3D Pose Recovery of the Human Arm

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Outline of Presentation

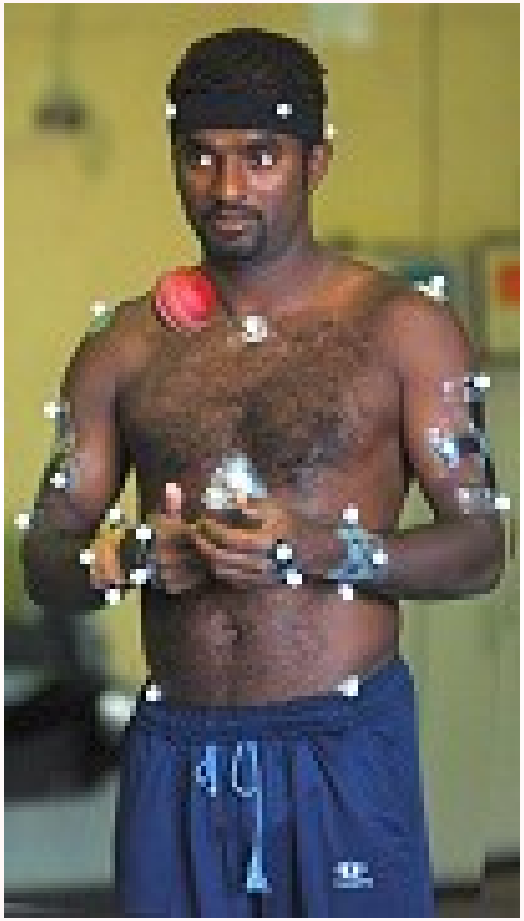
- Introduction to the Task
  - Markerless Motion Capture
- Implementation
  - Annealed Particle Filter
- Experiments
  - Results and Discussion

Motion Capture

- *Motion Capture* is digitally recording the movements of a subject, usually a human.
- Motion can be defined by the pose of the subject at discrete time intervals.

Marker Based Systems

- Motion capture is currently performed with expensive *marker based technology*.
- Applications include computer animation, sports and biomechanical analysis.



Markerless motion capture systems

- could be applied to uncooperative subjects, e.g. in surveillance.
- could be used for analyzing differences in movement, e.g. rehabilitation analysis of poses/movements of human subjects after an injury.
- offer a cheaper alternative technology.

The aim of this Project

- To build a system to recover the 3D motion of a human arm from a *single* video sequence.
- To evaluate the accuracy of the system.

Particle Filter

- A single video frame provides only weak evidence about the pose of the arm.
- Instead of simply calculating the most likely pose at each frame, a particle filter is used to maintain a set of possible poses.
- More particles = more poses maintained.
- The likely pose of the arm in each frame becomes the weighted average pose of all the particles.

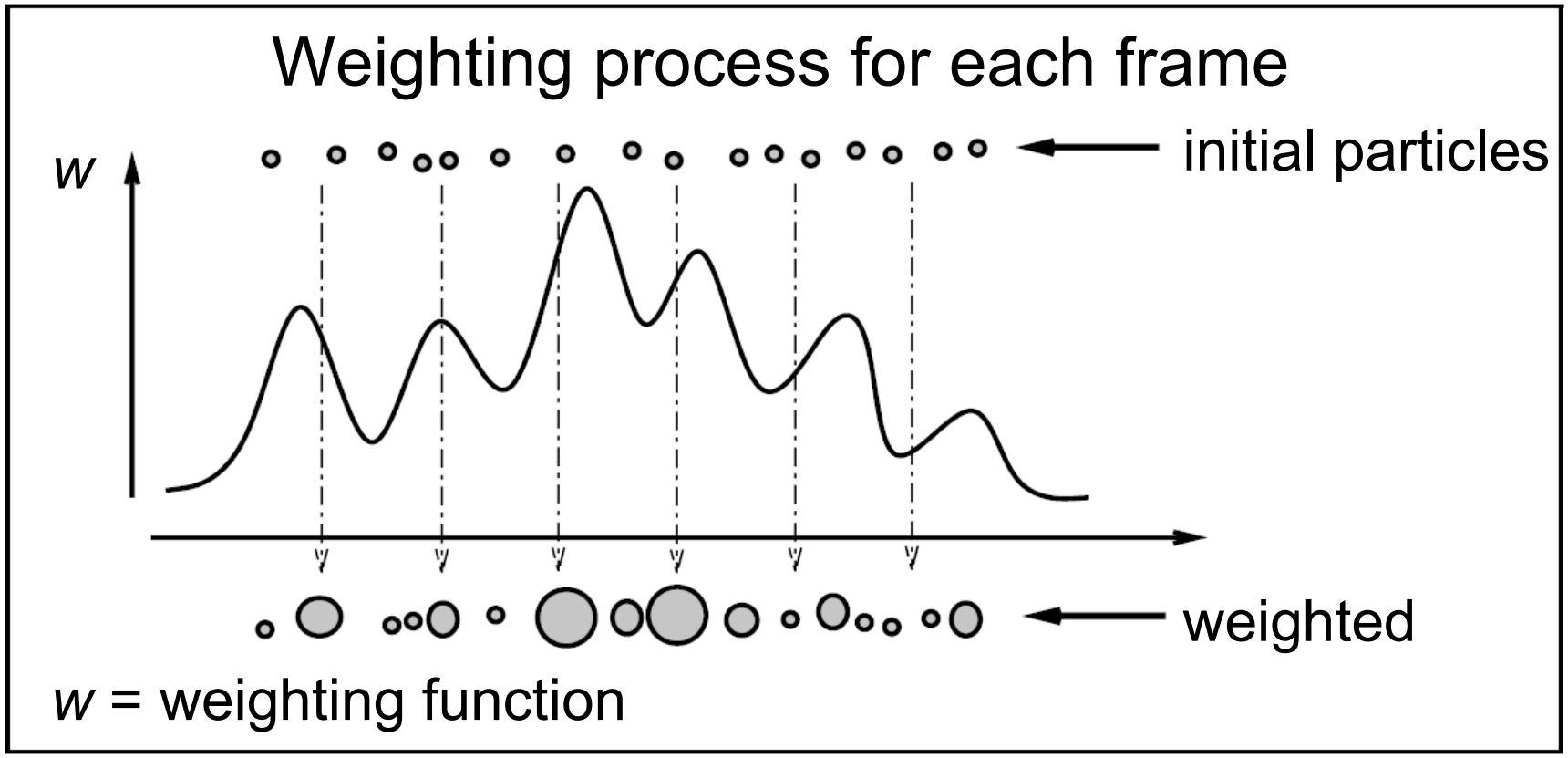
Particle Filter

- The Particle Filter is a *sequential Monte Carlo* based method, which employs sequential importance sampling and resampling.
- Each particle is a vector of model parameters that define one pose.
- A set of these particles is maintained and updated for each new observation (video frame).
- The update is done by *weighting*, *resampling*, and *diffusing* the particle set.

