Optical Tracking for Teleoperation Space Applications

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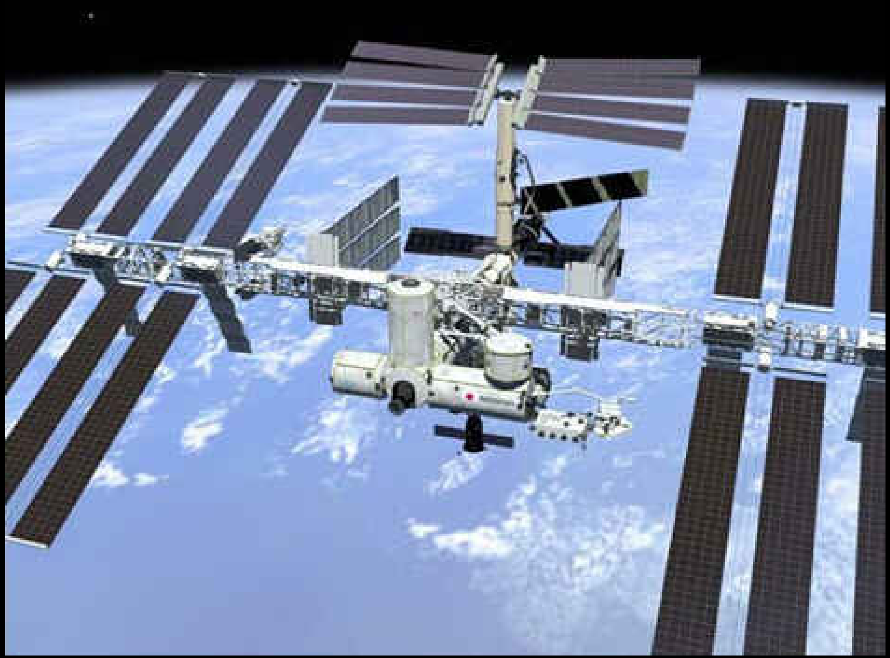
Overview

- Motivation
- Problem statement
- Maximum-Likelihood motion estimation
- Results
- Summary

Motivation (1)

Space exploration

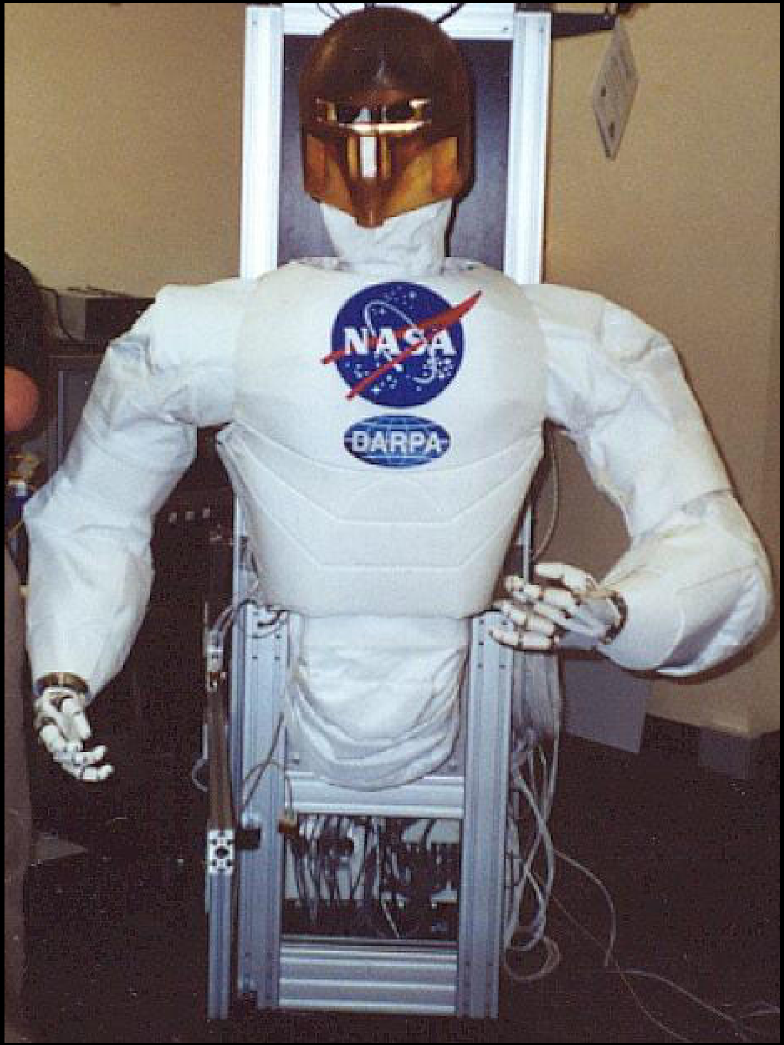
- Heavy workload from a small number of astronauts



