Vision Based hand tracking for Interaction

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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

1. 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

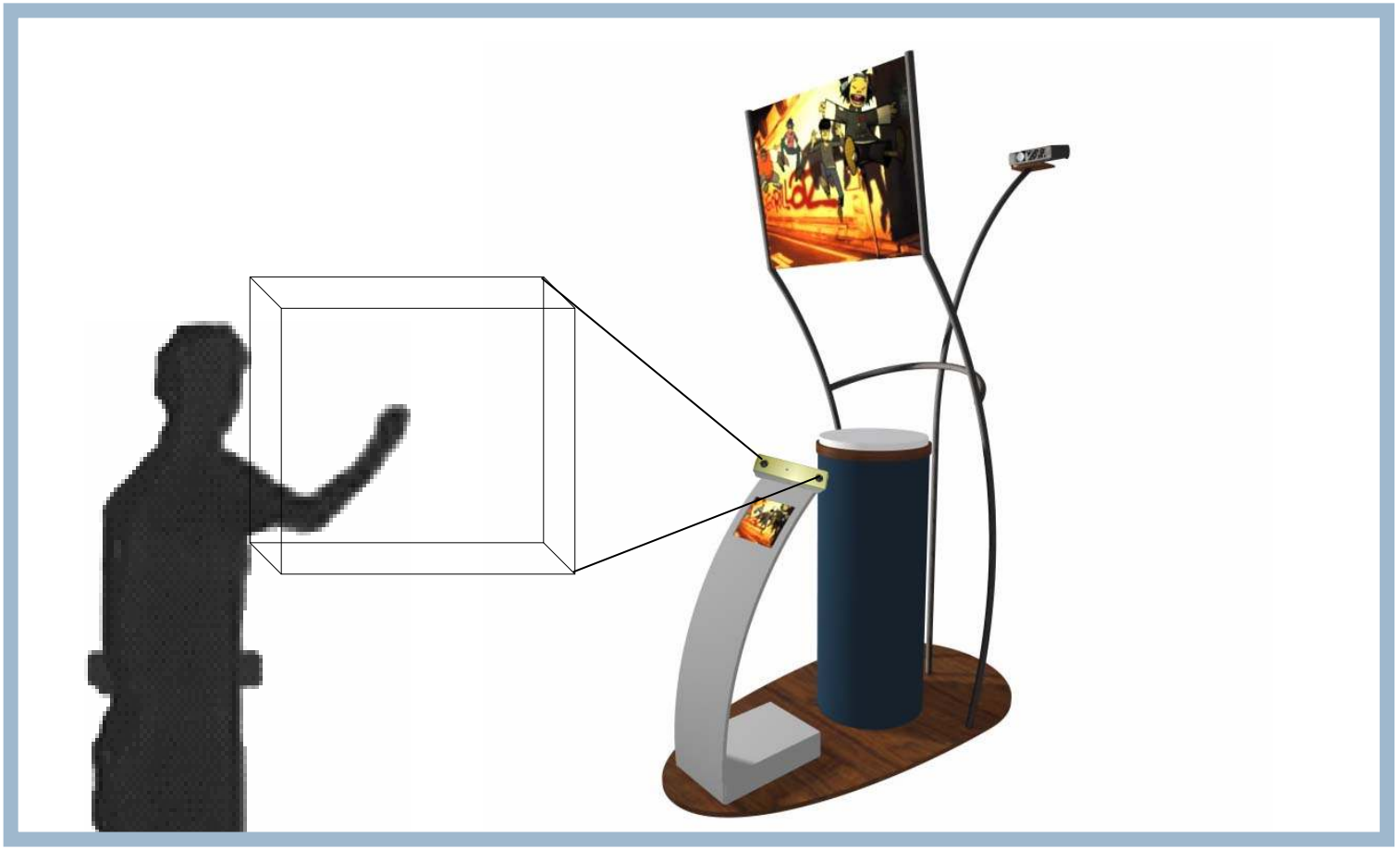
bumblebee™

Specifications:

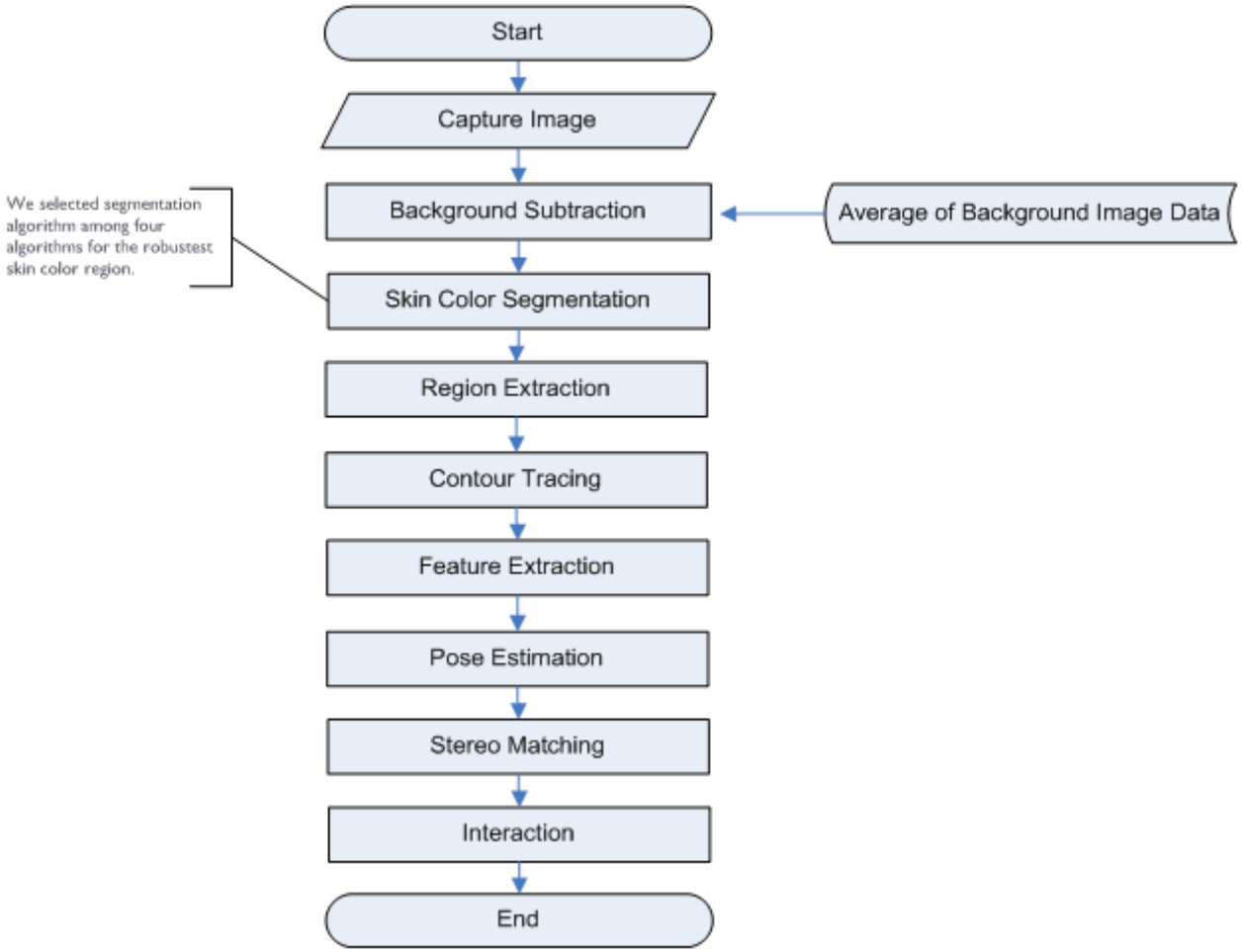
- 640x480 Option: two Sony ICX084 Color or BW CCDs
- 1024x768 Option: two Sony ICX204 Color or BW CCDs
- 1/3 inch, progressive scan CCDs
- 640x480 square pixels at 30 Hz frame rate
- 1024x768 square pixels at 15 Hz frame rate
- 10 bit A/D
- Shutter speed: 1/16000 to 1/30 second
- Baseline: 12cm
- Choice 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

