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Model-based Hand Pose Estimation for Real-time Virtual Object Manipulation

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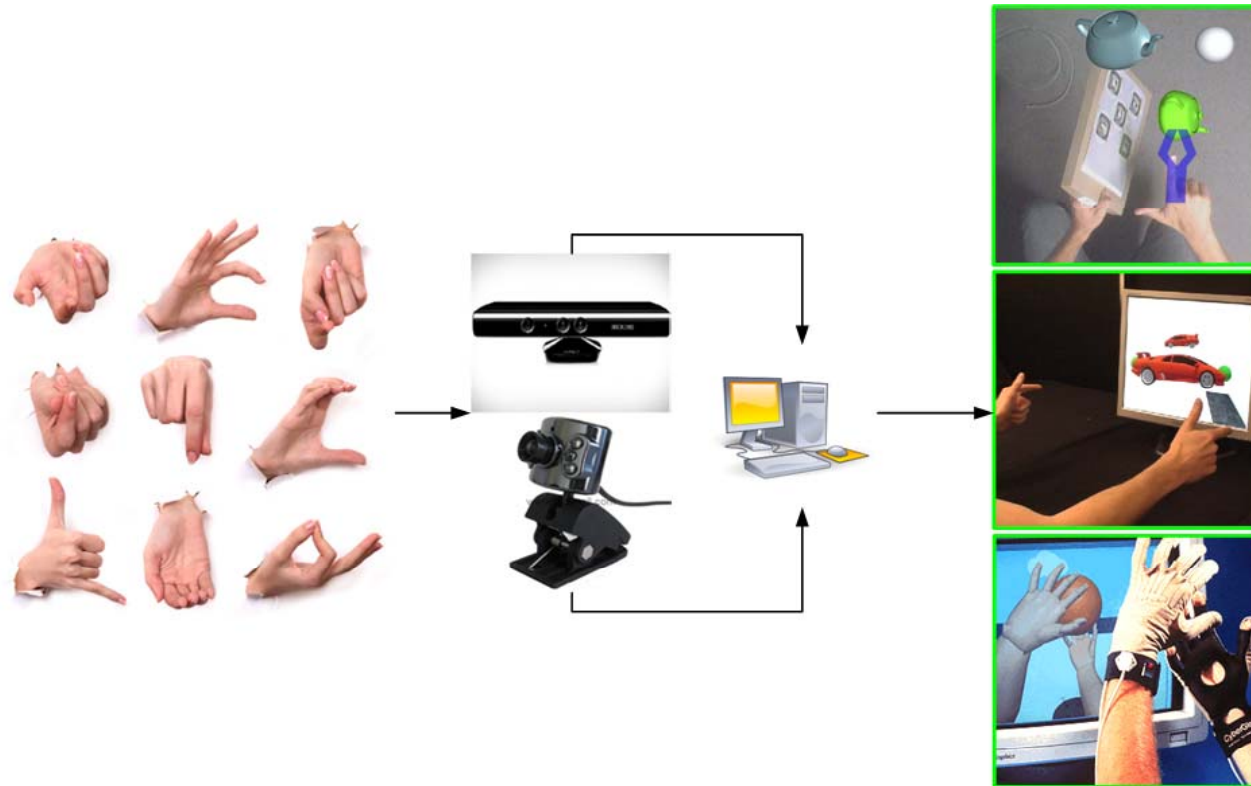
– Institute for Media Innovation.



Outline

- Introduction
- 3D Fingertip detection and tracking
- Hand pose estimation
- Virtual object manipulation
- Future Work

Introduction



[1] Hand Tracking with Flocks of Features, in CVPR 2005.

[2] Efficient Bimanual Symmetric 3D Manipulation for Markerless Hand-Tracking, in VRIC 2009.

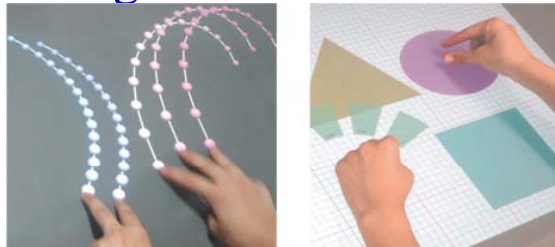
[3] <http://www.cyberglovesystems.com/>

Fingertip Detection

- Why fingertips are useful for hand pose estimation
 - Strong correlation with the hand pose [1][2]



- Use for gesture recognition or multi-touch purposes [3][4]



[1] Model-based 3d hand posture estimation from a single 2d image, in Image and Vision Computing 2002 .