Motivation (2)

ROBONAUT

- Developed at NASA-JSC for alleviating astronaut workload
- Anthropomorphic
- Arms capable of dexterous, human-like maneuvers
- Teleoperated



Motivation (3)

Teleoperation

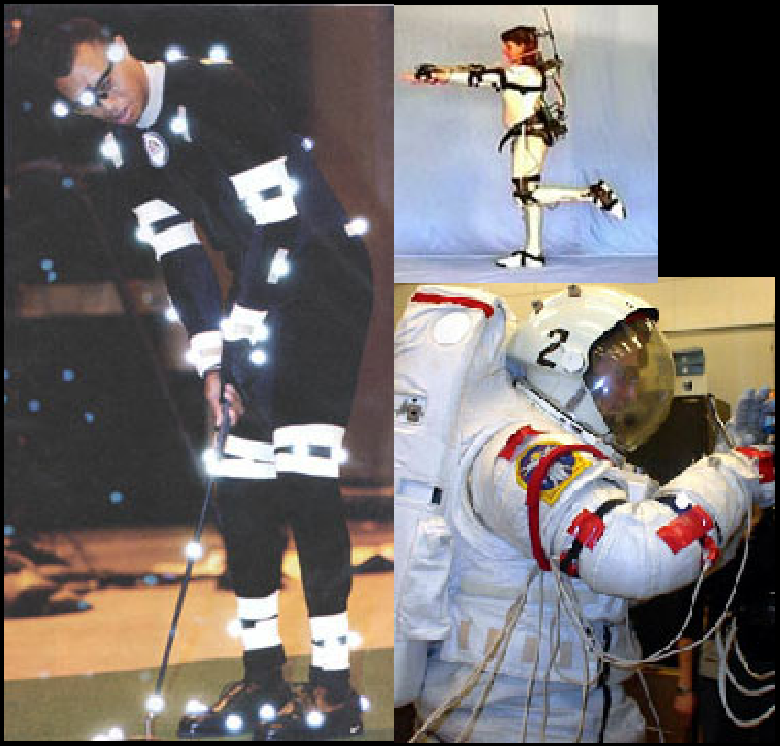
- Human operator controls ROBONAUT movements from a distance
  - Motion estimation of the operator's body parts
  - Motion estimates use to control the robonaut

video

Motivation (4)

Challenge

- Off-the-shelf systems for human motion estimation
  - Intrusive
  - Encumbering



Problem statement

Non-intrusive human motion estimation from a single video camera

Approach

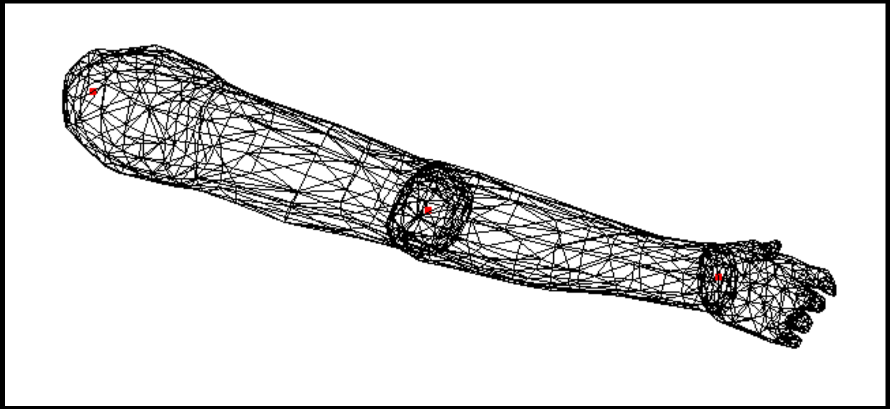
The motion is estimated by maximizing the conditional probability of the frame to frame intensity differences at observation points*

* G. Martinez, PhD Dissertation, University of Hannover, Germany, 1998.