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

$$OR$$

* Flashlight or light daylight

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

2.3 The segmentation of a hand region

- Hsu and Mottaleb Jain's Central 2002

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

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

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

$RGB\ to\ YC_bC_r$

$$Y = 0.299R + 0.587G + 0.144B$$
$$C_b = -0.168R - 0.331G + 0.5B$$
$$C_r = 0.5R - 0.418G - 0.081B$$

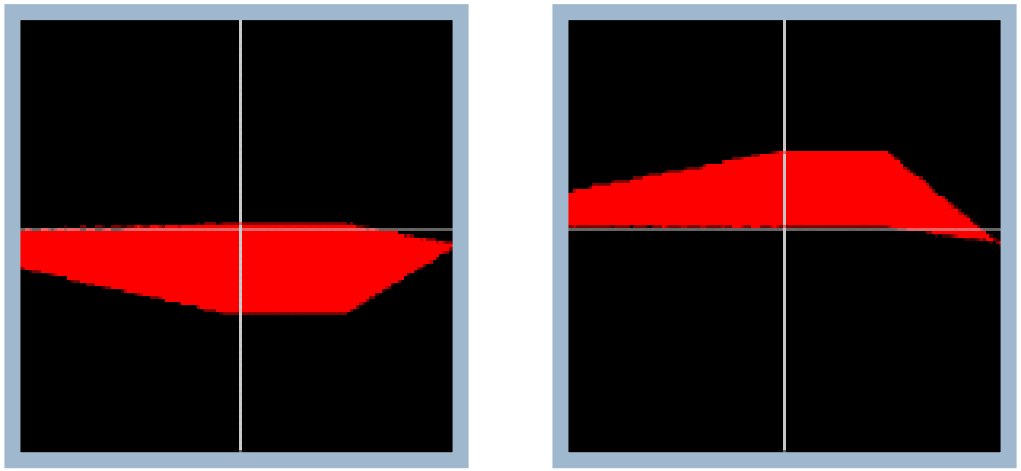
$where\ i\ in\ W_{Ci}(Y)\ is\ b\ or\ r, W_{Cb} = 46.97, W_{LCb} = 23, W_{HCb} = 14, W_{Cr} = 38.76,$
$W_{LCr} = 20, W_{HCr} = 10, K_l = 125, K_h = 188, Y_{min} = 16, Y_{max} = 235$

2.3 The segmentation of a hand region

- Hsu and Mottaleb Jain's Central 2002

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

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



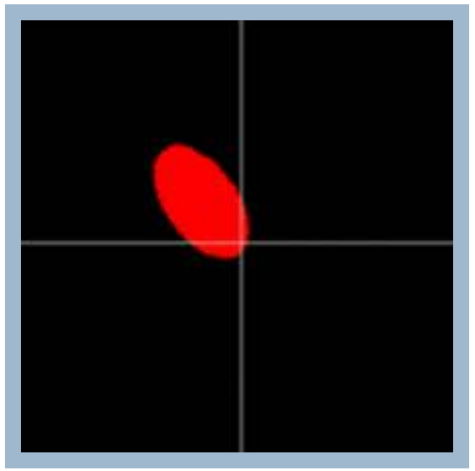
a) b)

2.3 The segmentation of a hand region

- Hsu and Mottaleb Jain's Ellipse 2002

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

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



$$c_x=109.38, c_y=152.02, \theta=2.53 radian$$

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

[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

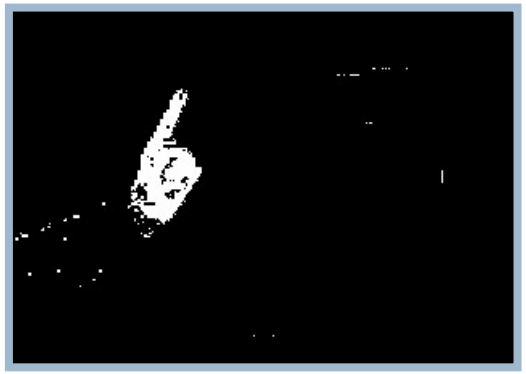
T_s : The total counts contained in H_s

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]



