

Vision Based hand tracking for Interaction

The 7th International Conference on Applications and
Principles of Information Science (APIS2008)

Dept. of Visual Contents, Dongseo University

2008. 01. 29

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Outline

1. Purpose
2. System overview
3. Flow chart
4. Segmentation of a hand region
5. Matching stereo data
6. Conclusion
7. Future work

I. Introduction to hand tracking for interaction

1.1 Purpose

- ▶ Any user can interact anytime without any condition of space.
- ▶ More comfortable to use digital-device on public place.



1.2 Optical vs. computational reconstruction

▶ Hardware

- ▶ Bumblebee stereo camera
- ▶ Display device
- ▶ PC

▶ Software

- ▶ Image processing
- ▶ Stereo matching



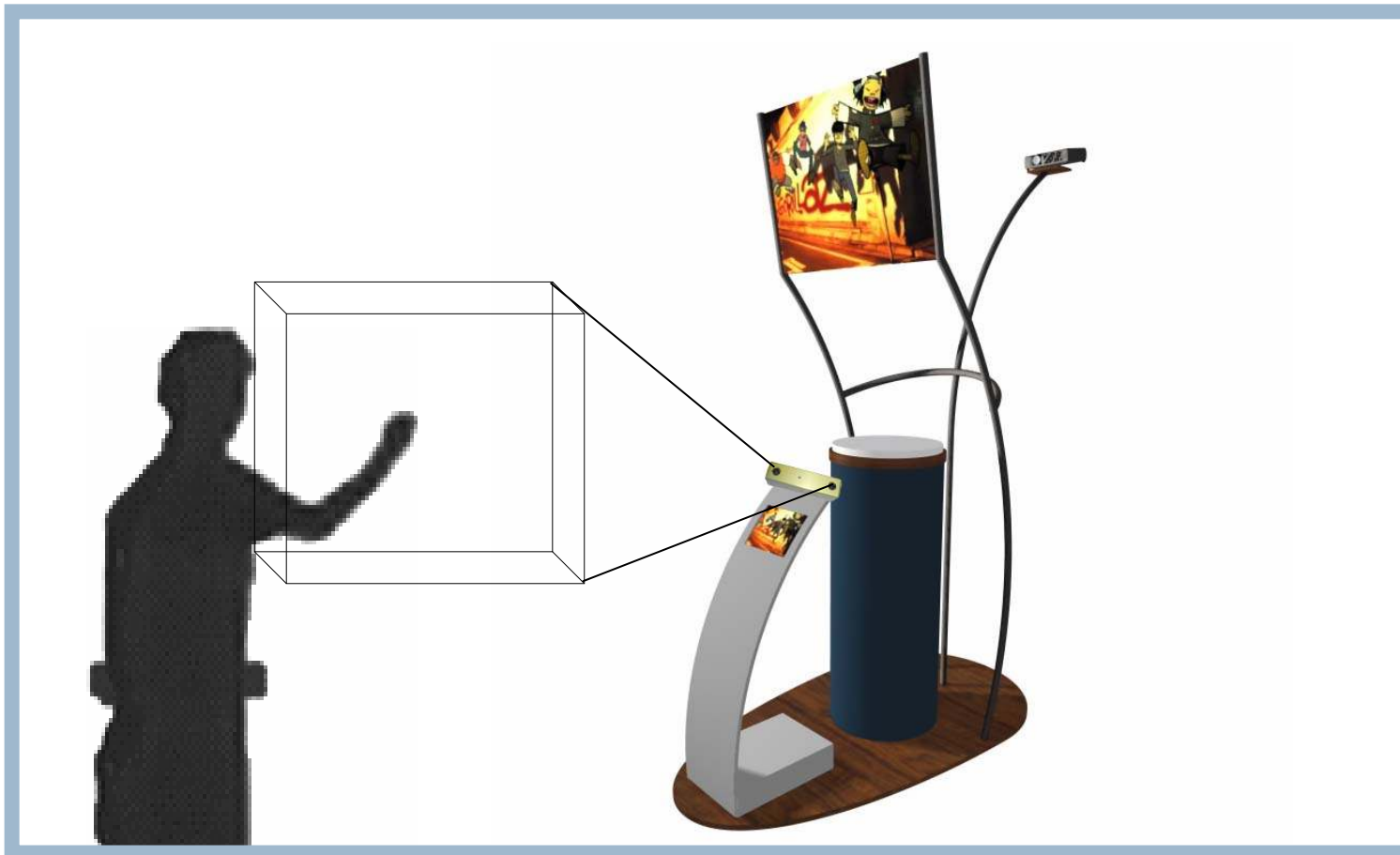
bumblebee™

Specifications:

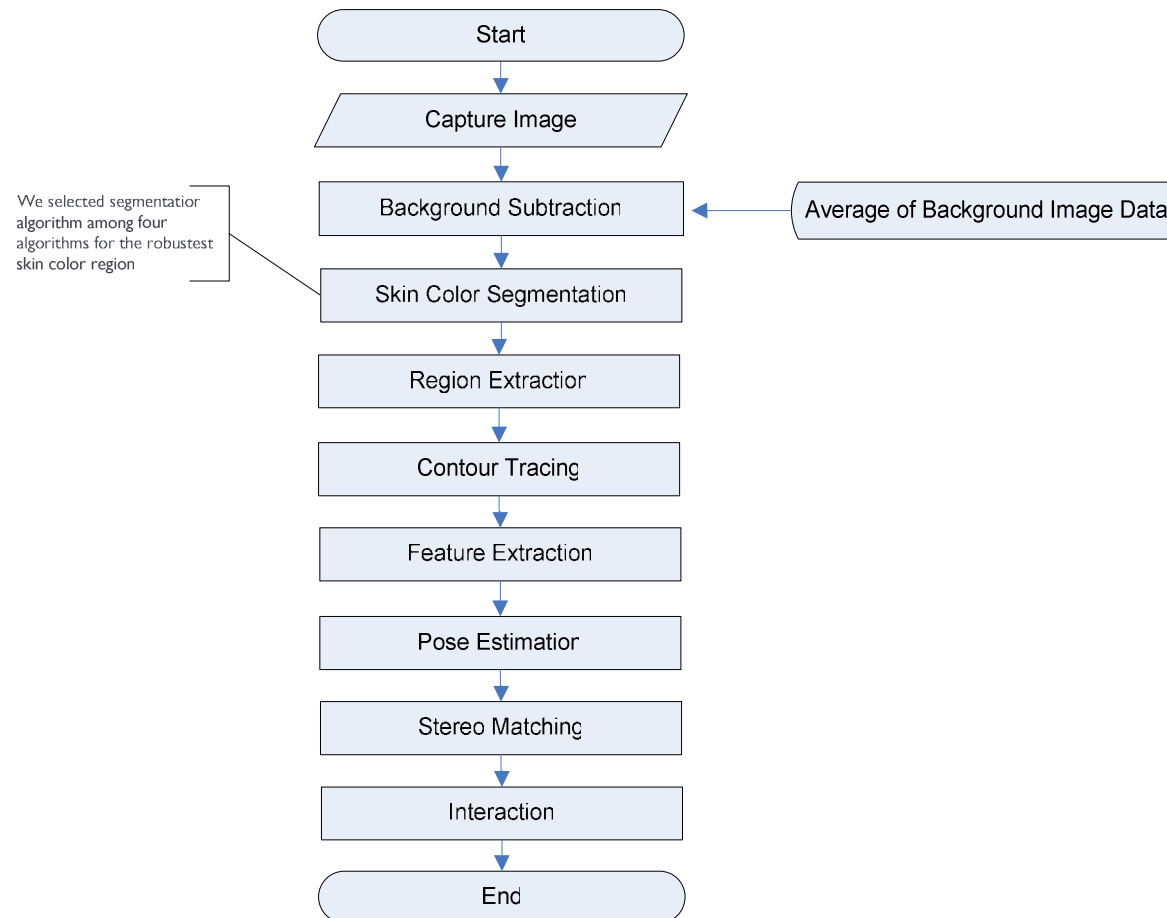
- 640x480 Option: two Sony ICX084 Color or BW CCDs
- 1024x768 Option: two Sony ICX204 Color or BW CCDs
- 1/3 inch, progressive scan CCDs
- 640x480 square pixels at 30 Hz frame rate
- 1024x768 square pixels at 15 Hz frame rate
- 10 bit A/D
- Shutter speed: 1/16000 to 1/30 second
- Baseline: 12cm
- Choice of 2mm, 4mm or 6mm focal length lenses (100°, 70°, and 50° HFOV respectively)

2. System overview

2.1 System architecture



2.2 Flow chart



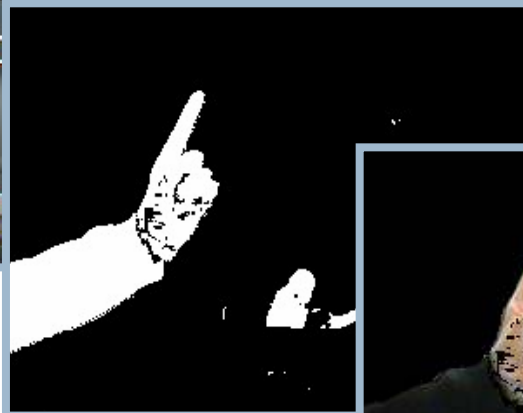
2.3 The segmentation of a hand region



[Background]