Maximum-Likelihood motion estimation (1)

Shape model

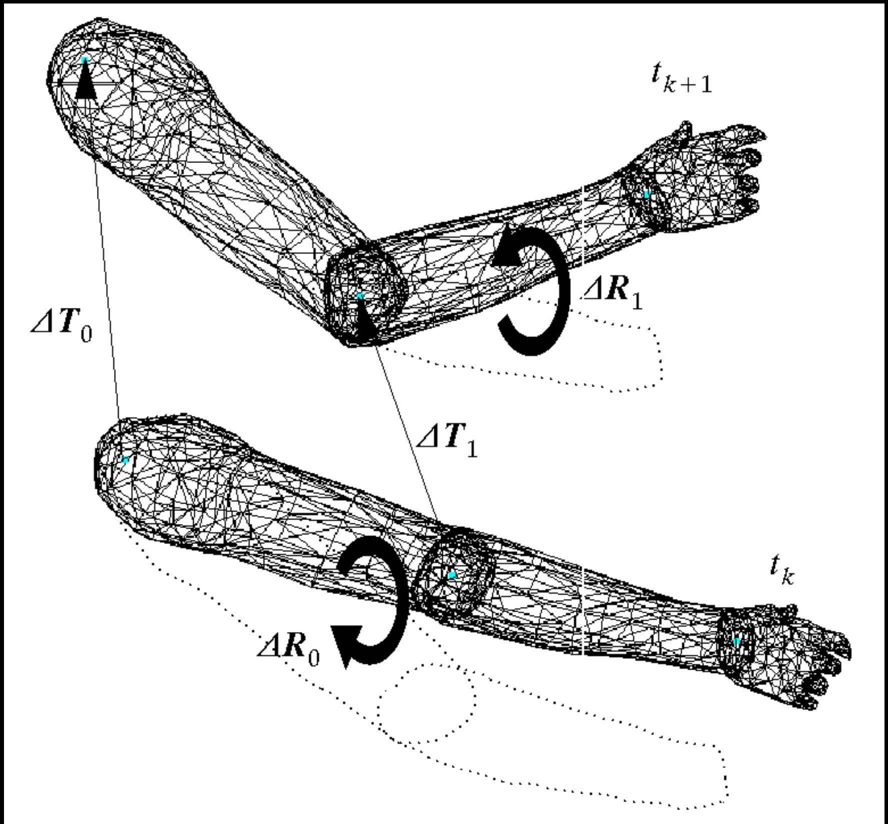
- The human body is represented by an articulated 3D model consisting of several rigid links connected by spherical joints
- The 3D shape of a link is described by a triangular mesh



Maximum-Likelihood motion estimation (2)

Motion model

- The 3D motion of a link from time t_K to t_{k+1} is described by six parameters **B** : one three dimensional translation vector ΔT and three rotation angles ΔR



Maximum-Likelihood motion estimation (3)

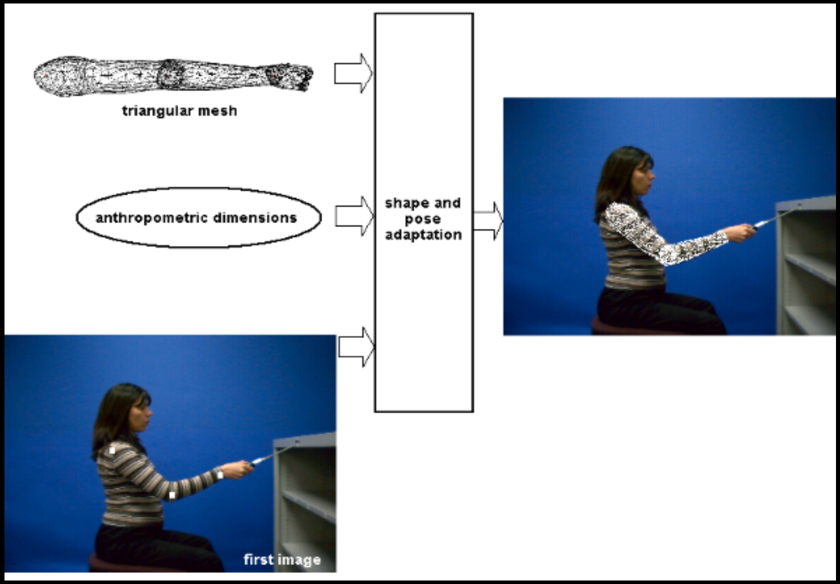
Other assumptions

- Perspective projection
- Static camera
- Diffuse illumination

Maximum-Likelihood motion estimation (4)

Algorithm

1. Read first image
2. Adapt shape, position, and orientation of the mesh
3. Select observation points



Maximum-Likelihood motion estimation (5)