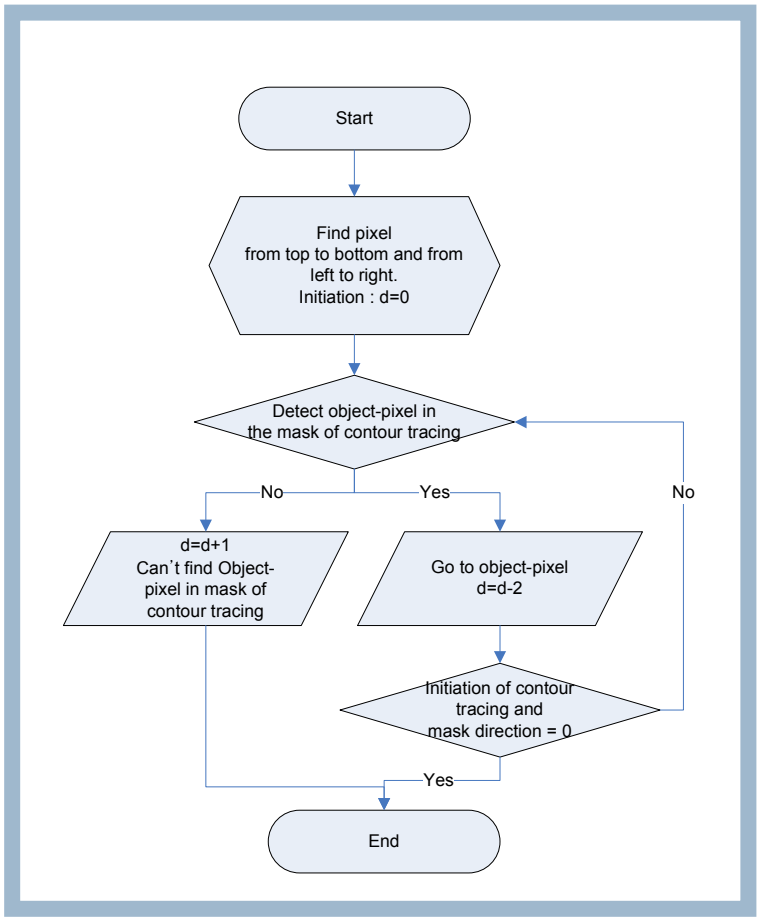
[Binary image of background subtraction]

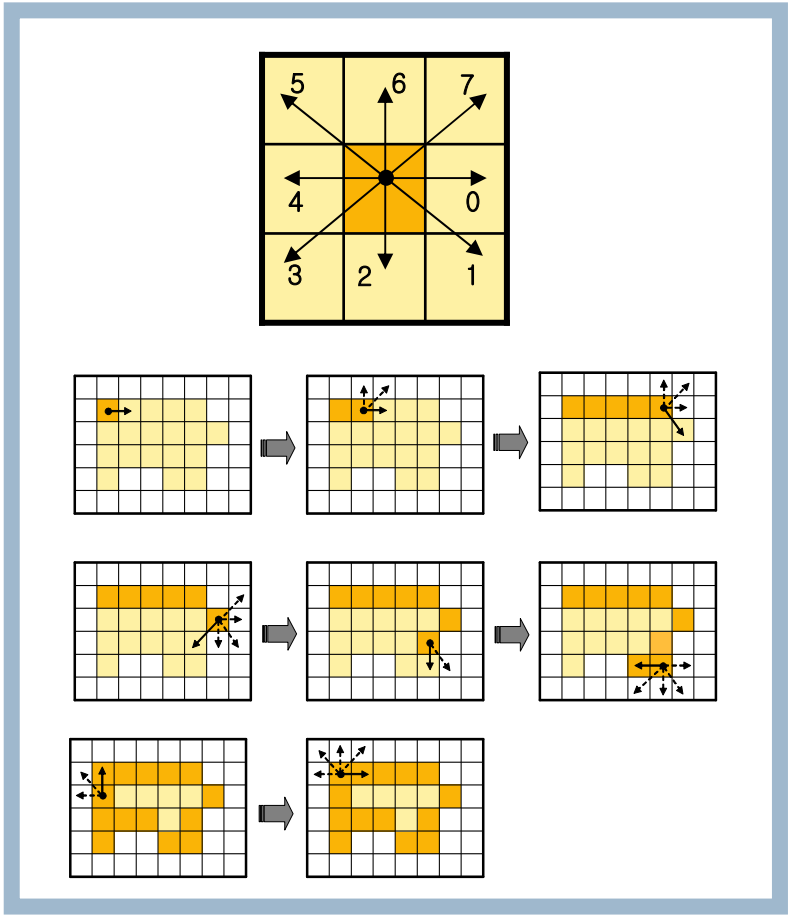
[Blob analysis of binary image]

[Binary morphological opening]