[2] Motion Capture with Constrained Inverse Kinematics for Real-Time Hand Tracking, in ISCCSP 2010.

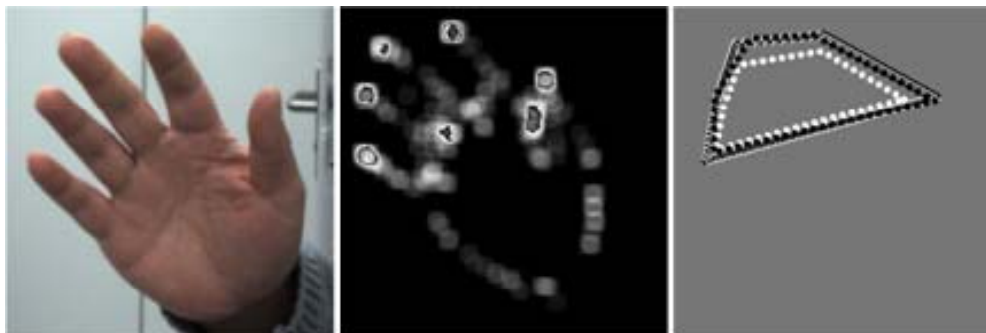
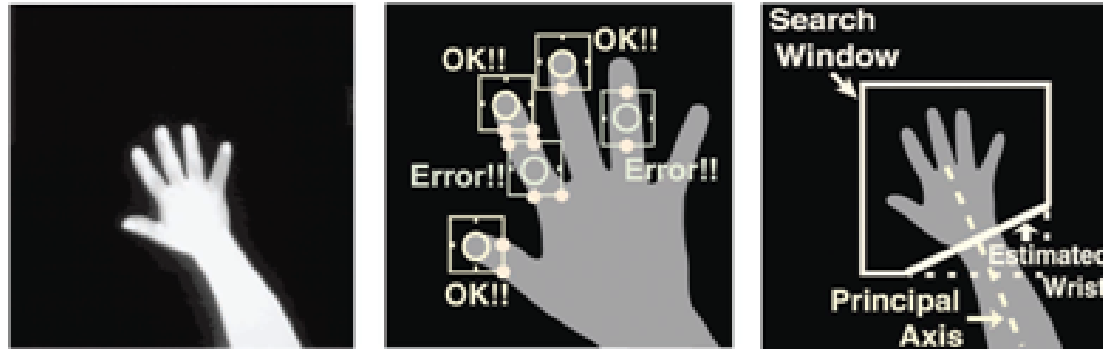
[3] Real-time tracking of multiple fingertips and gesture recognition for augmented desk interface systems, in AFGR 2002.

[4] Fast fingertip positioning by combining particle filtering with particle random diffusion, in ICME 2008.

Previous Researches on Fingertip Detection

- 2D template matching

Square window template (Real-Time Fingertip Tracking and Gesture Recognition)



Circular image feature (Particle Filter-Based Fingertip Tracking with Circular Hough Transform Features)

Previous Researches on Fingertip Detection

- Use of depth info

Detect pointing fingertips
(Tracking of Fingertips
and Centers of Palm using
KINECT)



- The above researches lack discriminative features for 3D fingertip detection
- Most of them can only detect fingertips for stretched fingers

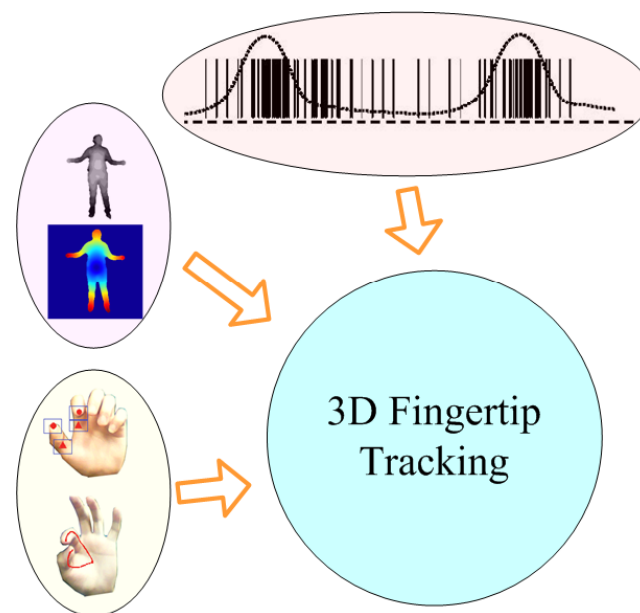
Fingertip Detection

- The difficulty of 3D fingertip detection and labeling
 - Side-by-side fingers
 - Bending fingers
 - Near-by fingertips