4. Read next image
5. Measure the frame to frame intensity differences **FD**
6. Compute the conditional probability p(**FD**/**B**)
7. Find those motion parameters **B** which maximize p(**FD**/**B**)

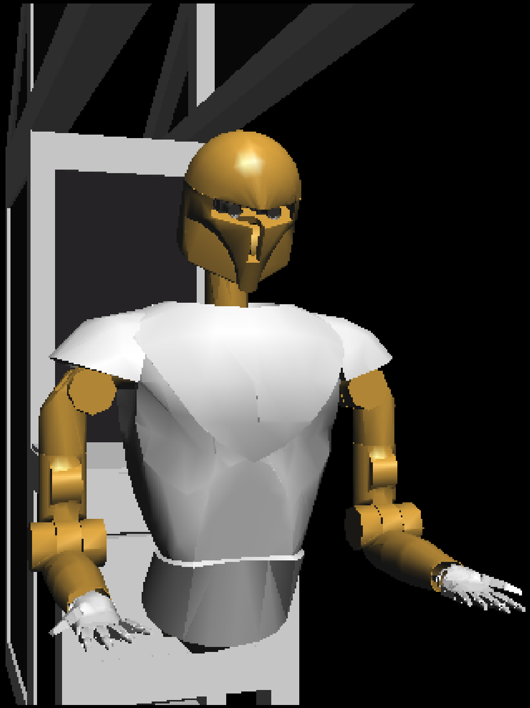
$$p(\boldsymbol{FD}/\hat{\boldsymbol{B}}) \geq p(\boldsymbol{FD}/\boldsymbol{B}) \quad \forall\, \boldsymbol{B}$$

$\hat{\boldsymbol{B}}$: Maximum–Likelihood motion estimates

8. Move mesh and observation points with motion estimates

Teleoperation of ROBONAUT (1)

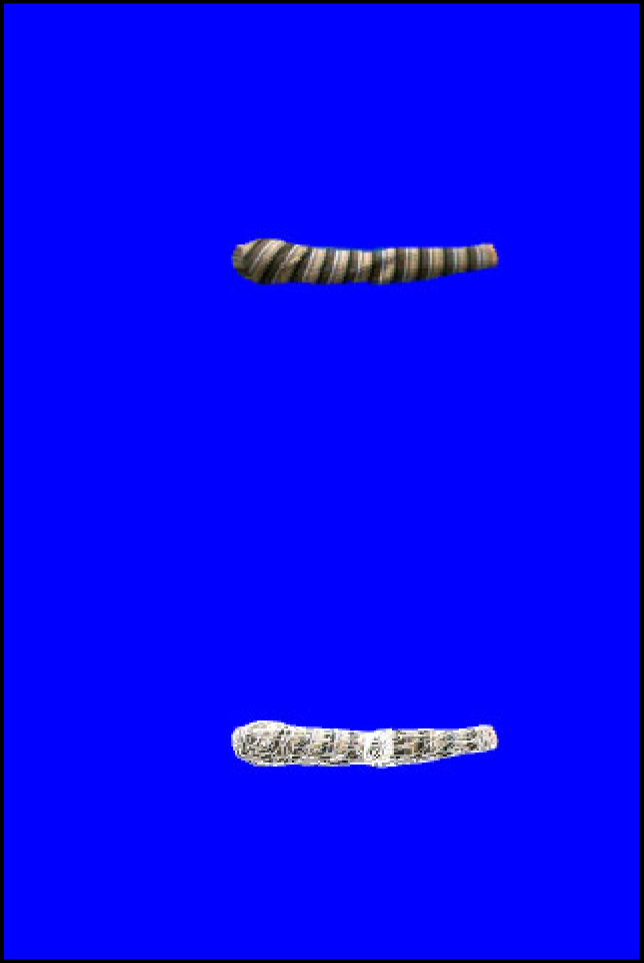
- ROBONAUT simulation developed at NASA-JSC
- Control communication through ROBONAUT API and Network Data Delivery Service (NDDS)
- Currently only teleoperation of the right arm