2.4 Detection of fingers

- Contour tracing with clockwise algorithm

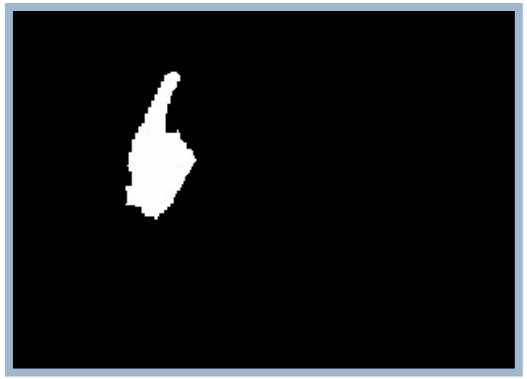




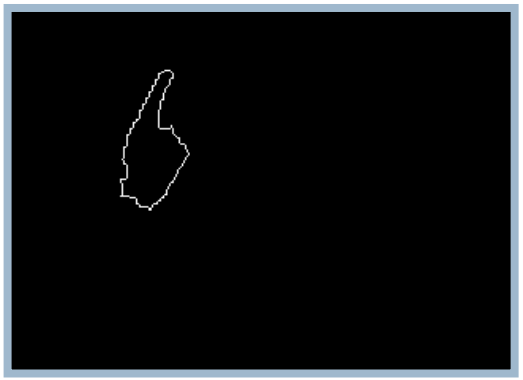
[5] Image Processing Program by Visual C++ , *Published by HANBIT Media*, pp.672-679, Vol. 10, No. 1779, 2007.

2.4 Detection of fingers

- Result of contour tracing



[Result of binary morphological opening]



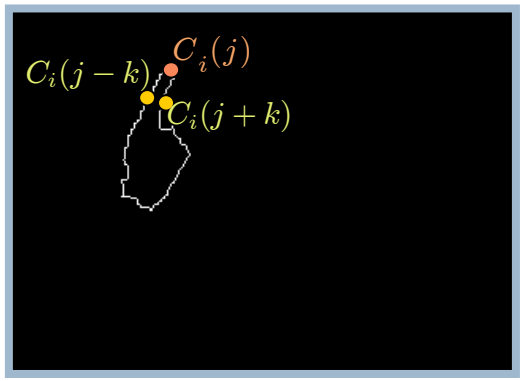
[Contour tracing result of feature extraction]

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 $\theta_k > \theta_{max}$

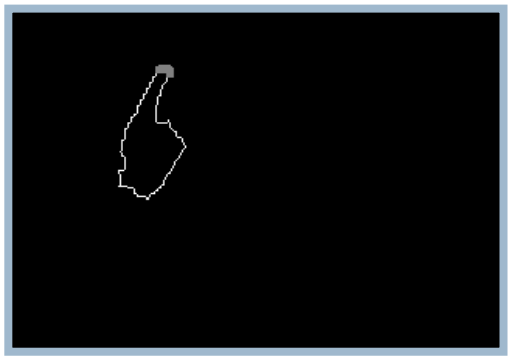
    $where,\ \theta_{min} = 90^\circ,\ \theta_{max} = 200^\circ$



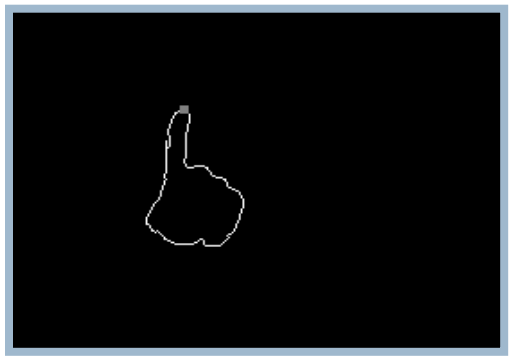
[4] Shahzad Malik, "Real-time Hand Tracking and Finger Tracking for Interaction", CSC2503F Project Report, December 18, 2003.

