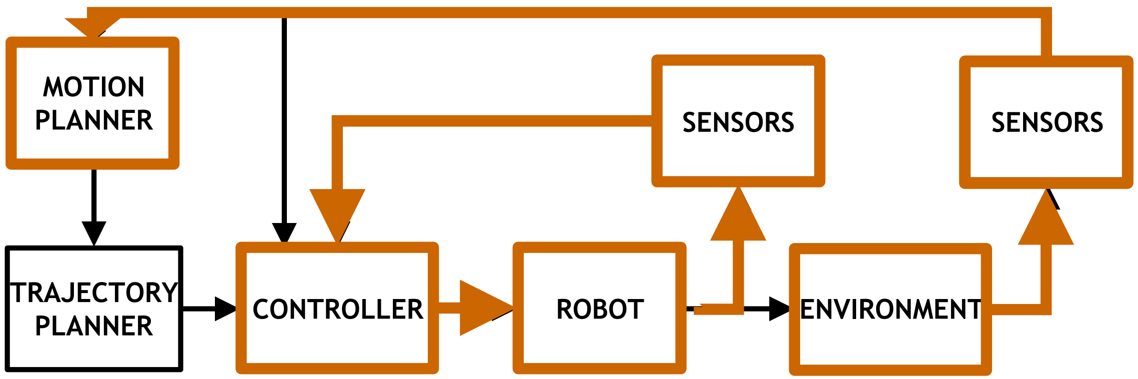


Project Goals



Project Goals



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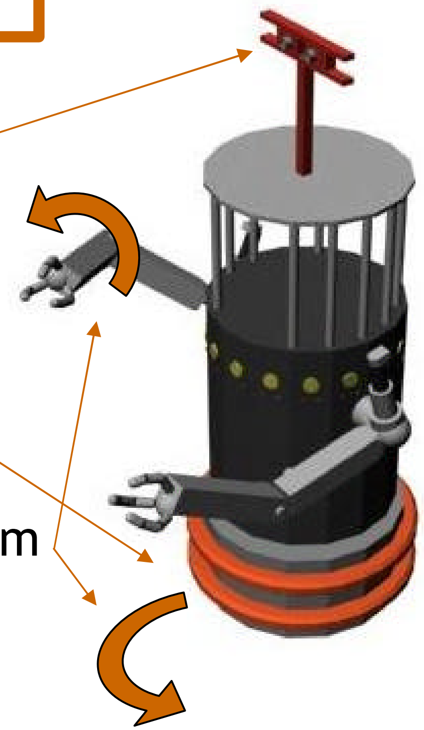
A. Visual perception system

B. Dynamic joint control

C. Behaviour-based control system



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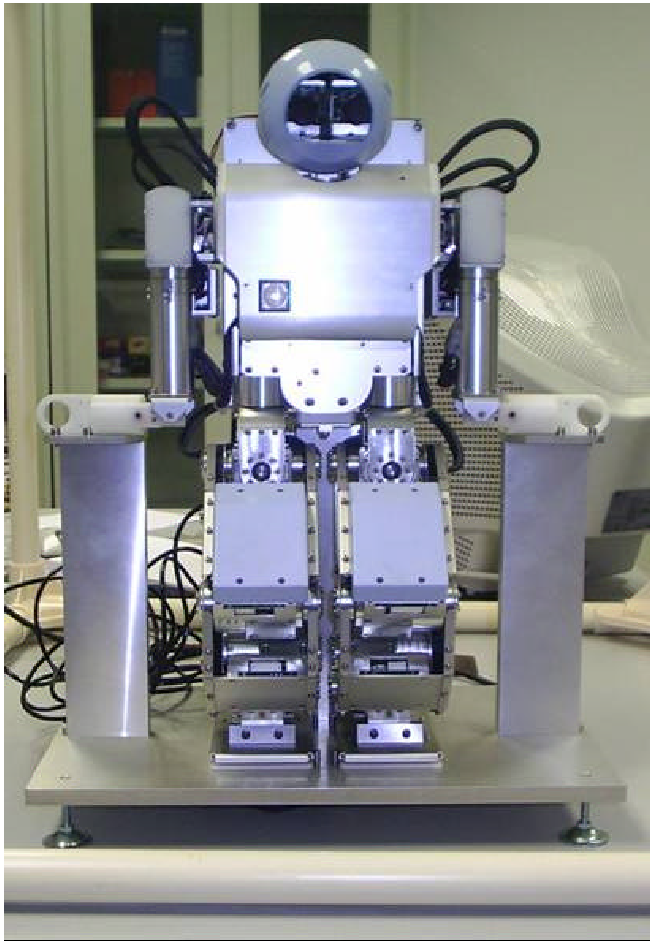
- Project Goals
- Platform
- Visual Perception System
- Dynamic joint control
- Testing the quality of the HMC
- Behaviour-based control

First iteration

- We wanted to ‘close a first loop’ to get familiar with Dynamic joint control, Social Robotics, and Learning by Demonstration problems.
- Platform used: HOAP-1 robot
    - 20 degrees of freedom.
    - 6 kg, 48 cm tall.
    - Four pressure sensors in each foot.
    - Accelerometer, gyro.
    - Stereo cameras.

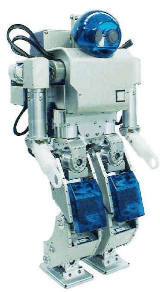


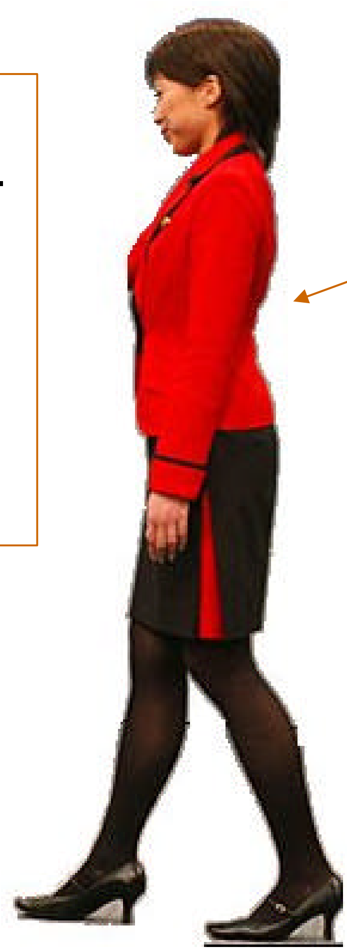
First iteration

- There is a main problem in the use of HOAP-1 as a social robot…

Size: 48 cm.
Stereo baseline:28 mm.
Walking speed some meters per hour.
Very constrained arm movements.
and…
No neck to look up

Human size: 165 cm.
Eye separation ~100 mm.
Walking pace ~ 5 kmh (3 mph)





HOAP-1 wasn't designed as a social robot!