[Captured]



[Foreground]



[Subtraction]

$$I_f = \begin{cases} 255, & |I_i - I_b| > Threshold \\ 0, & otherwise \end{cases}$$

2.3 The segmentation of a hand region

▶ Detection algorithm

- ▶ Peer and Solina's 2003 [1]
- ▶ Hsu and Mottaleb Jain's Central 2002 [2]
- ▶ Hsu and Mottaleb Jain's Ellipse 2002 [2]
- ▶ M. Jones and J. Rehg's Color Histogram [3, 4]

[1] Kovac, J. Peer, P. Solina, F. "Human Skin Color Clustering for Face Detection", *The IEEE Region*, vol.2, pp.144-148, 2003.

[2] R.L.Hsu, M.Abdel-Mottaleb, A.K.Jain, "Face Detection in Colour Images", *IEEE transactions, on Pattern Analysis and Machine Intelligence*, vol.24, no.5, pp 696-706, 2002 .

[3] M. Jones, J. Rehg. "Statistical color models with application to skin", *In Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, Vol.1, pp.274-280, 2002.

[4] Shahzad Malik, "Real-time Hand Tracking and Finger Tracking for Interaction", CSC2503F Project Report, December 18, 2003.

2.3 The segmentation of a hand region

▶ Peer and Solina's 2003

* Uniform daylight illumination

$$R > 95, \quad G > 40, \quad B > 20 \quad \text{and}$$
$$\max\{R, G, B\} - \min\{R, G, B\} > 15 \quad \text{and}$$
$$|R - G| > 15 \quad \text{and} \quad R > G \quad \text{and} \quad R > B$$

OR

* Flashlight or light daylight

$$R > 220, \quad G > 210, \quad B > 170 \quad \text{and}$$
$$|R - G| \leq 15 \quad \text{and} \quad R > B \quad \text{and} \quad G > B$$

2.3 The segmentation of a hand region

▶ Hsu and Mottaleb Jain's Central 2002

$$W_{C_i}(Y) = \begin{cases} W_{LC_i} + \frac{(Y-Y_{min})(W_{C_i}-W_{LC_i})}{K_l-Y_{min}}; & Y < K_l \\ W_{HC_i} + \frac{(Y_{max}-Y)(W_{C_i}-W_{HC_i})}{Y_{max}-K_h}; & K_h < Y \\ W_{C_i}; & else \end{cases}$$

$$\bar{C}_b(Y) = \begin{cases} 108 + \frac{10(K_l-Y)}{K_l-Y_{min}}; & Y < K_l \\ 108 + \frac{10(Y-K_h)}{Y_{max}-K_h}; & K_h < Y \\ 108; & else \end{cases}$$

$$\bar{C}_r(Y) = \begin{cases} 154 - \frac{10(K_l-Y)}{K_l-Y_{min}}; & Y < K_l \\ 154 + \frac{22(Y-K_h)}{Y_{max}-K_h}; & K_h < Y \\ 108; & else \end{cases}$$

RGB to YCbCr

$$Y = 0.299R + 0.587G + 0.144B$$

$$C_b = -0.168R - 0.331G + 0.5B$$

$$C_r = 0.5R - 0.418G - 0.081B$$

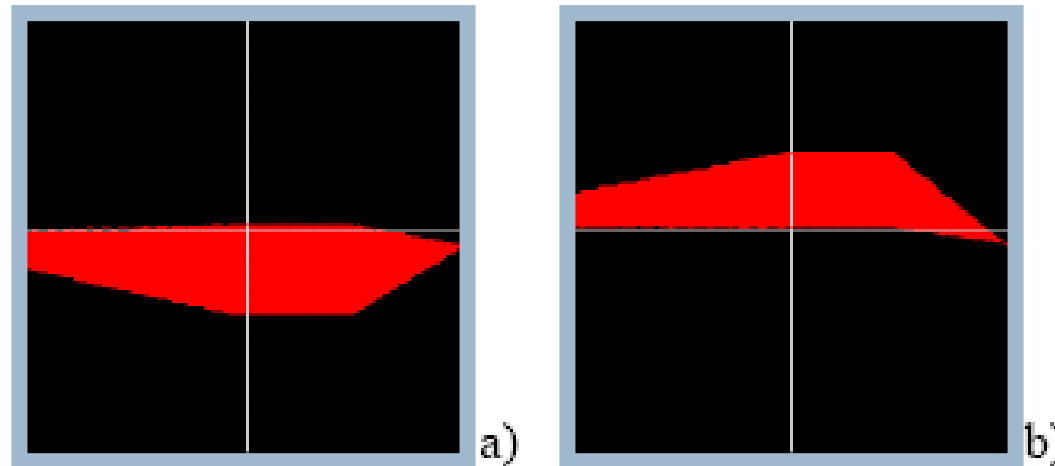
where i in $W_{C_i}(Y)$ is b or r , $W_{C_b} = 46.97$, $W_{LC_b} = 23$, $W_{HC_b} = 14$, $W_{C_r} = 38.76$,
 $W_{LC_r} = 20$, $W_{HC_r} = 10$, $K_l = 125$, $K_h = 188$, $Y_{min} = 16$, $Y_{max} = 235$