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

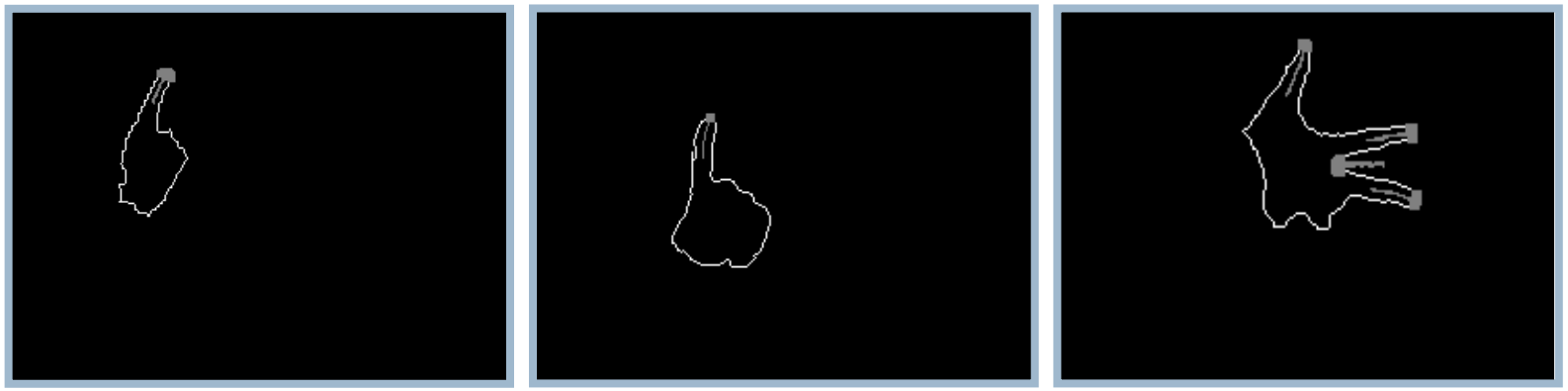
[4] Shahzad Malik, "Real-time Hand Tracking and Finger Tracking for Interaction", CSC2503F Project Report, December 18, 2003.

2.4 Detection of fingers

- Detection of midpoint
  - A midpoint $Q(k)$

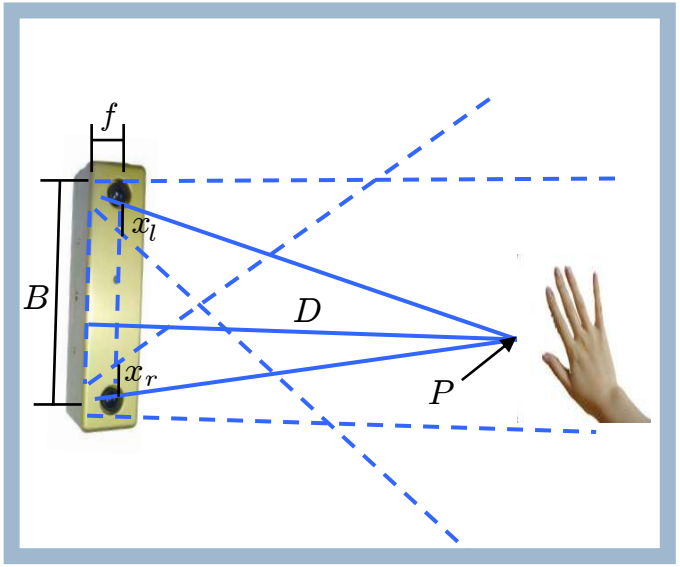
$$Q(k) = \frac{P(cnorm(i_{ft} + k)) + P(cnorm(i_{ft} - k))}{2}$$

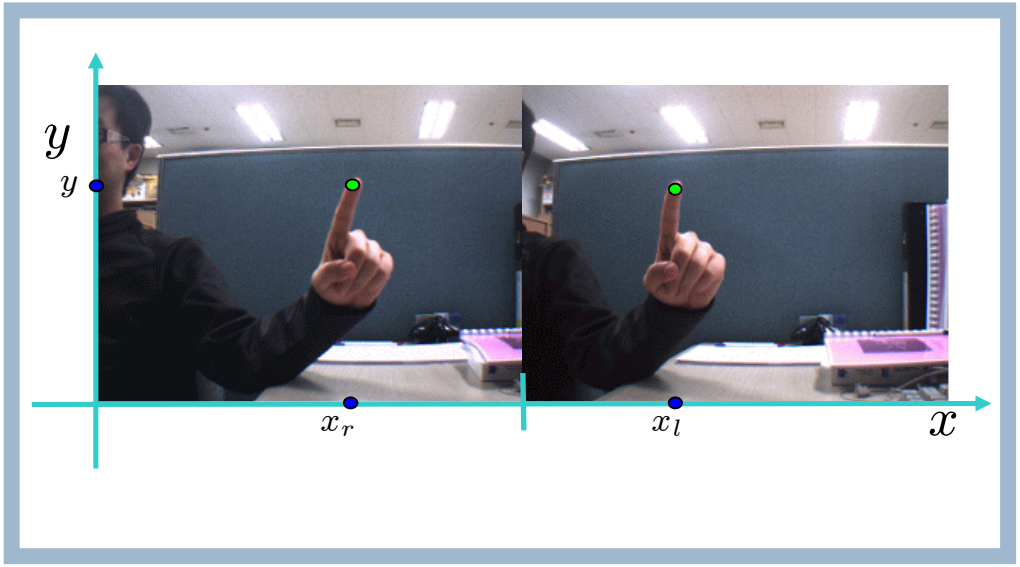
  - Compute $Q(k)$ for $k_{min} < k < k_{max}$