Particle Filter

- The initial set of particles for a video frame represent the *predicted poses* of the arm.
- Each particle is then assigned a weight based on how well the predicted pose ‘fits’ what is observed in the video frame.
- Resampling keeps the poses that fit best.
- Diffusion creates the predicted poses for the next video frame.

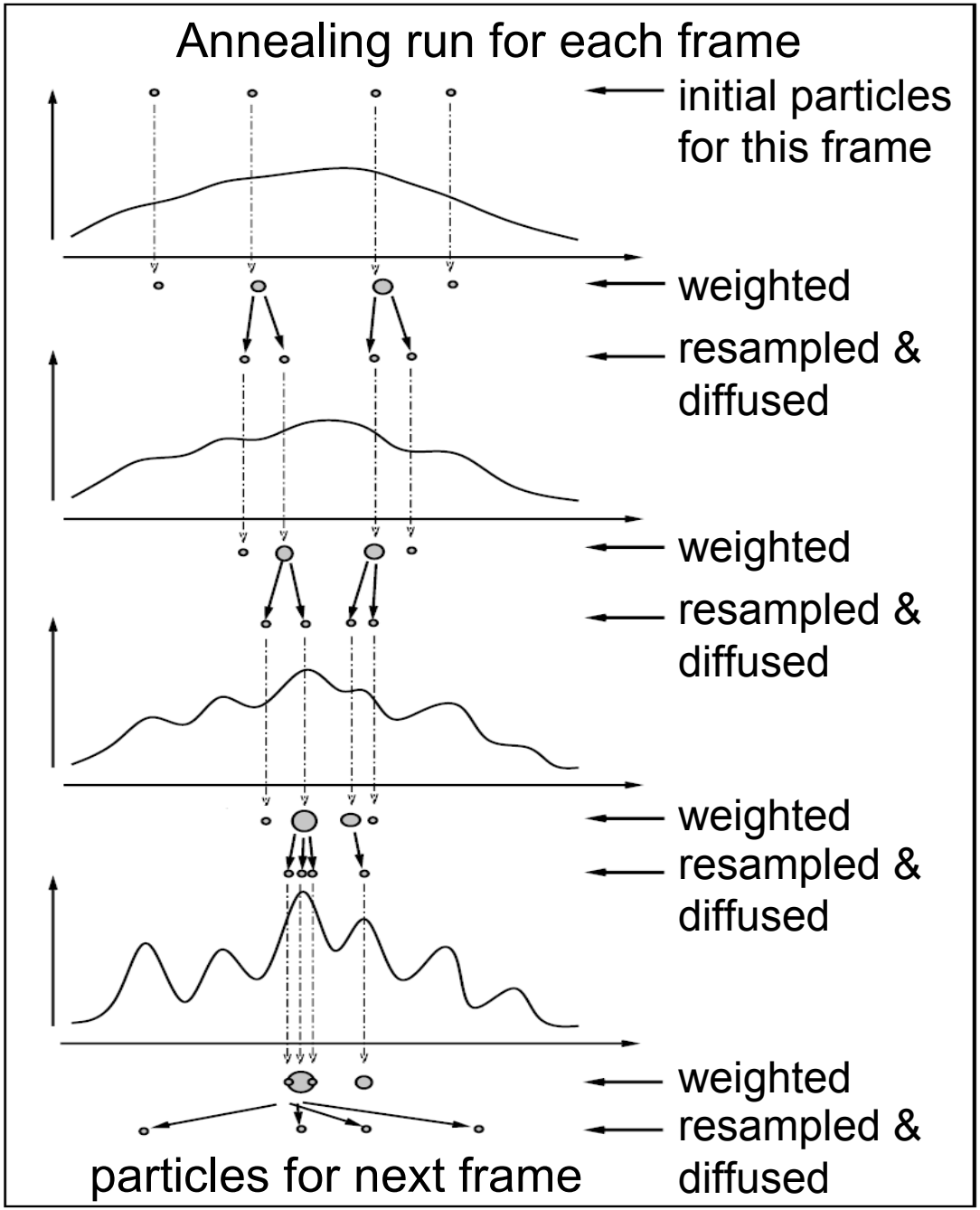
Particle Filter



Annealed Particle Filter (APF)

- The annealed particle filter (APF) incorporates the optimisation technique *simulated annealing* into the particle filter.
- APF has multiple *layers*.
- Each layer has a weighting, resampling and diffusion step.

APF:


Annealing run for each frame
initial particles for this frame
weighted
resampled & diffused
weighted
resampled & diffused
weighted
resampled & diffused
weighted
resampled & diffused
particles for next frame

Recovered Pose

- The motion is defined by a single pose at each video frame.
- When dealing with APF, a single pose is calculated by the average pose of the final weighted particle set in each annealing run.

Skeletal Model

- A *skeletal model of the arm* provides information about its dimensions and the restrictions in all the joints. Limbs are modelled as truncated cones.
- A pose is defined by the value of 7 model parameters:
  - x, y, and z coordinates of the shoulder
  - rotation of the shoulder about the x, y, and z axes
  - rotation of the elbow