Second iteration

- The second iteration involves the use of a different robot

Size ~ 155 cm.
Baseline ~100 mm.
Speed ~ 5 kmh (3 mph)

Human size: 165 cm.
Eye separation ~100 mm.
Walking pace ~ 5 kmh (3 mph)

New robot. The Nomad

- It is still under construction. Progress so far:

The head (Biclops).
Pan, tilt, vergence HW
PID controllers.

Another ‘head’ (Videre).
Static parallel cameras.

The body (Nomad 200).
Good wheeled locomotion.
Bumpers, sonars, infrared sensors.

One arm.
4 DOF.

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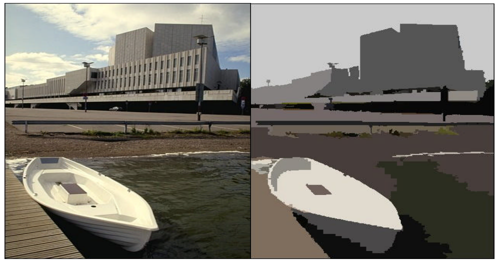
Visual Perception System: Hardware

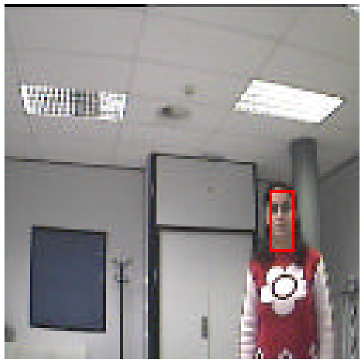
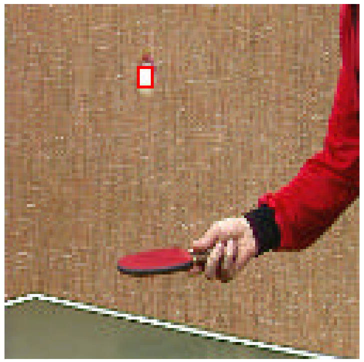
- Small Vision System (www.videredesign.com)
- Baseline: 10,7 cm.
- It can perceive the upper-body movements of a human at about 1,80 meters (natural interaction distance).

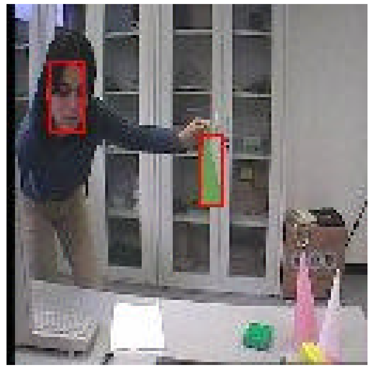
Visual Perception System: Low level

- Segmentation

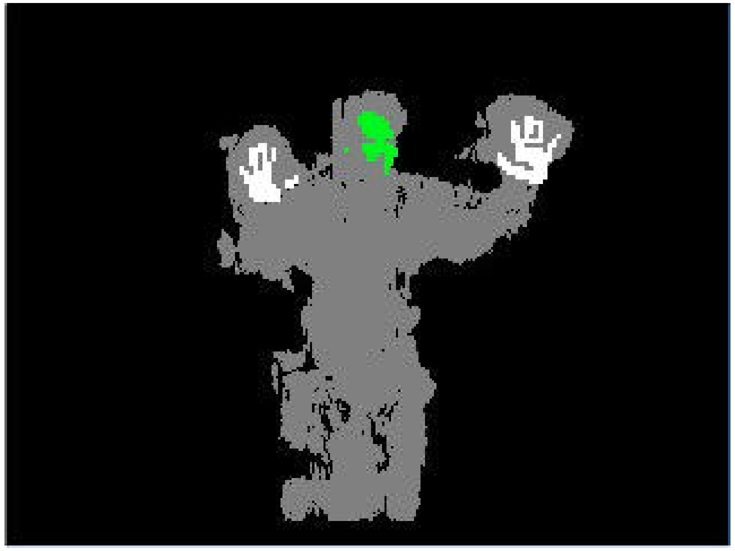
- Attentional mechanism
- Regions of interest (ROIs) tracking