2.3 The segmentation of a hand region

▶ Hsu and Mottaleb Jain's Central 2002

$$\bar{C}_b(Y) - \alpha W_{C_b}(Y) < C_b < \bar{C}_b(Y) + \alpha W_{C_b}(Y), \quad : \text{a)}$$

$$\bar{C}_r(Y) - \alpha W_{C_r}(Y) < C_r < \bar{C}_r(Y) + \alpha W_{C_r}(Y) \quad : \text{b)}$$



2.3 The segmentation of a hand region

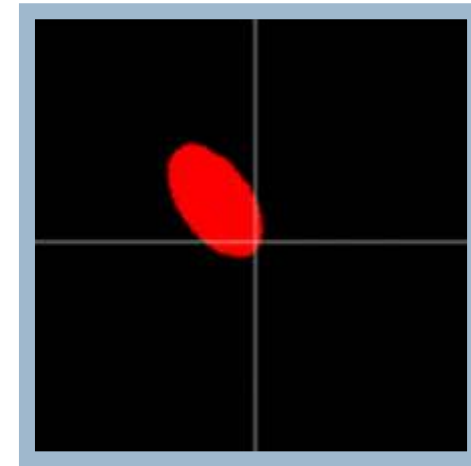
▶ Hsu and Mottaleb Jain's Ellipse 2002

$$\frac{(x - e_{cx})^2}{a^2} + \frac{(y - e_{cy})^2}{b^2} \leq 1$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} C_b - c_x \\ C_r - c_y \end{bmatrix}$$

$$c_x = 109.38, c_y = 152.02, \theta = 2.53 \text{radian}$$

$$e_{cx} = 1.6, e_{cy} = 2.41, a = 25.39, b = 14.03$$



[2] R.L.Hsu, M.Abdel-Mottaleb, A.K.Jain, "Face Detection in Colour Images", *IEEE transactions, on Pattern Analysis and Machine Intelligence*, vol.24, no.5, pp.696-706, 2002 .

2.3 The segmentation of a hand region

▶ M. Jones and J. Rehg's color histogram

$$P(rgb|skin) = \frac{s[rgb]}{T_s}$$

$$P(rgb| - skin) = \frac{n[rgb]}{T_n}$$

$$P(skin|rgb) = \frac{P(rgb|skin)P(skin)}{P(rgb|skin)P(skin) + P(rgb| - skin)P(-skin)}$$

$$P(skin) + P(-skin) = 1$$

$$P(skin) = \frac{T_s}{T_s + T_n}$$

$$P(skin|rgb) \geq \sigma_s$$

H_s : The skin histogram

H_n : The non-skin histogram

$s[rgb]$: The pixel count in bin rgb of H_s

$n[rgb]$: The pixel count in bin rgb of H_n

T_s : The total counts contained in H_s

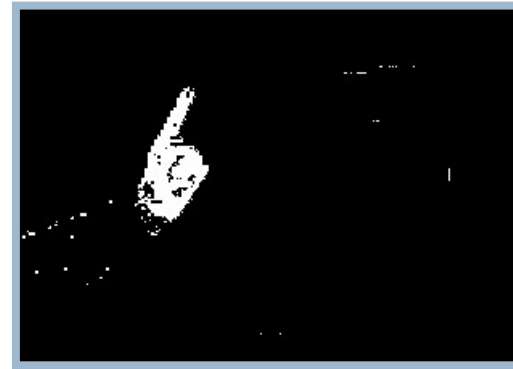
T_n : The total counts contained in H_n

2.3 The segmentation of a hand region

▶ Technique of region extraction



[Color image of background subtraction]



[Binary image of background subtraction]