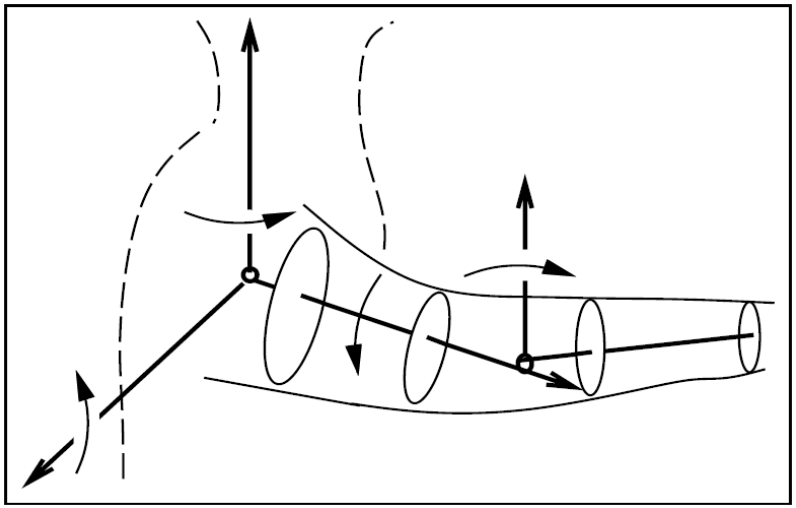
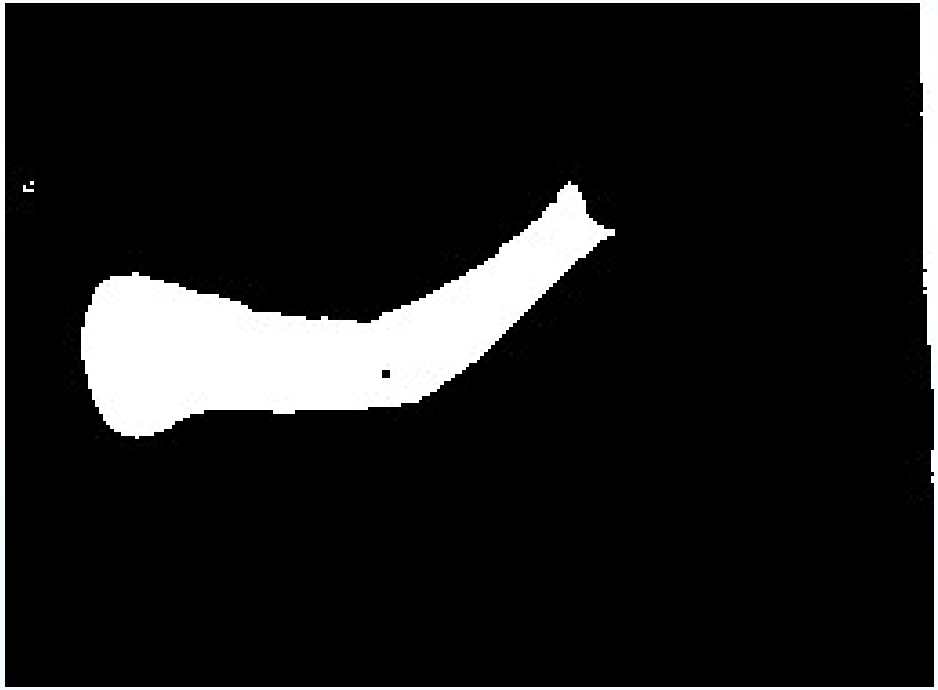


Image Features

- Image features provide evidence about the true pose of the arm.
- Two image features used:
  - Silhouette map
  - Edge map

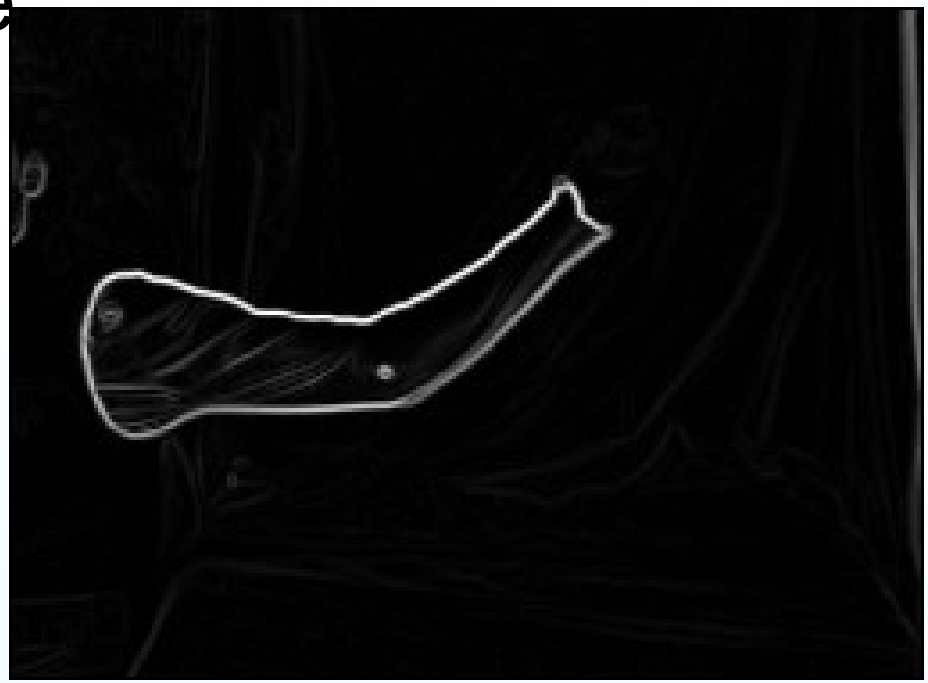
Silhouette Map

- A silhouette map is a binary image that distinguishes arm pixels from background pixels.



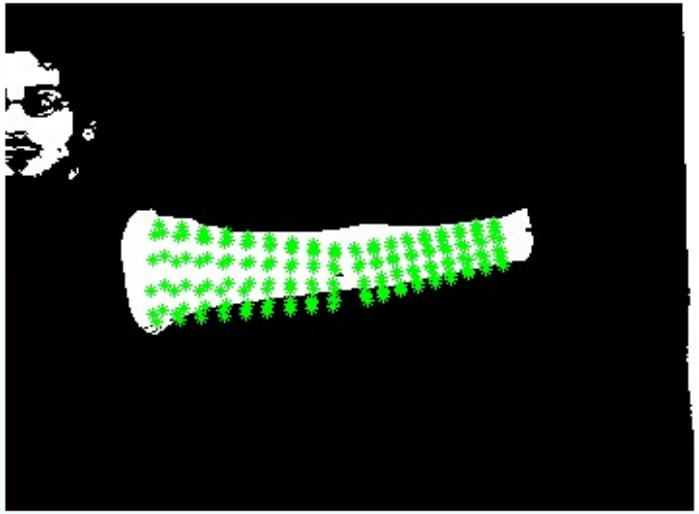
Edge Map

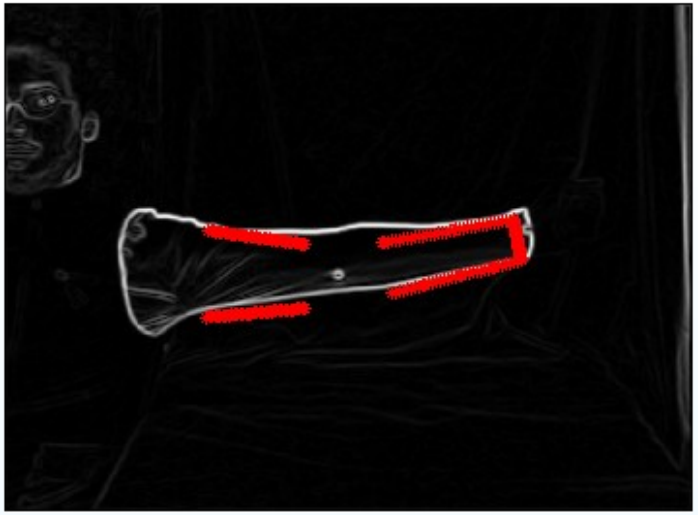
- The value of each pixel in the edge map represents the probability that the pixel lies on an edge



Weighting Function

- The weighting function assigns a weight to a particle by comparing the predicted pose to image features extracted from the video frame.