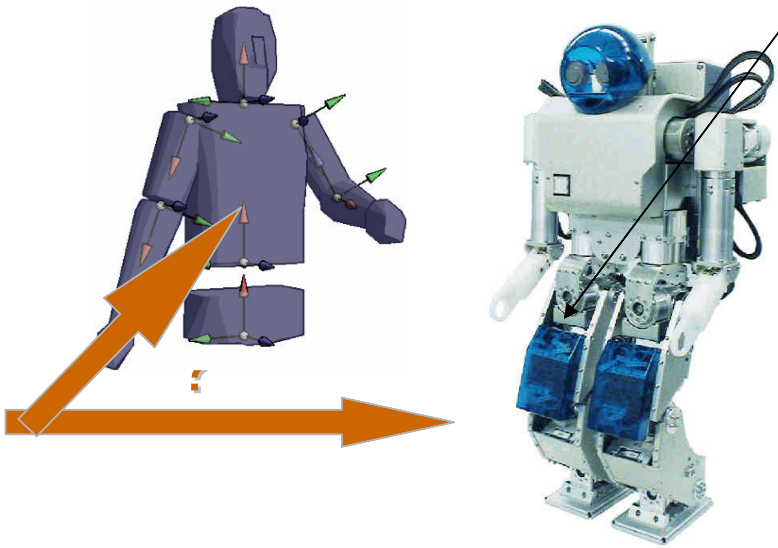



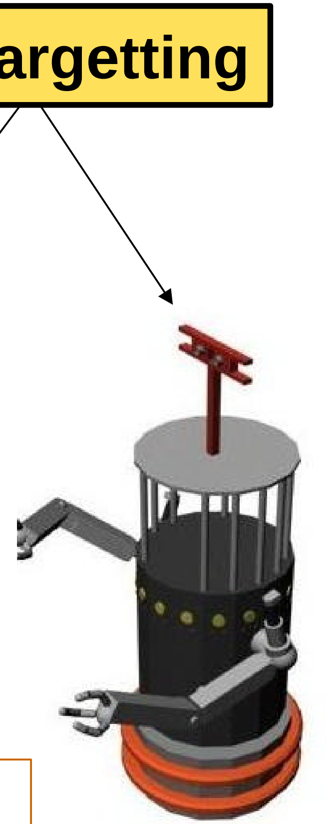


Visual Perception System: High level

- Person detection







- Model-based Human Motion Tracking
- Objects not involved

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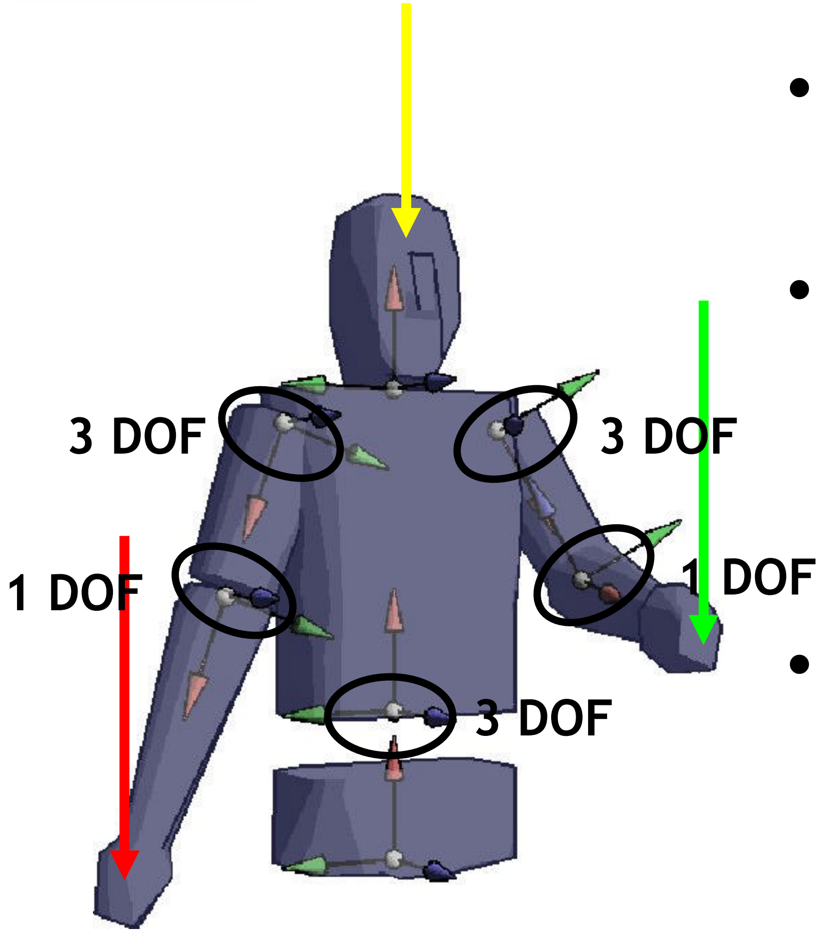
Dynamic joint control: IK

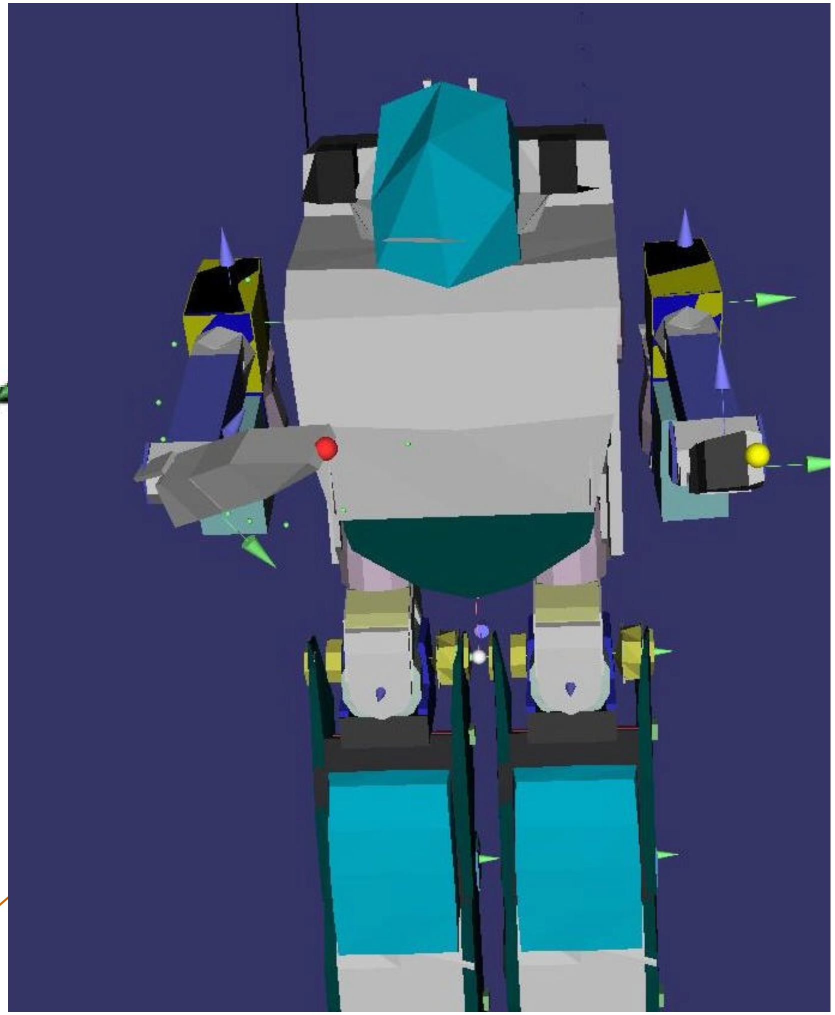


- Upper-body 3D human model with reduced DOF skeleton.
- Head and arms are ‘puppetered’ by recovered 3D positions of hand and face centroids.
- An analytic IK method [3] is used for fast computation of a feasible elbow position.

[3] J.R. Mitchelson, *Multiple-Camera Studio Methods for Automated Measurement of Human Motion*, Ph.D. dissertation, CVSSP, School of Electronics and Physical Sciences, Univ. of Surrey, UK, 2003.

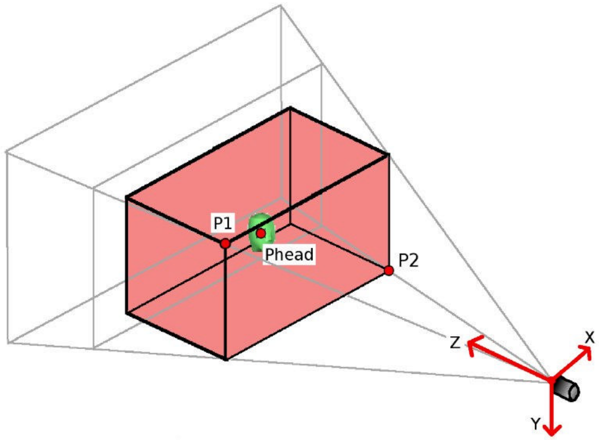
Dynamic joint control: Improving IK

- **Recovery:**
  - Once the system detects an incorrect joint angle or a collision it can:
    - Inform the user.
    - Return to the last valid pose.
    - Find an alternative pose.
  - Alternative poses will have the same hands positions, but different elbows positions.
  - Alternatives follow an exponential distribution around current position.
  - The system chooses the nearest valid alternative.