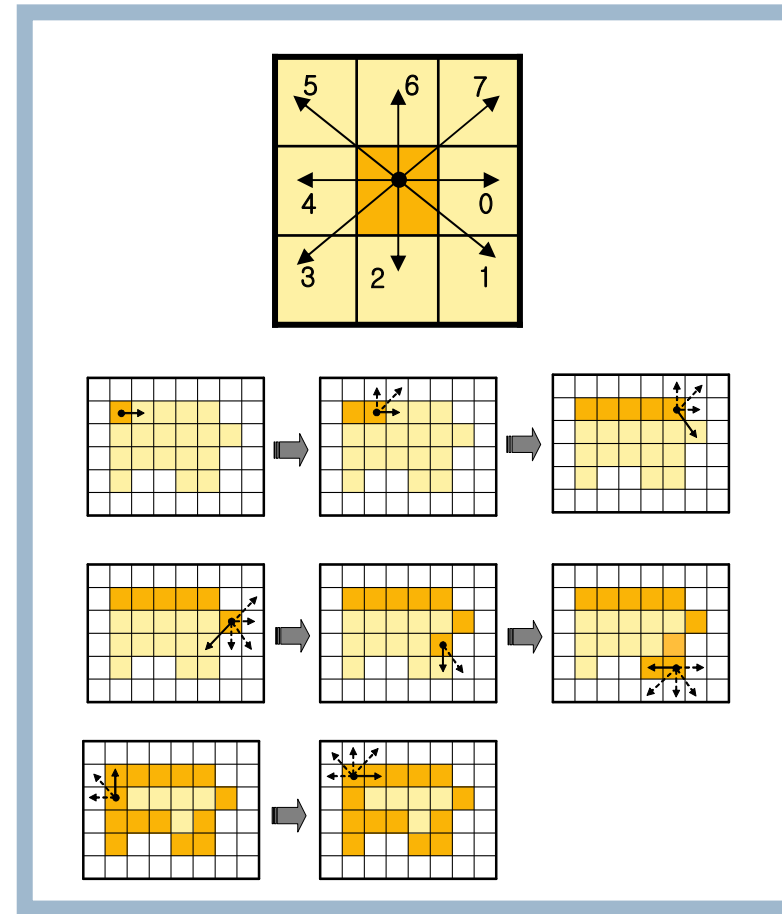
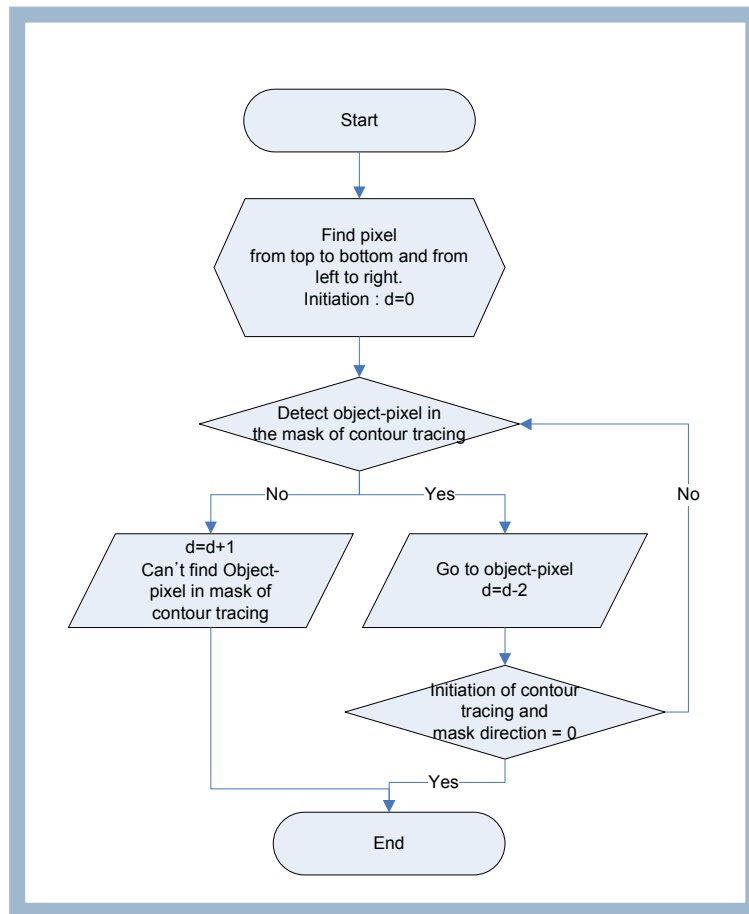
[Blob analysis of binary image]



[Binary morphological opening]

2.4 Detection of fingers

▶ Contour tracing with clockwise algorithm



[5] Image Processing Program by Visual C++ , Published by HANBIT Media, pp.672-679, Vol. 10, No. 1779, 2007.