Experiments

- Three experiments were carried out, each with a different video sequence.
- Each experiment tested different movements.
- Videos were made specifically for this project.

Experiments

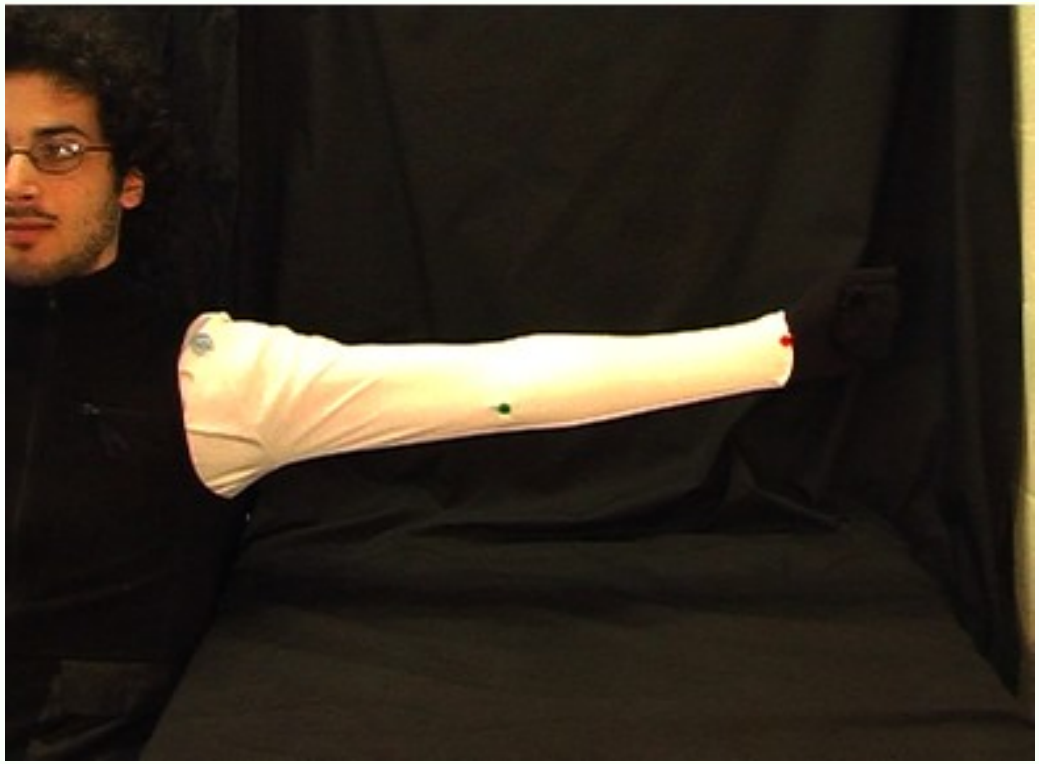
- The markerless motion capture system was run 50 times with each parameter set for each experiment.

Test 1	
#Particles	#Layers
25	5
50	5
100	5
200	5

Test 2	
#Particles	#Layers
100	1
100	3
100	5
100	7

Ground Truth

- Colour markers were attached to arm at locations of joints. Markers were tracked using a *2D APF* in the image space.



Ground Truth

- The arm movements were recorded using a secondary video camera.
- The 3D locations of markers were reconstructed via stereo triangulation. These provide the ground truth of pose and movement of the arm.
- Error of recovered pose and motion from markerless motion capture can then be evaluated.

Performance Indicators

- The *likely pose error* is the average error in the joint positions.
- The *optimistic error* is the minimum error of all the poses in the set of particles.
- The average of each error over the 50 trials was calculated.
- The standard deviation over the 50 trials was also calculated.

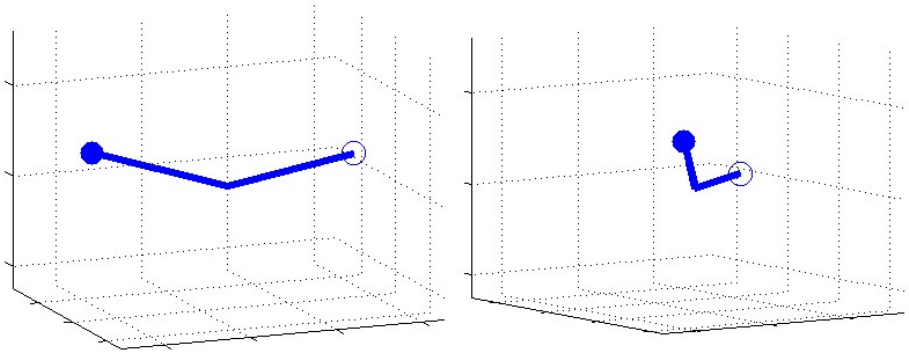
Results

View from Camera

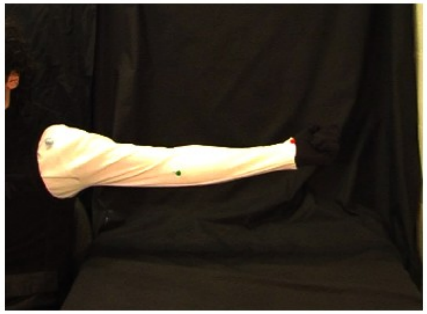
Side on View

Ground Truth Pose

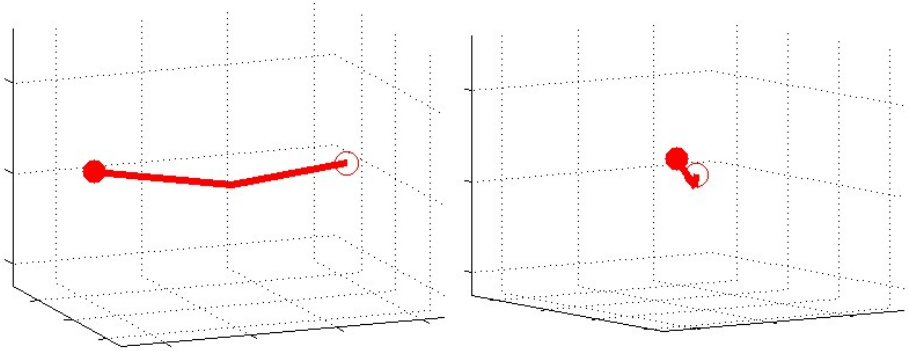
(shown in blue)