Dynamic joint control (for Human Model)

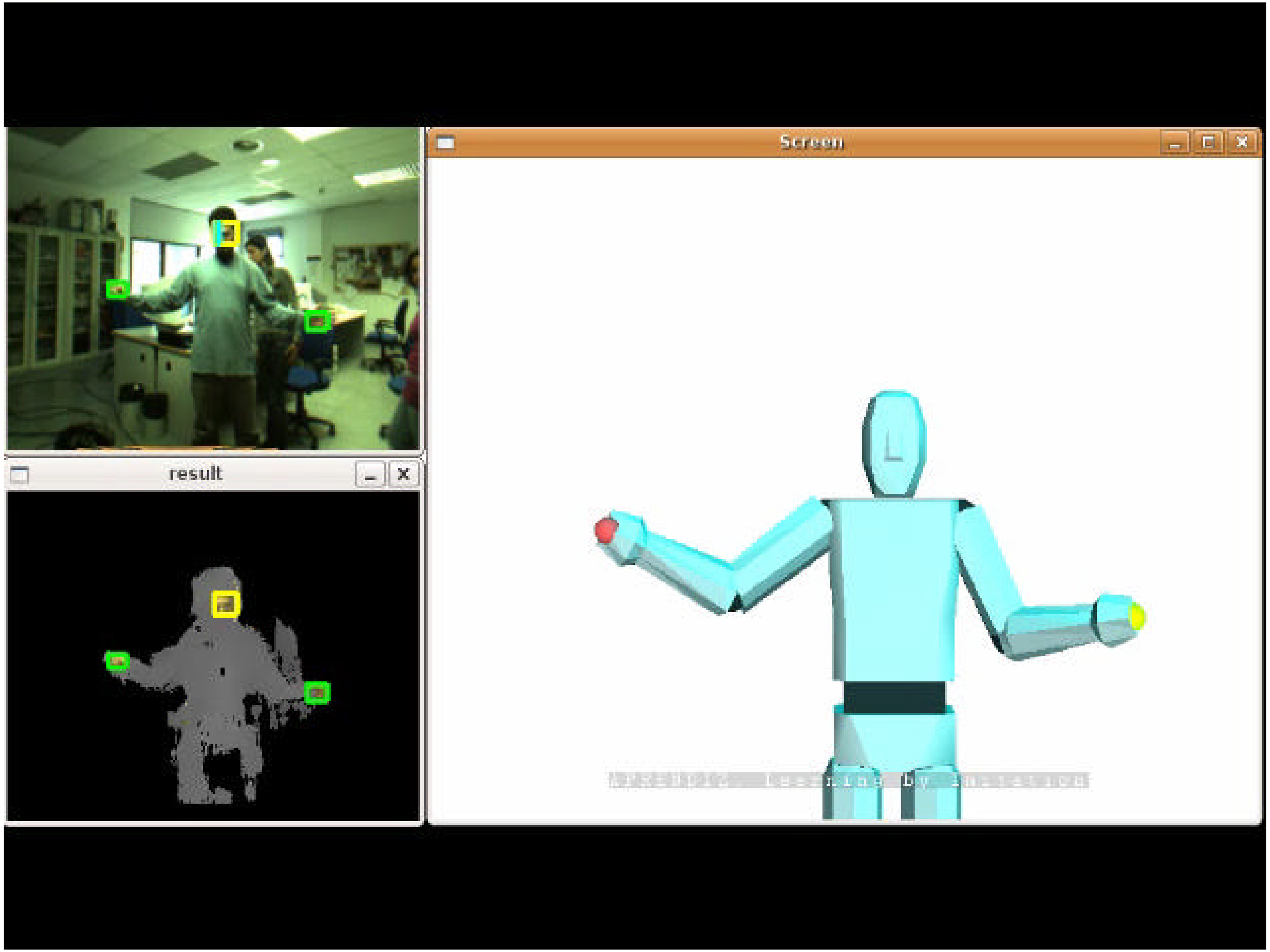
- Height adjustment: $ratio = \frac{height_{human}}{height_{model}}$
- We also added FIR filters (~ Gaussian) to smooth perceived trajectories
- Shoulder pose estimator:



✍ We use **EMD algorithm** to fit the disparity information inside the search cube with learned shoulder poses.

- Arm poses are generated using the same IK algorithm described before.

Model-based Human Motion Tracking



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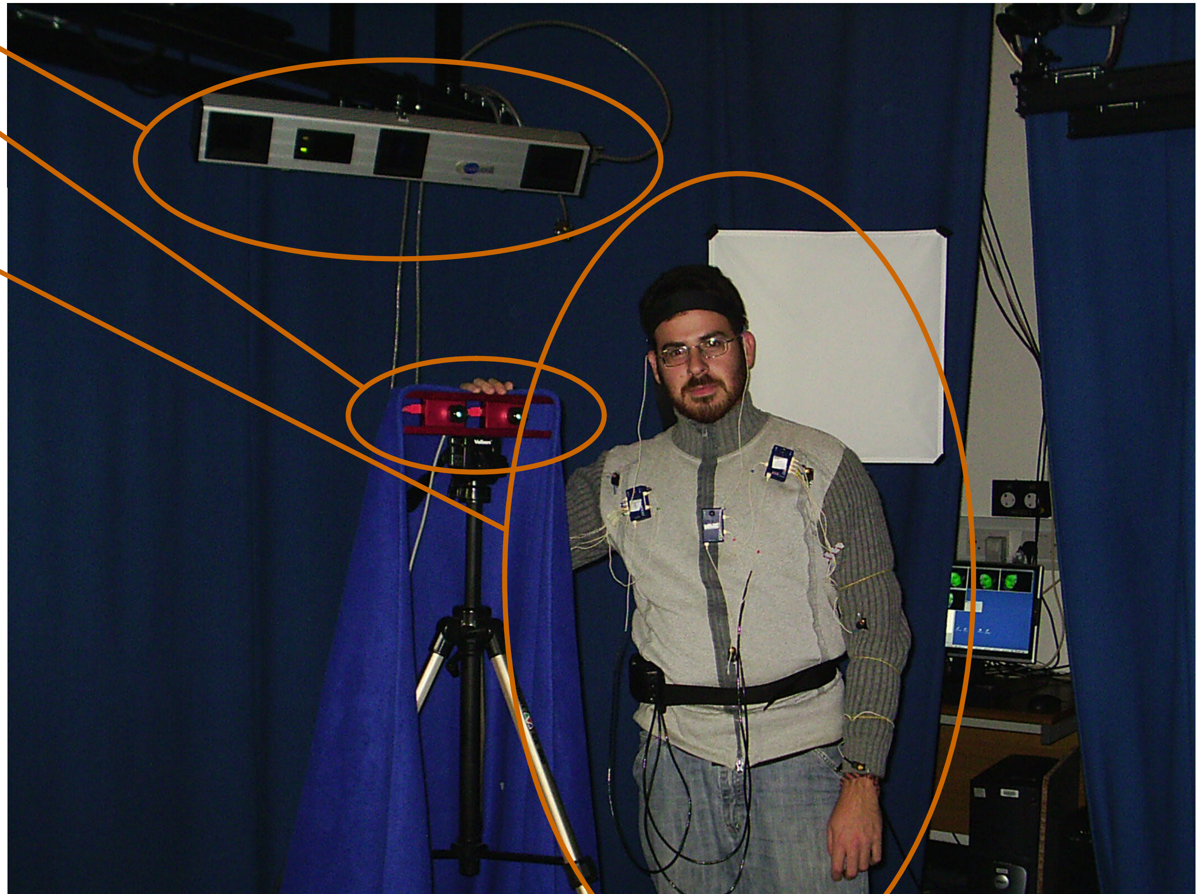
Setup

To provide a **quantitative evaluation** of our stereo based HMC system, we compare its results with a **ground truth** obtained using a CODAMotion motion capture system provided by the Centre for Vision, Speech and Signal Processing (**CVSSP**), at University of Surrey.