2.4 Detection of fingers

- ▶ Result of contour tracing



[Result of binary morphological opening]



[Contour tracing result of feature extraction]

2.4 Detection of fingers

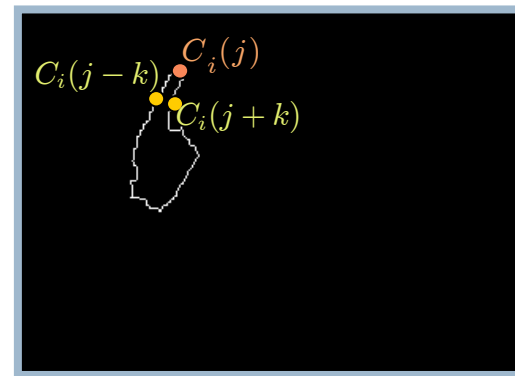
▶ Detection of peak point

- ▶ At each pixel j in a hand contour i
- ▶ Compute k-curvature θ_k
 - ▶ Angle between the two vectors $[C_i(j), C_i(j - k)]$ and $[C_i(j), C_i(j + k)]$ where, k is constant

▶ Peak point and valley point

- ▶ Peak point $\theta_k < \theta_{min}$
- ▶ Valley point $\theta_k > \theta_{max}$

where, $\theta_{min} = 90^\circ$, $\theta_{max} = 200^\circ$

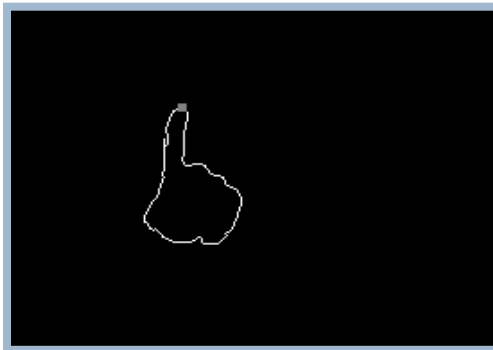


2.4 Detection of fingers

- ▶ Detection of peak point



[Peak point detection]



[Valley point detection]

2.4 Detection of fingers

- ▶ **Detection of midpoint**

- ▶ Define $cnorm(x)$ as:

$$cnorm(x) = \begin{cases} x + N & : x < 0 \\ x - N & : (x + 1) > N \\ x & : otherwise. \end{cases}$$

where N represent the number of points along the contour perimeter.

- ▶ **Midpoints represent the axis of the finger.**
 - ▶ $P(cnorm(i + k))$ is a point that is k points to the left along a hand contour
 - ▶ $P(cnorm(i - k))$ is a point to the right
 - ▶ Let i_{ft} is the index of a finger tip