Video Sequence



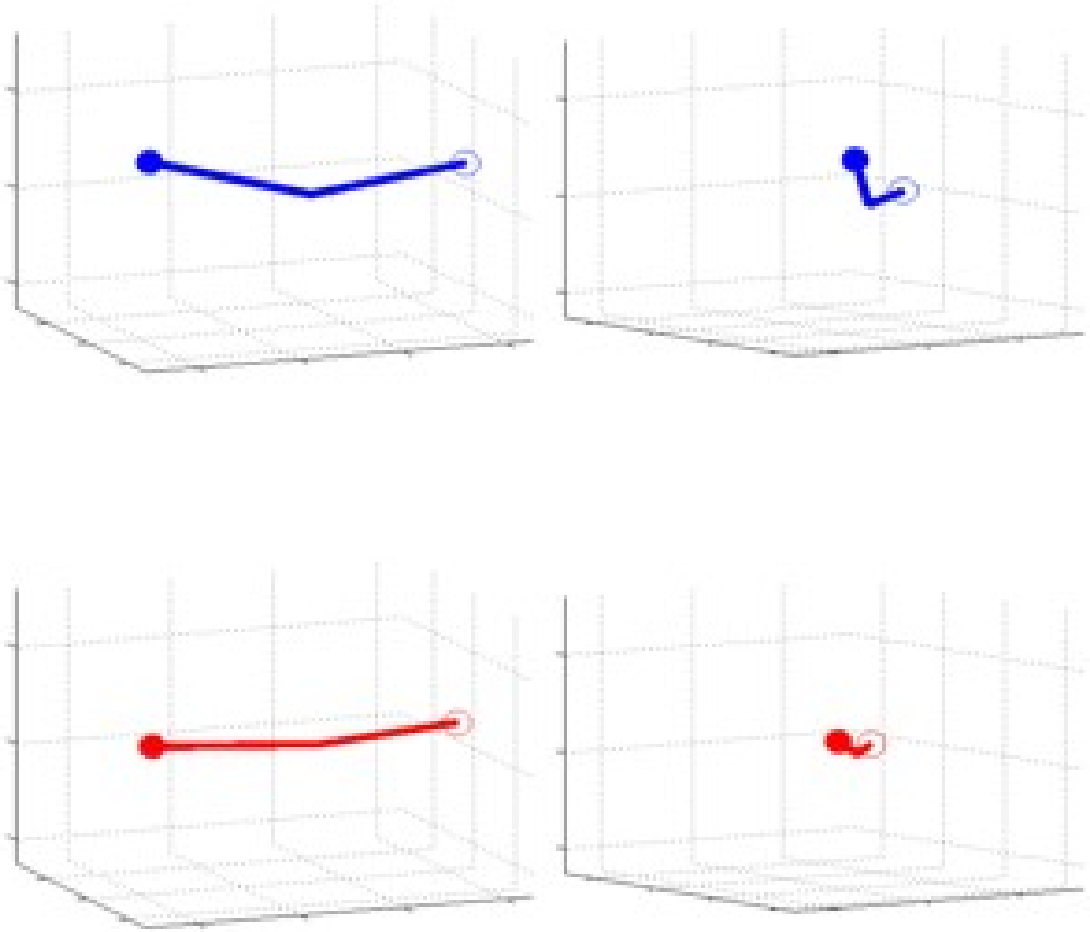
● shoulder joint ○ wrist joint



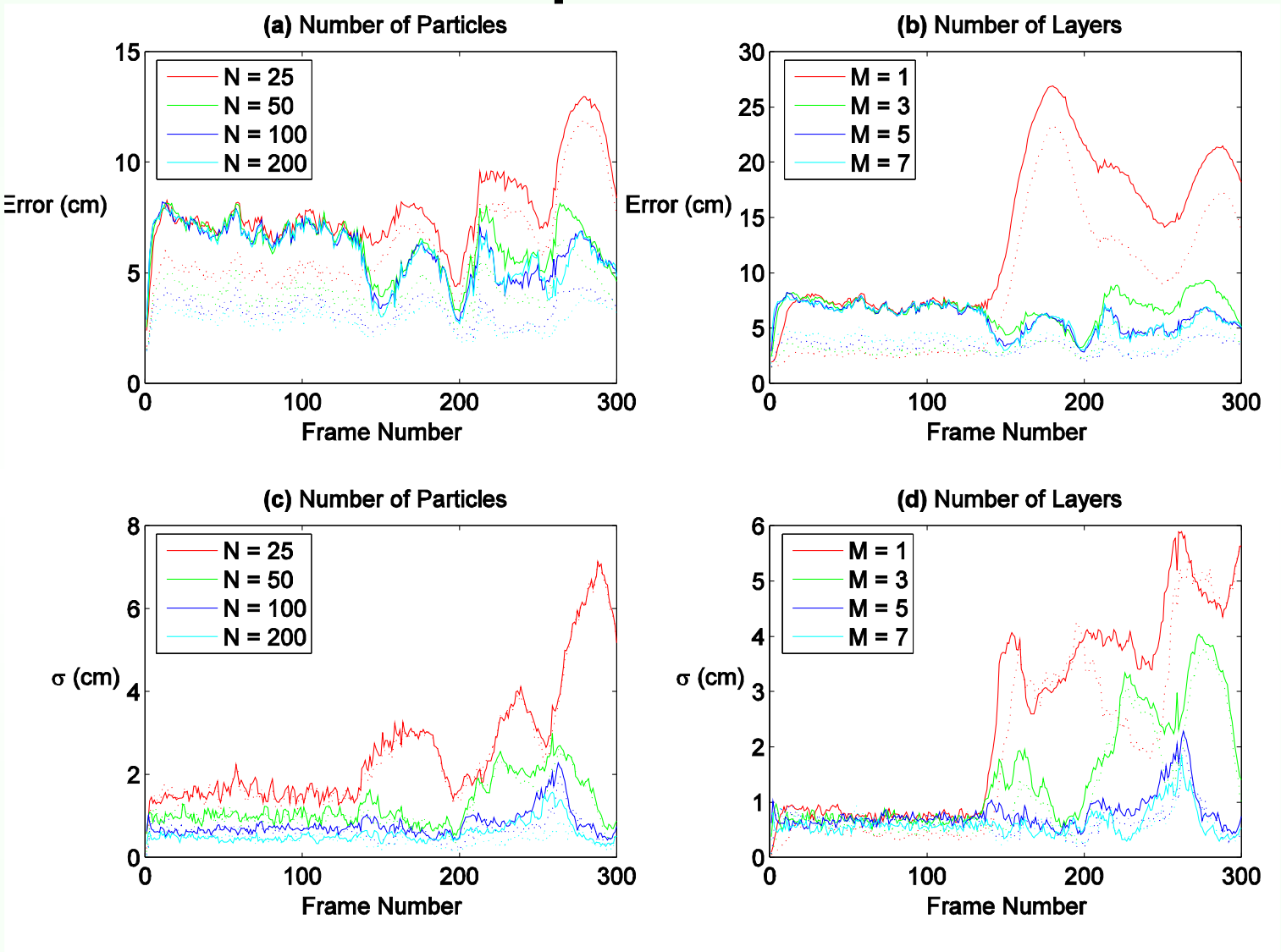
Recovered Pose

(shown in red)