One of the CODA units

The stereo vision system

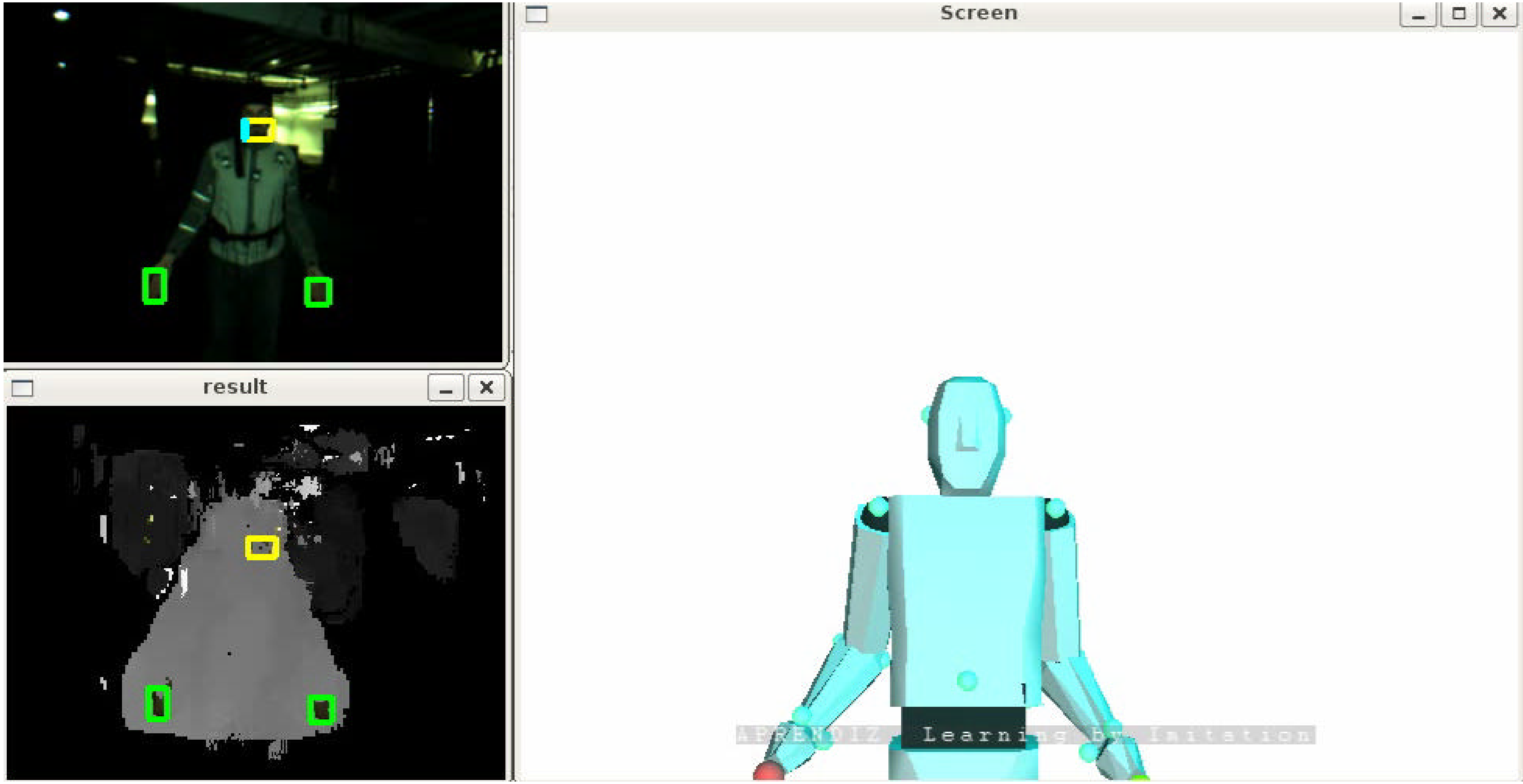
The performer



13 markers

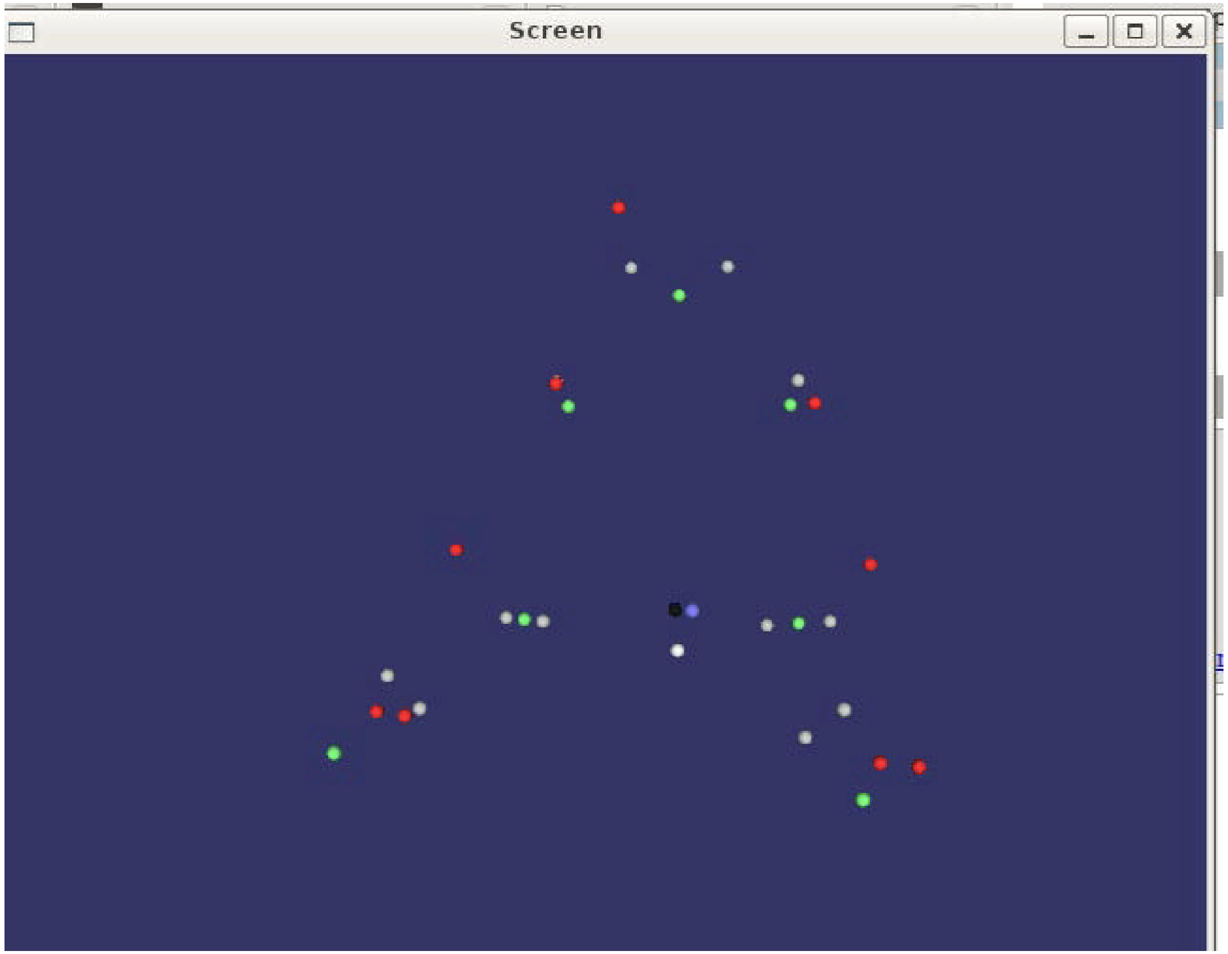
www.codamotion.com