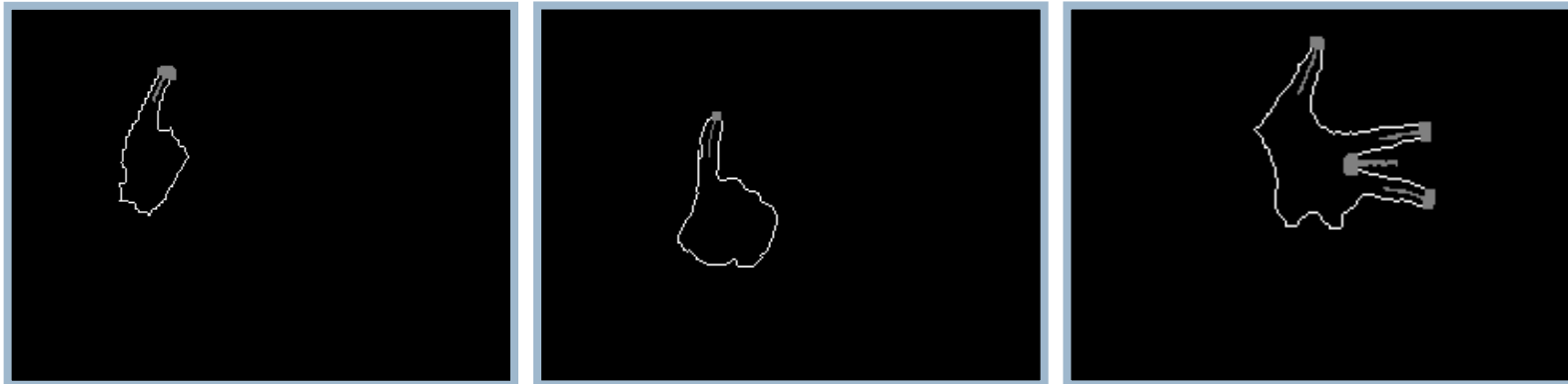
2.4 Detection of fingers

- ▶ Detection of midpoint

- ▶ A midpoint $Q(k)$

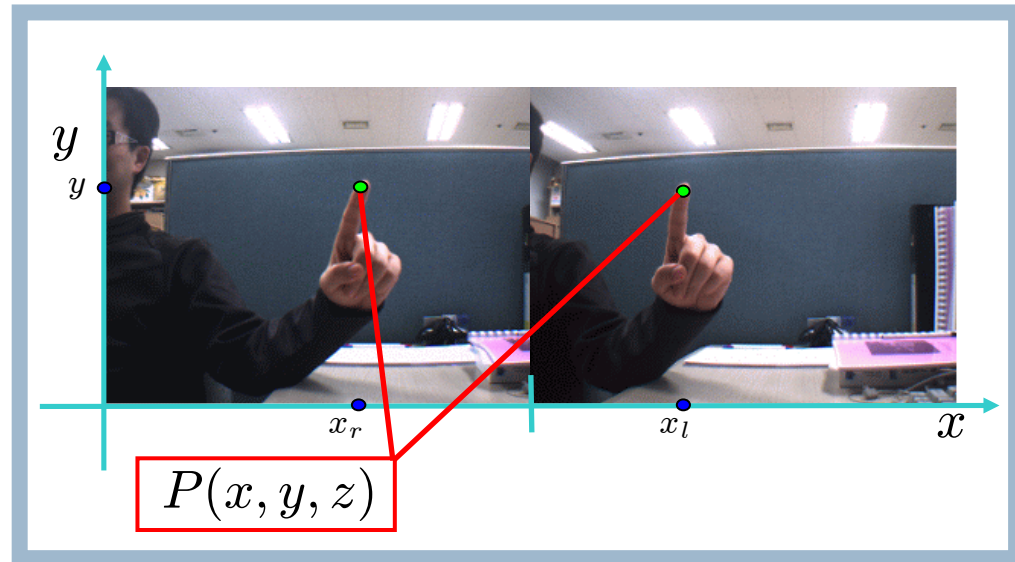
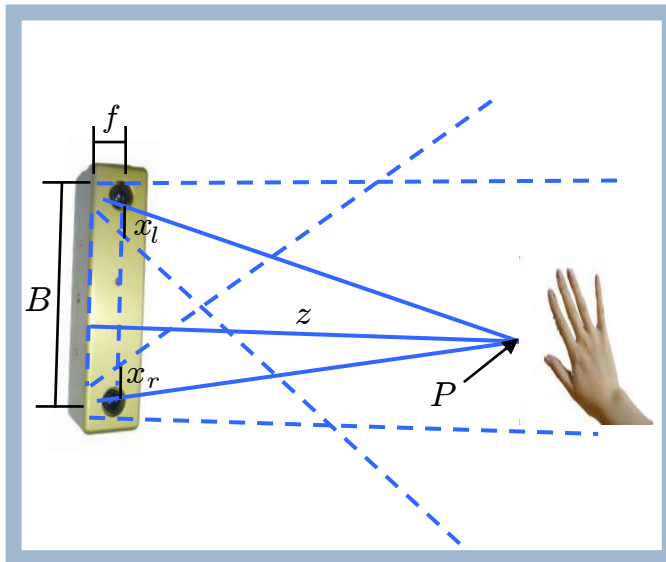
$$Q(k) = \frac{P(\text{cnorm}(i_{ft} + k)) + P(\text{cnorm}(i_{ft} - k))}{2}$$

- ▶ Compute $Q(k)$ for $k_{min} < k < k_{max}$



2.5 Matching stereo data

► Calculation of depth value



$$P_x = \frac{x_l + x_r}{2}, \quad P_y = \frac{y_l + y_r}{2} = y, \quad P_z = f \frac{B}{|x_l - x_r|}$$