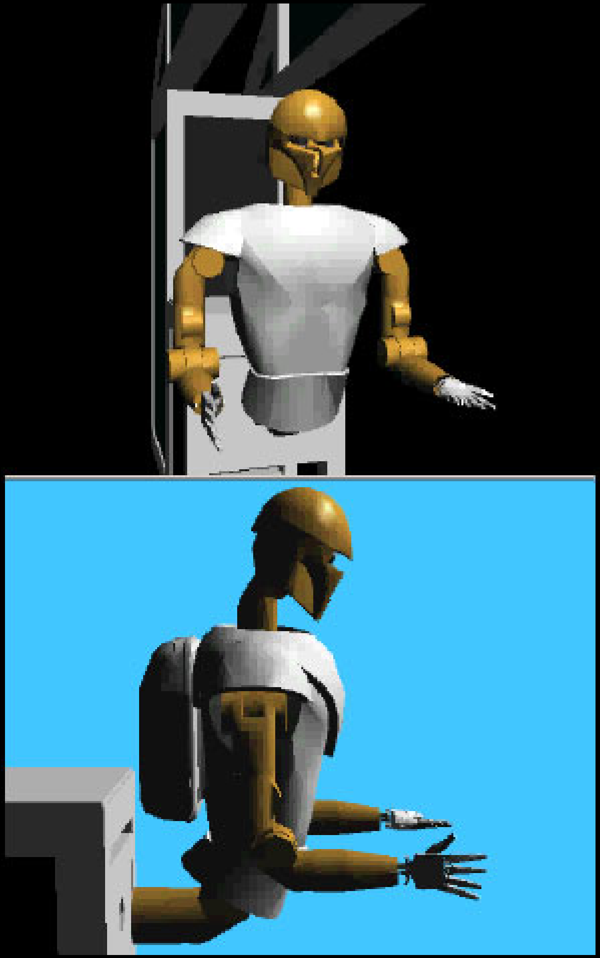


Teleoperation of ROBONAUT (2)

- Estimate the motion parameters of the right upper and lower arm of the operator
- Compute the new position of the ROBONAUT's right palm using the estimated motion parameters
- Send a command to ROBONAUT with the new right palm position

Results (1)

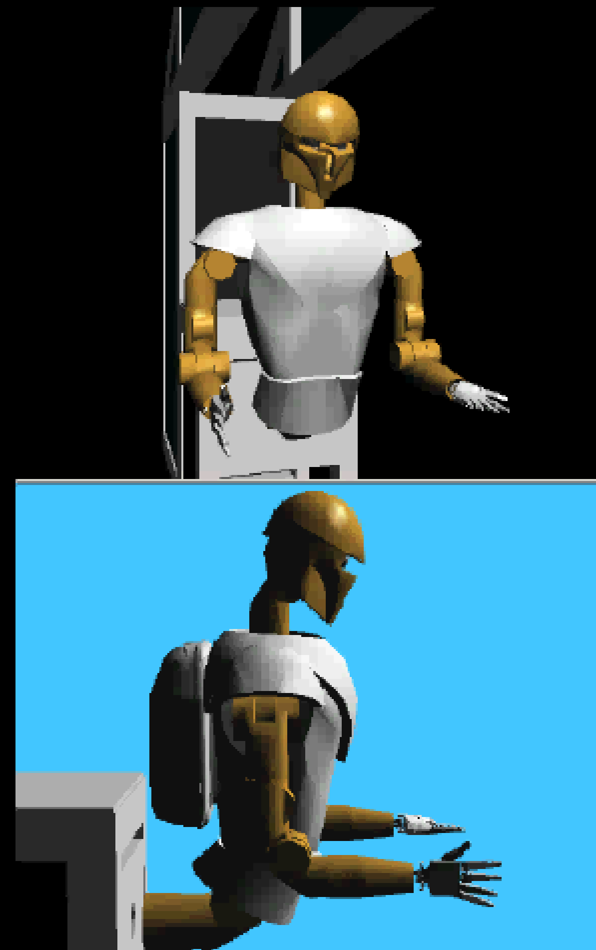




video

video

Results (2)

