Development of an intuitive Man-machine interface using facial special feature points
顔特徴点を利用して直観的なマンマシンインタフェースの開発

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Interface Based on Facial Orientation
Aging Society with fewer children

Demand of Auto-wheelchair is higher in recent years

In Japan
Over 65 years old people = 29 millions  
(22.7% of Japanese population)
Existed interface for Auto-Wheelchair

→ Joystick is mainly utilized

Theme

Physical handicapped persons needs other interface.

Non-contact interface is available
Intuitive operations

In this study

Face orientation was used as an interface
Changes in nostril area

Both areas are increased
Left area is decreased
Right area is decreased

Up
Left Center Right
Down

Both areas are decreased

Nostril areas were reflected on recognition
Flow of image processing

USB Camera
- 320 × 240 [dots]
- RGB24
- 30 [fps]

PC
- Windows XP
- CPU core 2 duo 2.4GHz

Development
Microsoft C#2007
Nostril image

Nostril area

\[ S_{Left/Right} = \sum_{i} \sum_{j} g[i, j] \]

\[ g[i, j] = \begin{cases} 1 & (R[i, j] < \varepsilon) \\ 0 & (R[i, j] \geq \varepsilon) \end{cases} \]

\[ R[i, j]: 8 \text{ bit brightness of R} \]
\[ \varepsilon: \text{Threshold} \]

Where

\[ \sum_{ij} \]
\[ S_{Left} \]
\[ S_{Right} \]
\[ (i, j) \]

Processed area

\[ \sum_{xy} \]
\[ (x_0, y_0) \]
\[ (x, y) \]
Both nostril areas

Area data:  - $S_{\text{Left}}$  - $S_{\text{Right}}$

Time (sec)

Area $A(\text{dot})$

Center  Up  Down  Left  Right
Up and down recognitions

### Upward recognition

\[(S_{Left} - S_{L0} > t_{UL}) \cap (S_{Right} - S_{R0} > t_{UR})\]

Where
- \(S_{L0}\): Initial left nostril area
- \(S_{R0}\): Initial right nostril area
- \(u_{UL}\) \(u_{UR}\): Threshold of position

### Downward recognition

\[(S_{L0} - S_{Left} > t_{DL}) \cap (S_{R0} - S_{Right} > t_{DR})\]

Where
- \(u_{DL}\) \(u_{DR}\): Threshold of position
Left and right directions

Span decreases

Left direction

\[ (S_{R-L} > v_l) \cap (x_{dis} > w_{dis}) \]

Where

\[ S_{R-L} = S_{Right} - S_{Left} \]
\[ x_{dis} = (x_{R0} - x_{L0}) - (x_R - x_L) \]

\( v_l \): Threshold of area difference

\( w_{dis} \): Threshold of span

\( x_{L0} \): Initial position

Right direction

\[ (S_{L-R} > v_r) \cap (x_{dis} > w_{dis}) \]

Where

\[ S_{L-R} = S_{Left} - S_{Right} \]

\( v_r \): Threshold of area difference

Initial position

\( x_{R0} \): Initial position
Procedure field

User’s face wasn’t constrained

Problem
Nose protrudes beyond rectangle

VTR Problem 1
Tracking for nostrils

Movement of origin $\sum_{ij}$

\[
\begin{align*}
    x_0^{(t)} &= x_0^{(0)} + \Delta x_{\text{Left} / \text{Right}}^{(t)} \\
    y_0^{(t)} &= y_0^{(0)} + \Delta y_{\text{Left} / \text{Right}}^{(t)}
\end{align*}
\]

Where

\[
\begin{align*}
    \Delta x_{\text{Left} / \text{Right}}^{(t)} &= x_{\text{Left} / \text{Right}}^{(t)} - x_{\text{Left} / \text{Right}}^{(0)} \\
    \Delta y_{\text{Left} / \text{Right}}^{(t)} &= y_{\text{Left} / \text{Right}}^{(t)} - y_{\text{Left} / \text{Right}}^{(0)}
\end{align*}
\]