$$D = \frac{P_z}{R \times C}$$

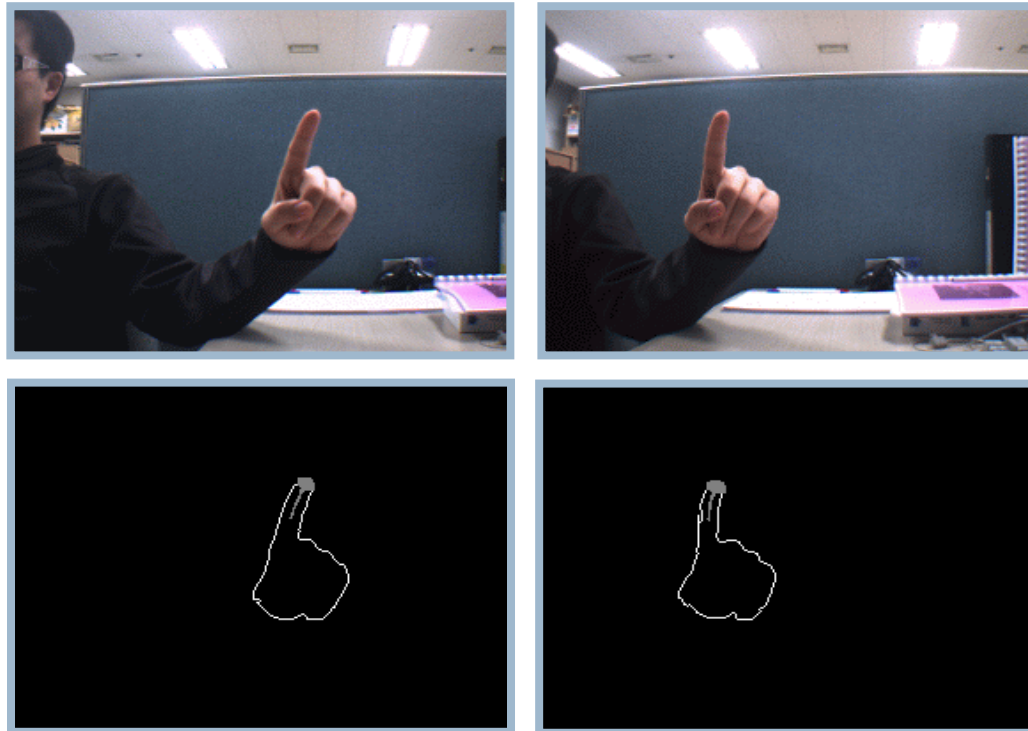
D : Distance using centimeter

R : Resolution ratio , C : CCD Sensor size

[6] Tomase Poggio, "Introductory Techniques for 3-D Computer Vision",
Massachusetts Institute of Technology, pp. 139-145, 1998.

2.5 Matching stereo data

- ▶ **Result of depth value**
 - ▶ Real distance \doteq 66 Cm
 - ▶ Calculated depth value : 67.5 Cm



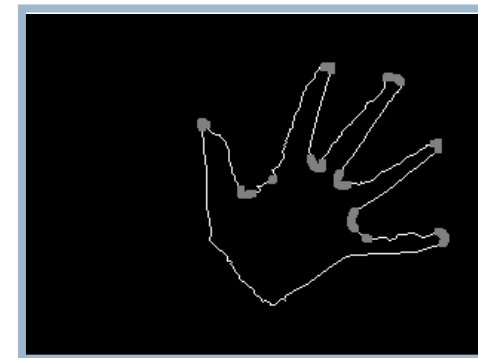
3. Conclusion

3.1 Conclusion

- ▶ The hardware costs very low.
- ▶ Hand tracking using an enhanced algorithm
- ▶ Interaction with system using user's hands
- ▶ Free of conditions of time & space

3.2 Future Work

- ▶ To perform a robust segmentation with ambient environment while detection the skin color.
- ▶ The determination of peak-point count and decision of location.
 - ▶ Gesture recognition performance
- ▶ To enhance the accuracy and speed of the system.
- ▶ Interaction using hands.



References

1. Kovac, J. Peer, P. Solina, F. “Human Skin Color Clustering for Face Detection”, The IEEE Region, vol.2, pp.144-148, 2003.
2. R.L.Hsu, M.Abdel-Mottaleb, A.K.Jain, “Face Detection in Colour Images”, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol.24, no.5, pp.696-706, 2002 .
3. M. Jones, J. Rehg. “Statistical color models with application to skin”, In Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Vol.1, pp.274-280, 2002.
4. Shahzad Malik, “Real-time Hand Tracking and Finger Tracking for Interaction”, CSC2503F Project Report, December 18, 2003.
5. “Image Processing Program by Visual C++”, Published by HANBIT Media, pp.672-679, Vol. 10, No.1779, 2007.
6. Tomase Poggio, “Introductory Techniques for 3-D Computer Vision”, Massachusetts Institute of Technology, pp.139-145, 1998.
7. George V. Paul, Glenn J. Beach, Charlesn J.Cohen, “A Real-time Object Tracking System using a Color Camera”, pp.137-142, 2001.
8. J. Segen, S. Kumar. “3D hand pose estimation using a single camera”, In Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Vol.1, pp.479-485, 1999.

Thank You