2.5 Matching stereo data

- Calculation of depth value





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

$$D = \frac{P_z}{RC}$$

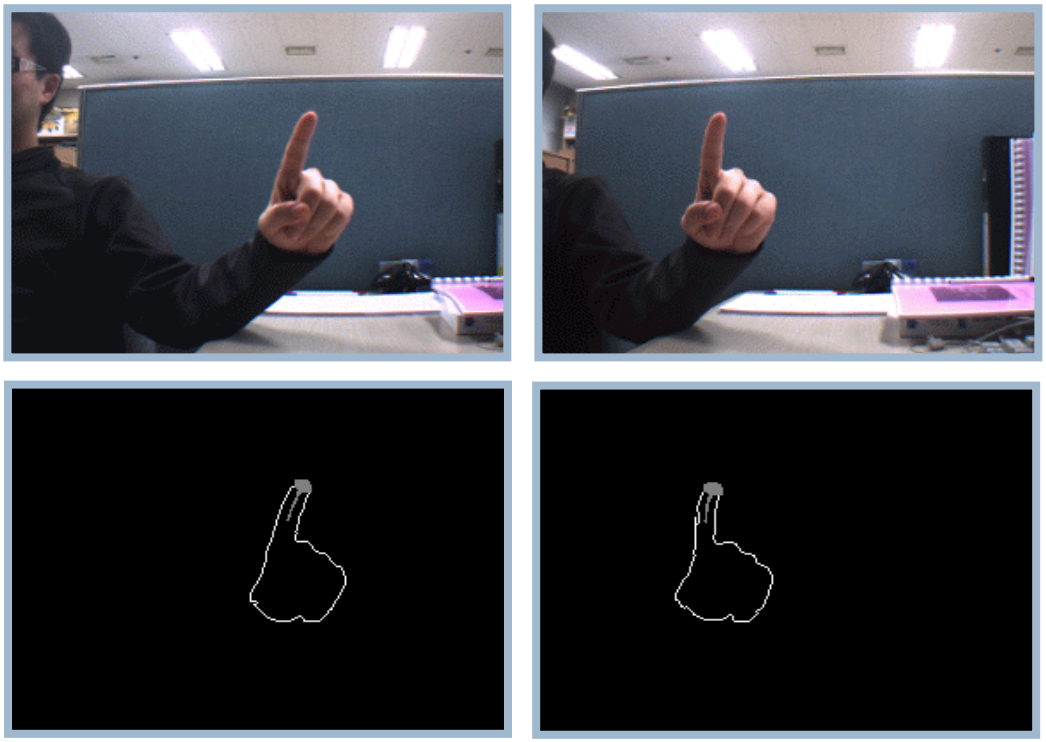
D : Distance using centimeter

R : Resolution ratio , C : CCD Sensor size

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

2.5 Matching stereo data

- Result of depth value
  - Real distance ≒ 66 Cm
  - Calculated depth value = 67.5 Cm



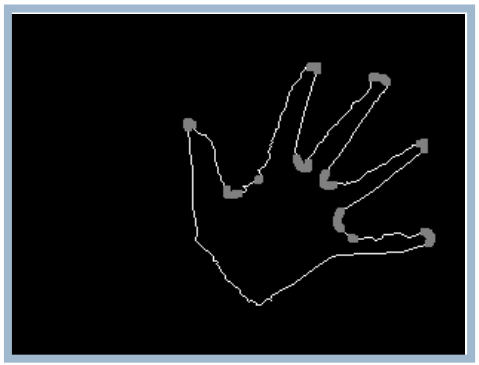
3. Conclusion

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", Massachussetts 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