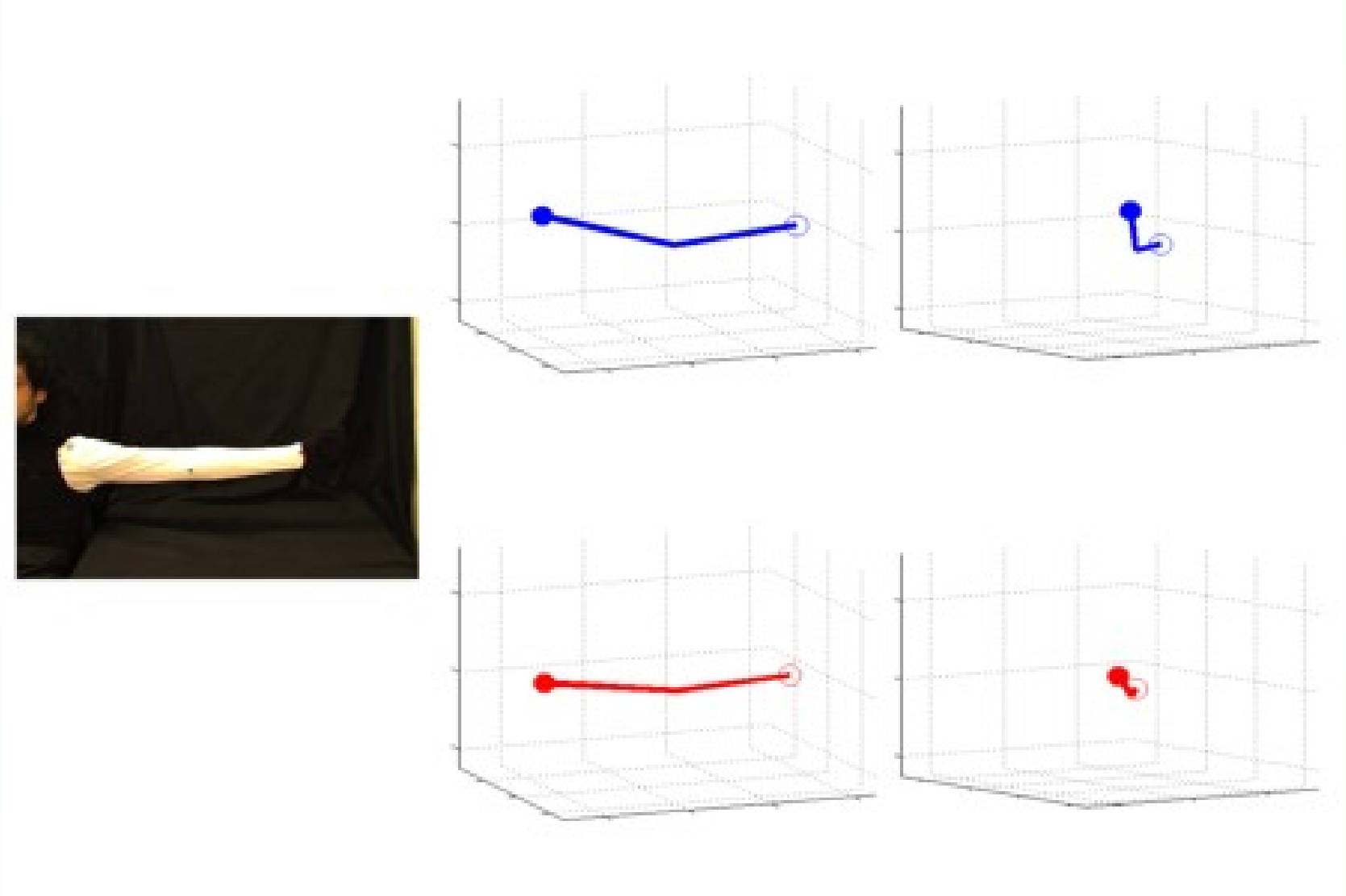
Results – Experiment 1



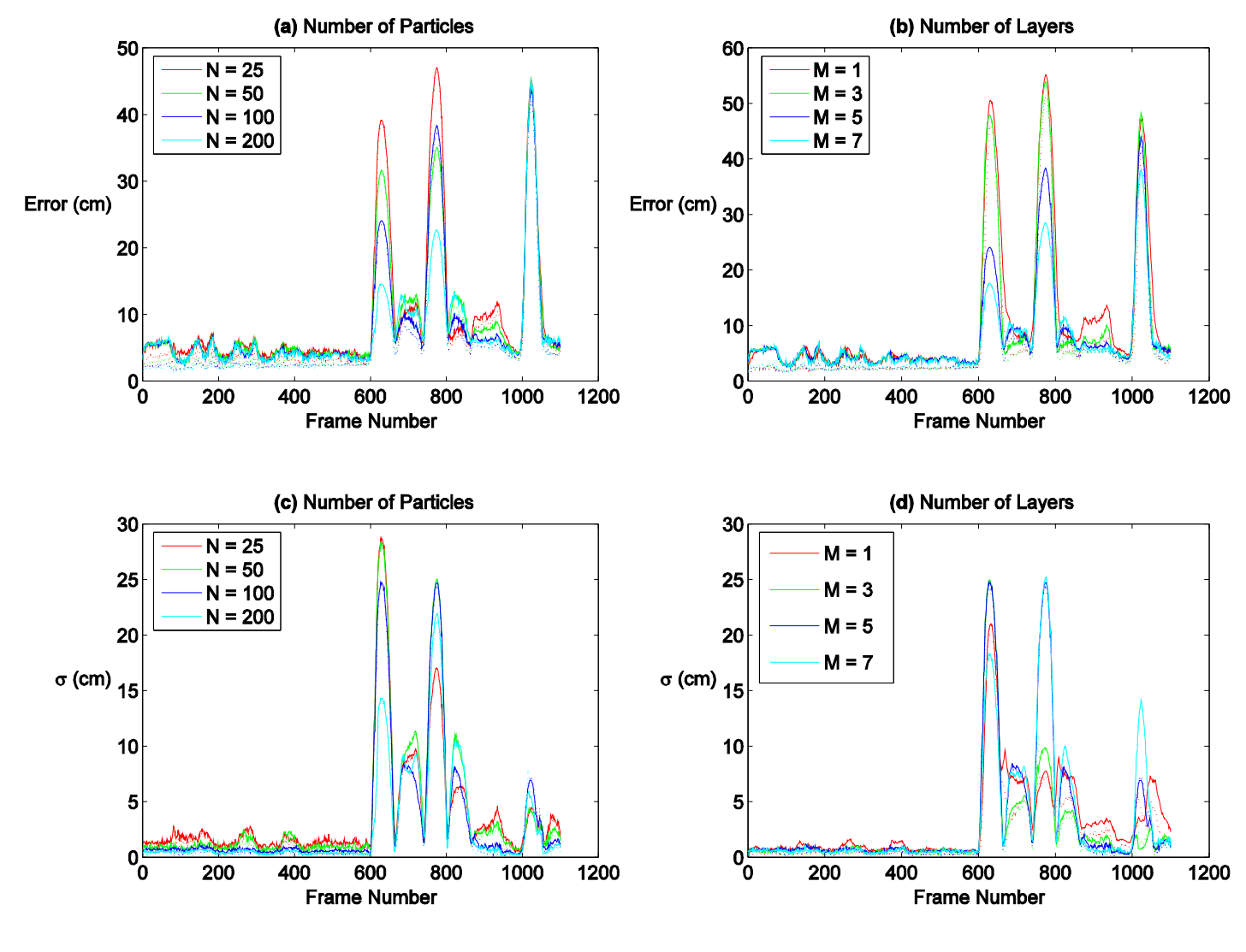
Results – Experiment 1



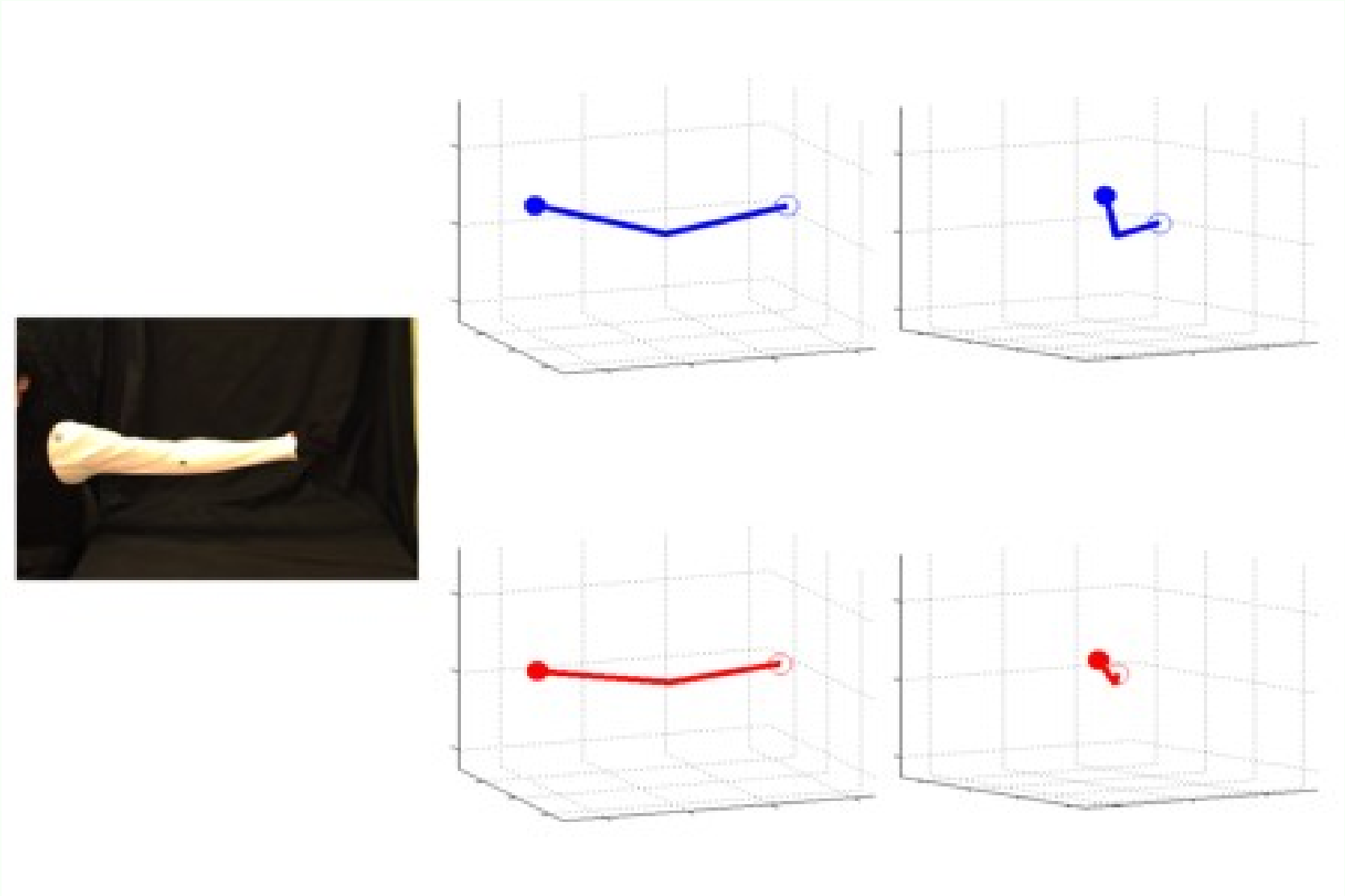
Results – Experiment 2



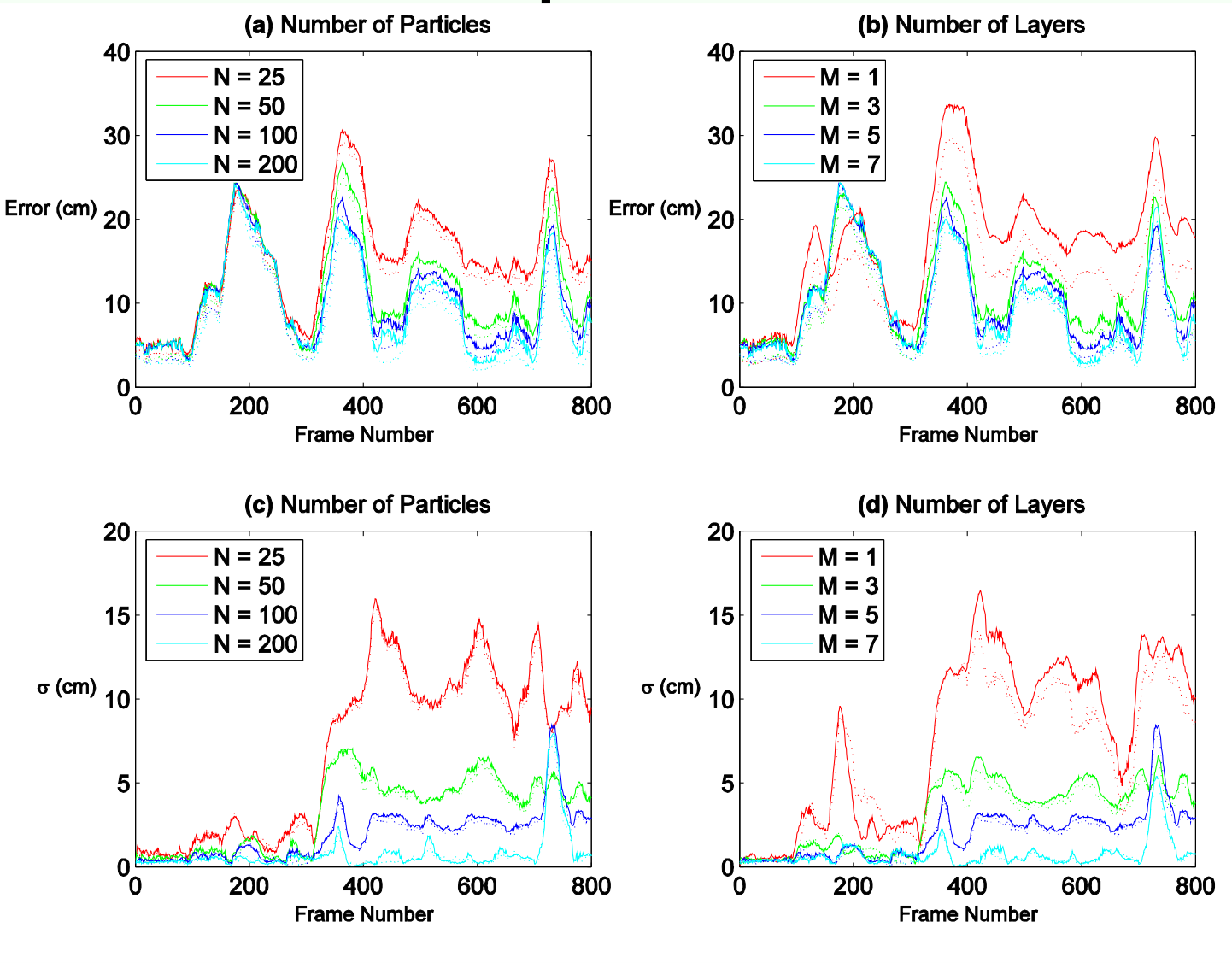
Results – Experiment 2



Results – Experiment 3



Results – Experiment 3

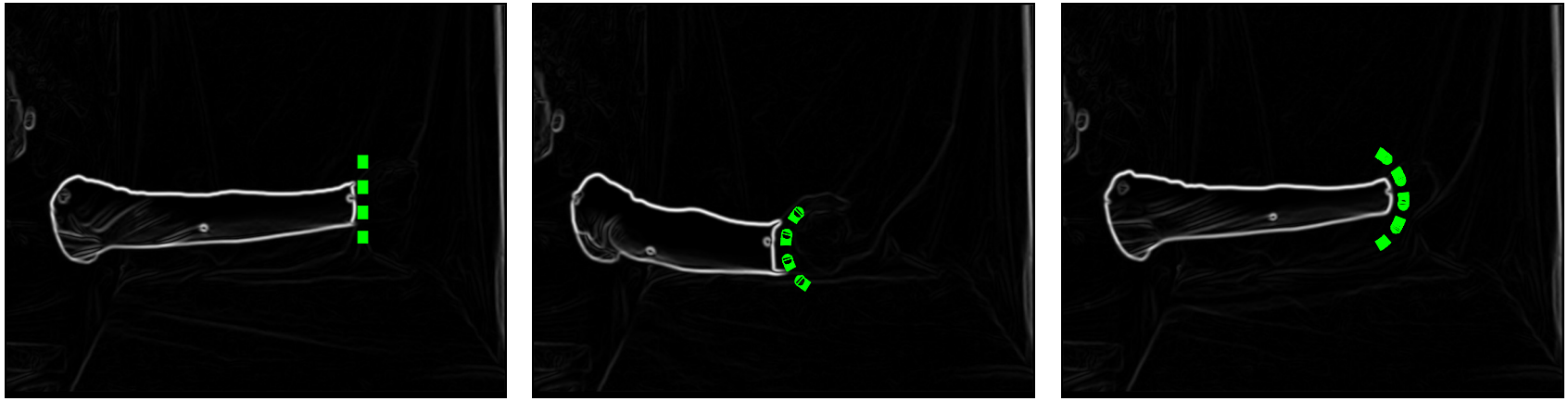


Results

- Can recover pose accurately.
- Has difficulty sometimes in recovering depth.
- Not maintaining competing poses.

Discussion

- The arm is of high resolution in each video frame.
- Assumptions on model are approximate only:
  - conical arm segments
  - straight edge wrist



Future work

- Weighting function:
  - improvements
  - independent testing
- Extension of APF to Adaptive APF
- Incorporating kinematics constraint into arm movement
- Use of multiple cameras to better recover depth
- Full body motion capture

References

- J. Deutscher, A. Blake, and I. Reid, “Articulated Body Motion Capture by Annealed Particle Filtering”, *Proc. IEEE Conference on Computer Vision and Pattern Recognition*, vol. 2, pp. 126-133, 2000.
- A. O. Bălan, L. Sigal, and M. J. Black, “A Quantitative Evaluation of Video-based 3D Person Tracking”, *Performance Evaluation of Tracking and Surveillance*, 2005.

The Honours thesis can be downloaded from

http://www.csse.uwa.edu.au/~du/HonsProjects/Deluca-Cardillo-2006.pdf