3D Fingertip Tracking

- Inspiration
 - Geodesic distance for body part identification [1]
 - Use a particle filter [2] to track each fingertip
- More discriminative features
 - Geodesic distance
 - Rectangle local feature (RL)
 - Geodesic Shortest Path (GSP)



[1] Estimating Human 3D Pose from Time-of-Flight Images Based on Geodesic Distances and Optical Flow, in FGR 2011.

[2] CONDENSATION - conditional density propagation for visual tracking, in IJCV 1998.

3D Fingertip Tracking

- Depth-based features
 - Geodesic distance from the palm center
 - Rectangle local feature (RL)

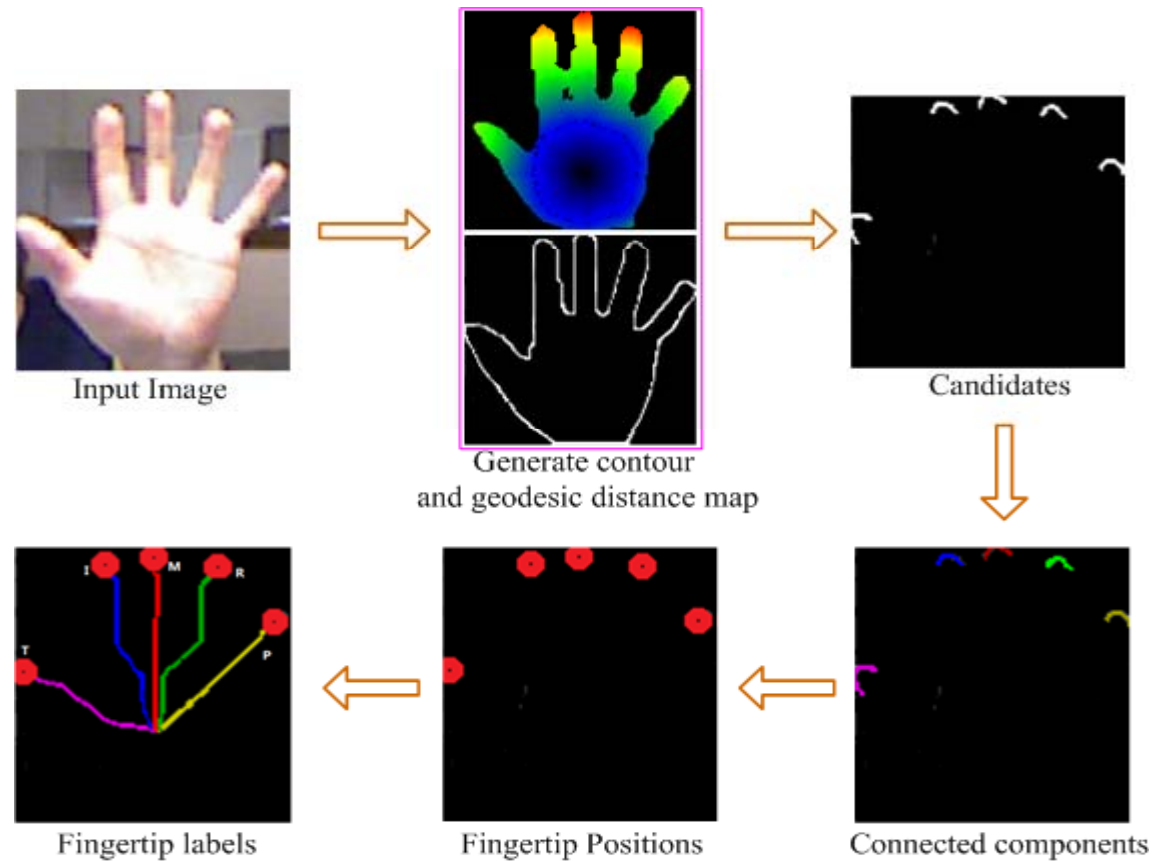
$$I(q) = \begin{cases} 1 & \text{if } |z(p) - z(q)| \leq z_T \\ 0 & \text{otherwise} \end{cases}$$

- Geodesic Shortest Path (GSP): the shortest path from the palm center to the current pixel on the geodesic distance map



3D Fingertip Tracking

- Initialization and Re-initialization



3D Fingertip Tracking

- Fingertip Tracking

Algorithm 3 Particle Filter based Fingertip Tracking.