Testing the quality of the HMC



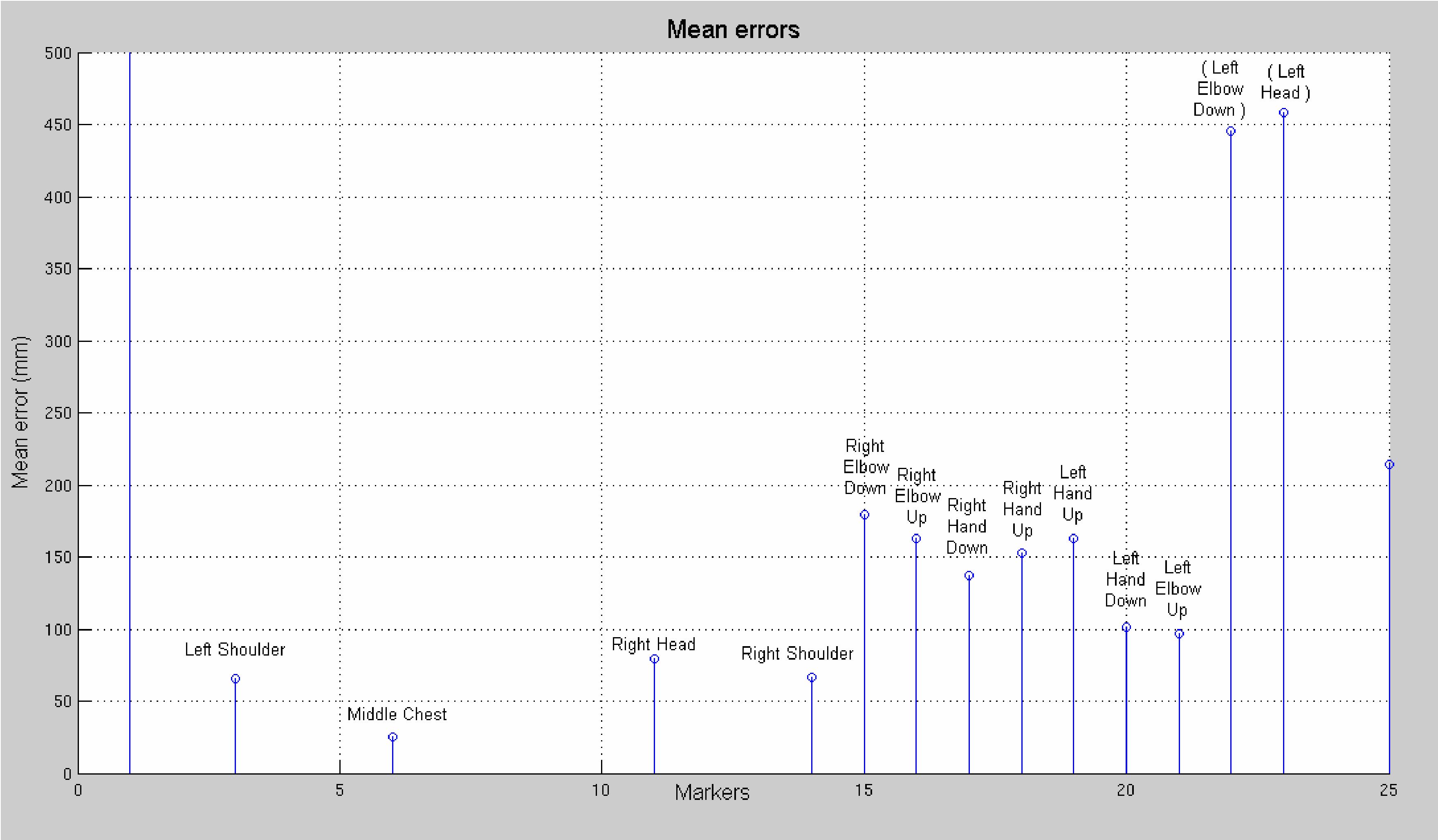
Testing the quality of the HMC

CODA markers
red dots.
3D model virtual markers
grey dots.
3D model joint positions
green dots.