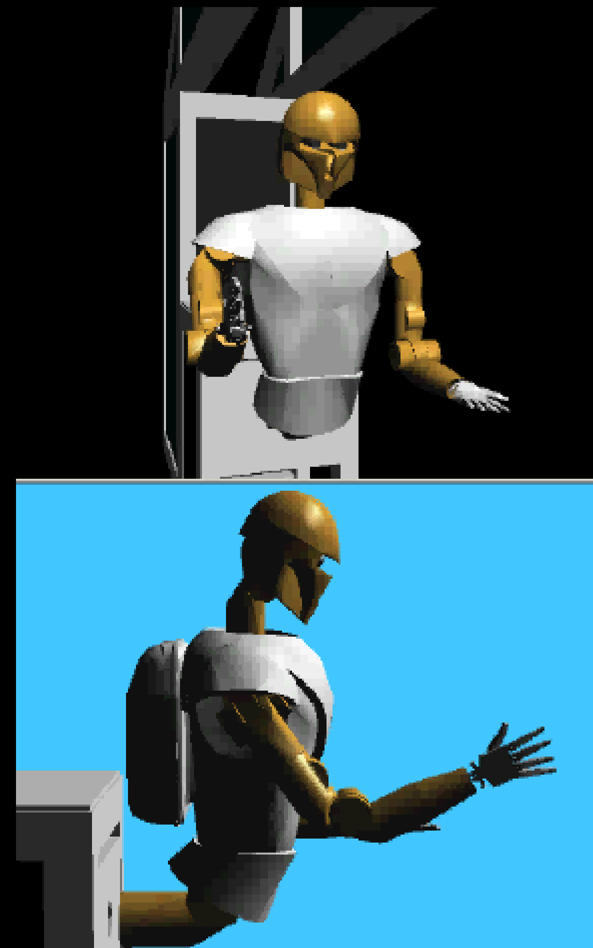


video

video

Results (3)

video



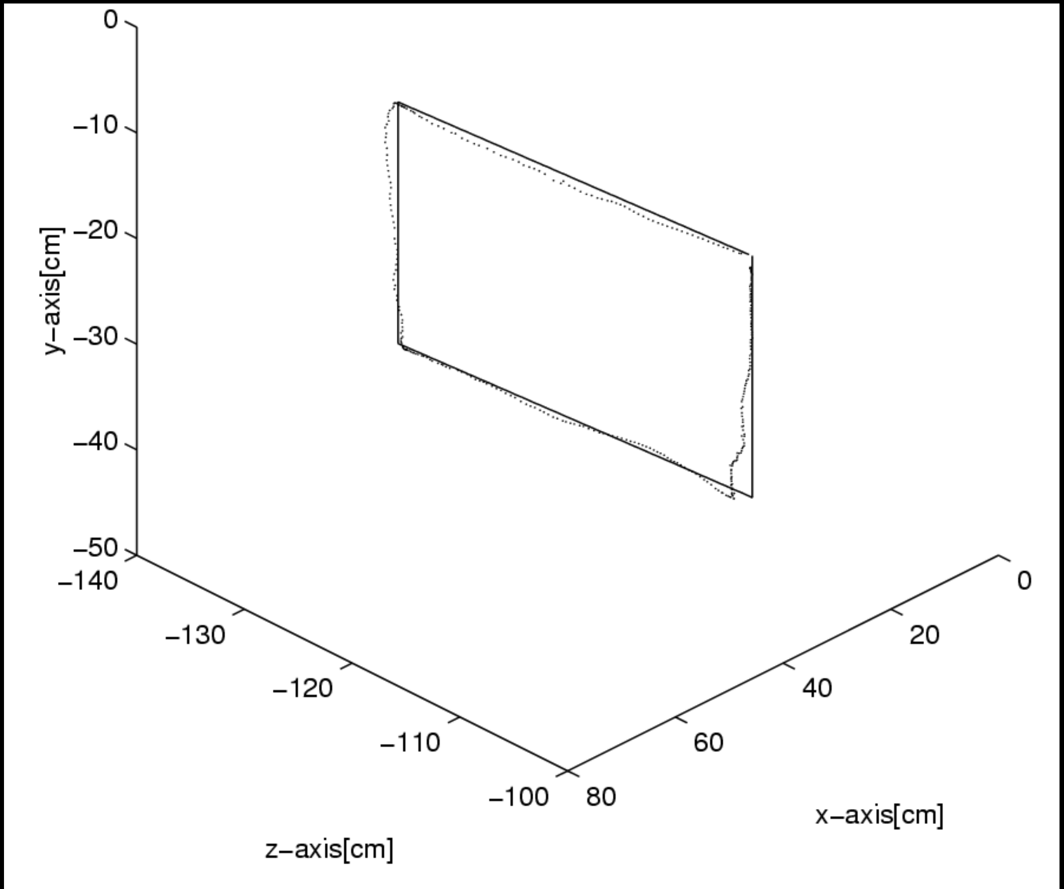
video

Performance evaluation (1)

video

video

Performance evaluation (2)



Position error: 0.57 ± 0.31 cm

Summary

- Implemented a prototype for motion estimation of a human arm from a single video camera.
- Motion estimates were successfully used to remotely command the ROBONAUT simulation.
- Experimental results reveal a position error of 0.57 cm.