Input:

The initially detected fingertip position, p_f^i ;

Output:

The updated position of the fingertip, p_f^i ;

- 1: If $k = 0$, generate N random particles at positions x_k^j , $j = 1, 2, \dots, N$ around p_f^i , $\omega_{k-1}^j = 1/N$;
 - 2: Diffuse the positions of the particles by finding their nearest neighbor in U_B ;
 - 3: Estimate $f(y_k|x_k^j)$ and update ω_k^j ;
 - 4: Update fingertip position $p_f^i = \arg \max_j \omega_k^j$;
 - 5: return p_f^i ;
-

- The likelihood function

$$\begin{aligned} f(y_k|x_k) &= f(d_g, RL, U_G|x_k) \\ &= f(d_g|x_k)f(RL|x_k)f(U_G|x_k) \end{aligned}$$

3D Fingertip Tracking

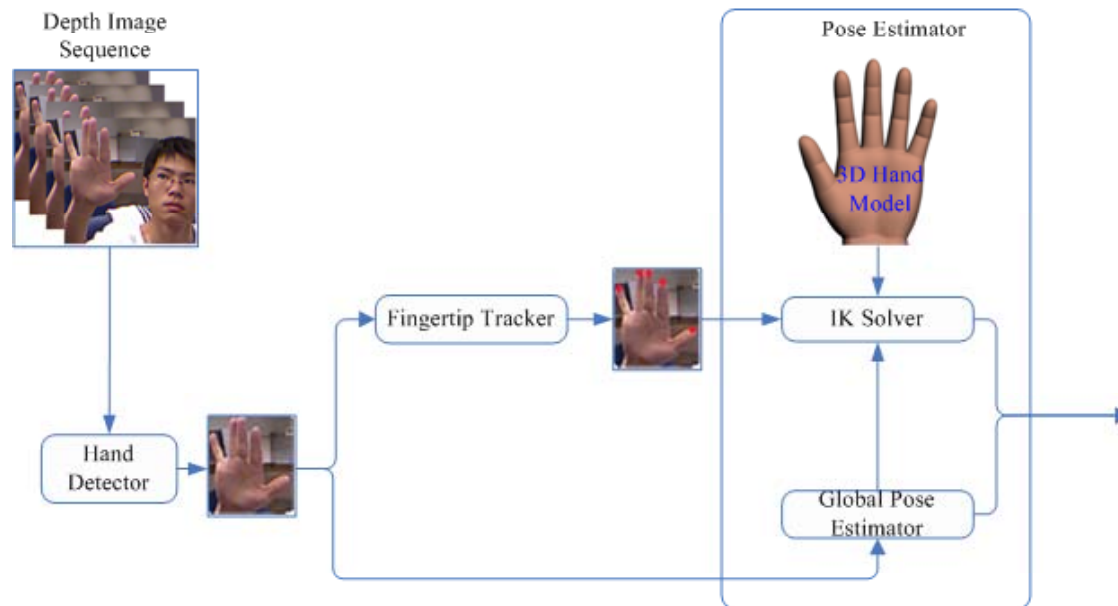
- Experimental Results
 - Dataset: six synthesized sequences of different types of hand motions

Table 1: Quantitative results on synthetic sequences

Seq. No.	Average Error (cm)				
	Thumb	Index	Middle	Ring	Pinky
Seq. 1	2.51	1.53	1.50	1.27	0.77
Seq. 2	1.63	0.93	0.78	0.74	0.69
Seq. 3	1.34	0.88	0.65	0.84	0.89
Seq. 4	2.11	1.15	1.16	0.84	0.81
Seq. 5	1.20	0.82	0.75	0.52	0.59
Seq. 6	1.44	0.93	0.89	0.77	0.86

Hand Pose Estimation

- Global pose estimation by PCA analysis
- Local pose estimation by inverse kinematics



Global Rotation Estimation

- Global rotation constraints

$$-15^\circ \leq \theta_x \leq 15^\circ, -15^\circ \leq \theta_y \leq 15^\circ, -90^\circ \leq \theta_z \leq 90^\circ$$

- Assume the palm is rigid
- Define the global rotation using two vectors
 - The normal vector of the palm, given by PCA analysis
 - Vector from the palm center to the fingertip of the middle finger
 - The Euler angles of global rotation are then calculated using the two vectors

Experimental results

- Quantitative tests
 - Dataset: six synthesized sequences of different types of hand motions
 - Evaluation metric: mean absolute errors between the recovered local joint angles and ground truth data.