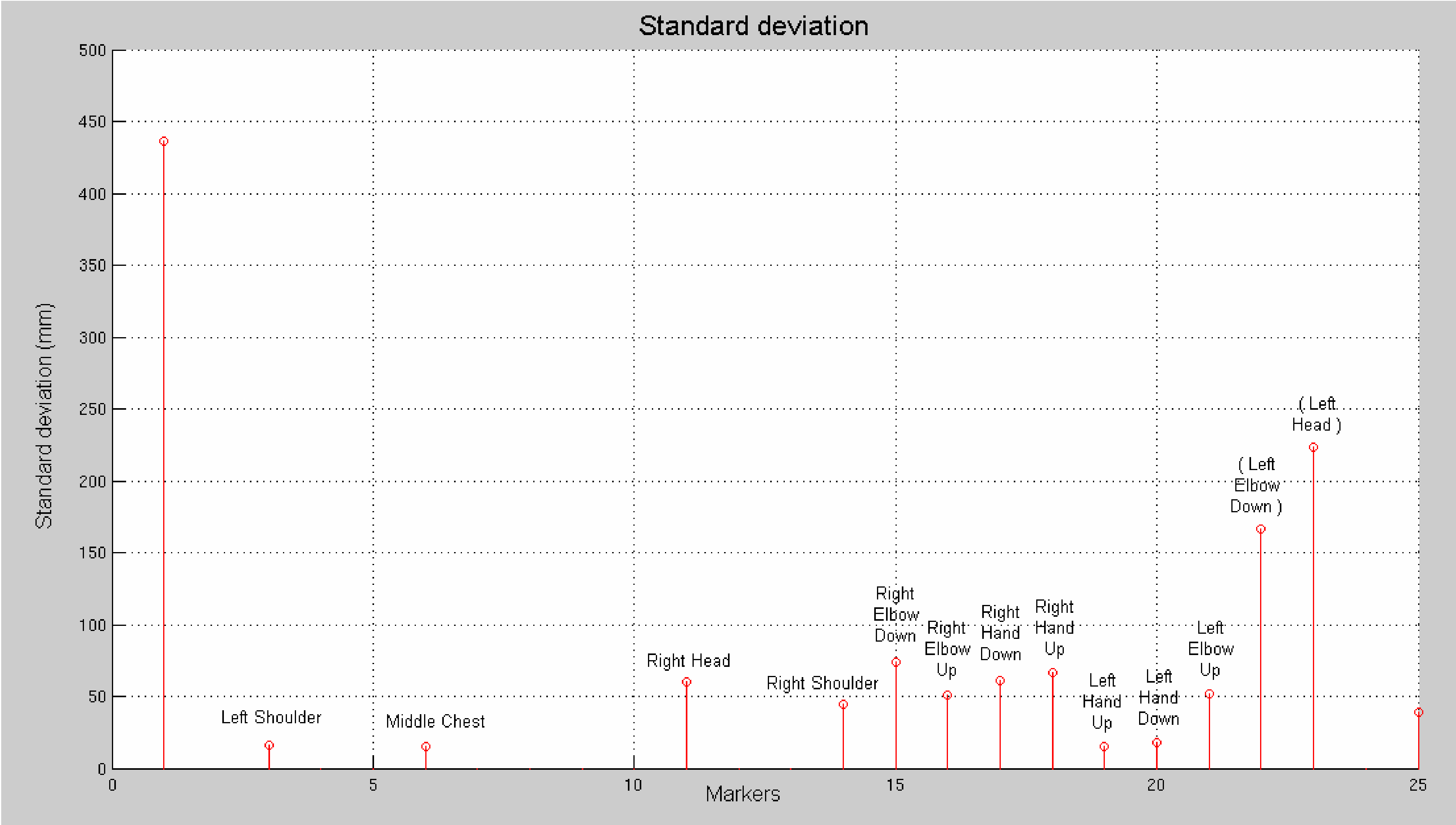


- Medium error is about **9 centimeters**.

Testing the quality of the HMC



Testing the quality of the HMC



Testing the quality of the HMC

Marker	Left Shoulder	Left Elbow	Left Hand
Error (cm)	5.74	12.53	11.51
Marker	Right Shoulder	Right Elbow	Right Hand
Error (cm)	6.72	12.41	11.47
Marker	Left Head	Abdomen	Right Head
Error (cm)	7.03	7.76	6.51

TABLE I

MEAN TRACKING ERRORS AVERAGED OVER 5300 FRAMES

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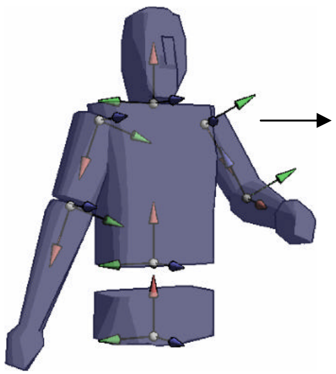
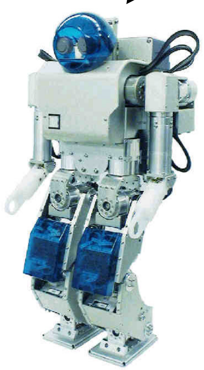
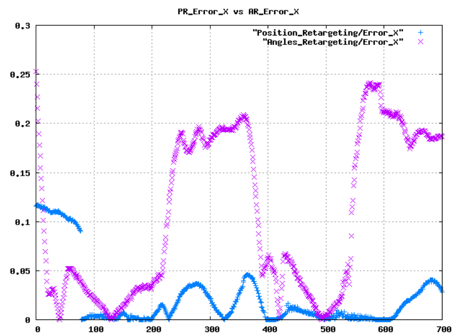
Behaviour-based Control: Imitation

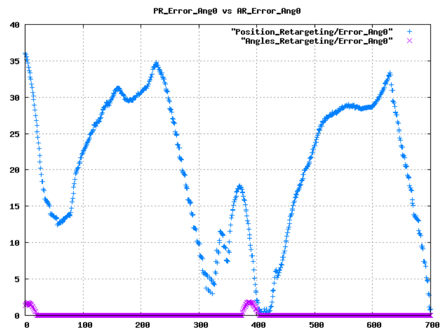


Retargetting

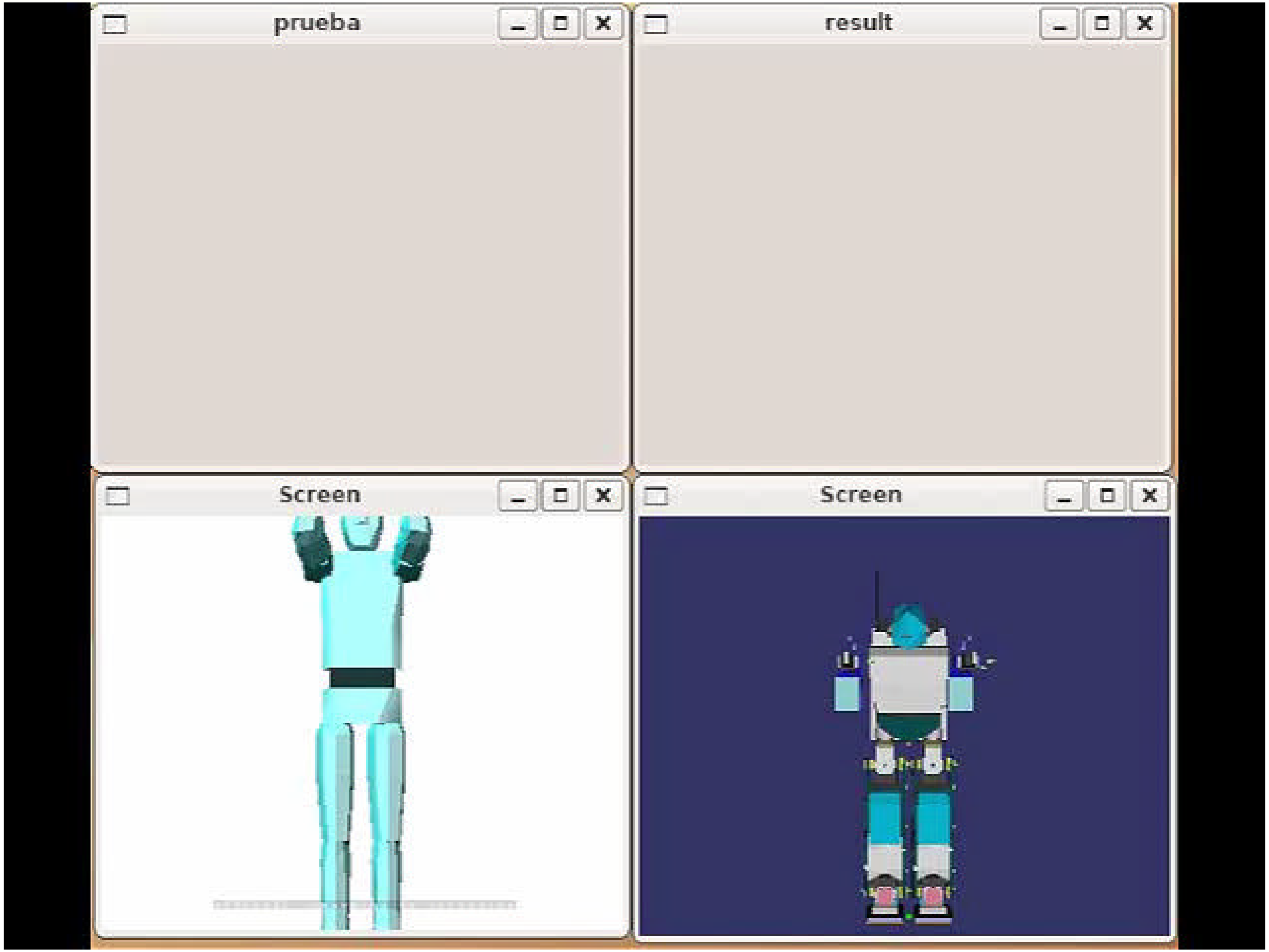


- Two options were evaluated:
  - **Preserve normalized XYZ positions**
    (better for pointing, static gestures)
  - **Preserve joint angles**
    (better for dynamic gestures)
- Both criteria can be combined, depending on the characteristics of the imitated gesture.

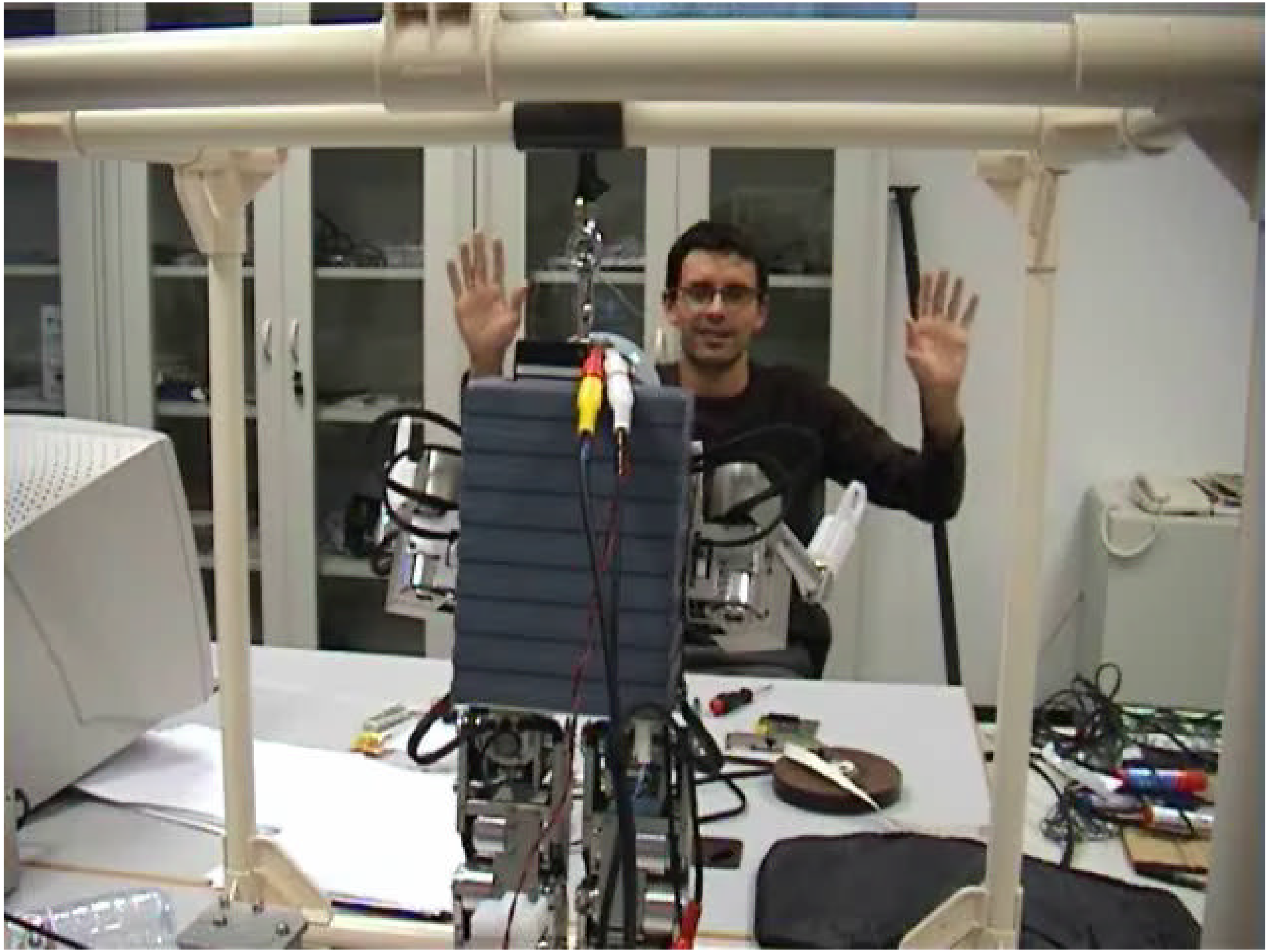




Behaviour-based Control: Imitation



Behaviour-based Control: Imitation



Conclusions

- The social robot has the following capacities:
  - It can maintain itself on its feet… or wheels.
  - It can perceive, imitate and recognize gestures in real-time.
  - It works in real indoor environments.
- Future work:
  - Finish the Nomad robot.
  - Improve visual perception and add more features to recognition.
  - Learn from more than one performer (interactions).
  - Perception of sounds, speech. Verbal communication.
  - Interact with objects.

Testing the quality of the human upper-body motion capture system

Thank you for your attention!

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