Motion	Seq. 1	Seq. 2	Seq. 3	Seq. 4	Seq. 5	Seq. 6
Local	10.6°	2.3°	4.0°	3.9°	2.2°	9.4°
Global-X	-	-	-	-	0.7°	0.5°
Global-Y	-	-	-	-	2.3°	2.2°
Global-Z	-	-	-	-	1.2°	1.7°

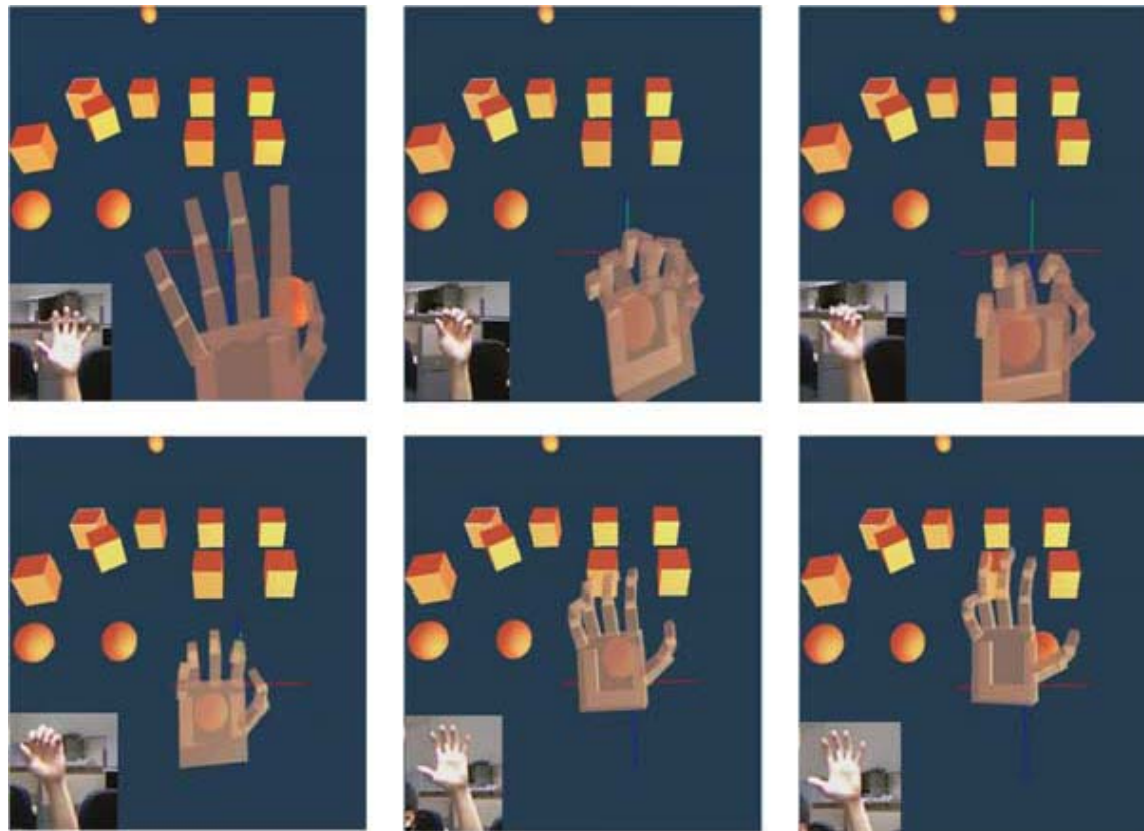
Experimental results

- Qualitative tests

[Real-world input test.wmv](#)

Experimental results

- Virtual Object Manipulation



Future Work

- Using data glove to learn the feasible static configuration and the motion dynamics of the hand
- More accurate virtual object grasping

Thank You!