Initial state
Positions of both nostrils

Coordinates of left nostrils

\[
\begin{align*}
x_{Left}^{(t)} &= \frac{a/2}{\sum_{i=0}^{a/2} \sum_{j=0}^{b} i \cdot g[i, j]} + \frac{a/2}{\sum_{i=0}^{a/2} \sum_{j=0}^{b} g[i, j]} \cdot x_0^{(t)} \\
y_{Left}^{(t)} &= \frac{a/2}{\sum_{i=0}^{a/2} \sum_{j=0}^{b} j \cdot g[i, j]} + \frac{a/2}{\sum_{i=0}^{a/2} \sum_{j=0}^{b} g[i, j]} \cdot y_0^{(t)}
\end{align*}
\]

Coordinates of right nostrils

\[
\begin{align*}
x_{Right}^{(t)} &= \frac{a}{\sum_{i=a/2}^{a} \sum_{j=0}^{b} i \cdot g[i, j]} + \frac{a}{\sum_{i=a/2}^{a} \sum_{j=0}^{b} g[i, j]} \cdot x_0^{(t)} \\
y_{Right}^{(t)} &= \frac{a}{\sum_{i=a/2}^{a} \sum_{j=0}^{b} j \cdot g[i, j]} + \frac{a}{\sum_{i=a/2}^{a} \sum_{j=0}^{b} g[i, j]} \cdot y_0^{(t)}
\end{align*}
\]
VTR (Test trial)
Application of Auto-Wheel chair
Control system

Controller

Image

Up
Left Center Right Down

USB Camera

Control System

IO Card
H8/3694 Tiny Micro Computer
PC
Servo Controller
Assignment of operations

MODE
Stop

RIGHT? CENTER? LEFT? DOWN?

MODE
Go-forward

RIGHT? CENTER? LEFT? DOWN?

Counter-clockwise turning
Clockwise turning
Stop
Go-back
Turn left
Go-forward
Turn right

Over 5 sec. ?

NO
YES
Scene 1 (Turning)
Scene2 (Go-forward)
Scene3 (Go-forward and turn)
Interface Based on Gazing Actions
Back Ground

Text description has shifted to electric media

Rehabilitation Field
There are needs of a page tuner machine to read a printed book for enabled persons

「Book Time」
(Nishizawa Electro. Corp.)

「Readable 3」
(Double Tech. Corp.)
General interface for page tuner machine
→ Button, Joystick, Breath switch (Contact type switch)

Dorsal position (on the bed) friction between a pillow and user head → Physical burden

In this research

Development of an intuitive interface for page tuner control

Gazing action was used for operation
Printed book is treated
- User doesn’t touch a book
- Machine turns over a page according to user’s sign
Page turner machine

Electro magnet picked up a clip and turned over a page

Page turning scene
Control system

System
   Capture image

USB camera
   Arm
   LED

Clip
   Book

Micro computer
   Motor
   Electromagnet
   IO

Gazing a camera
   Yes
   Manipulation mode
   Gazing left
   Gazing right

No
Measurement system

System

Operator’s face

USB camera

Input image into a PC

Bitmap

Recognition

Operation

Camera spec

- 320 × 240 [pixels]
- RGB 24
- 30[fps]

Control PC

- Windows XP
- CPU core2Quad

Development software

Microsoft Visual C# 2010
Image processing

**Equation**

\[ g_k(i,j) = \begin{cases} 1 & (r[i,j] \leq t) \\ 0 & (r[i,j] > t) \end{cases} \]

\( r[i,j] \) : Brightness  \( t \) : Threshold

**Influence of threshold**

- **Pupil**
  - \( t = 10 \)
  - \( t = 50 \)

- Inner and outer corner
  - \( t = 40 \)
  - \( t = 80 \)
Detection of feature points

Pupil

Center of gravity

\[
x_{pl/pr} = \frac{\sum \sum i \cdot g(i, j)}{\sum \sum g(i, j)},
\]

\[
y_{cl/cr} = \frac{\sum \sum j \cdot g(i, j)}{\sum \sum g(i, j)}.
\]

Procedure field

Variable threshold

Inner and outer corner

Outer corner

\(x_{cl/cr}, y_{cl/cr}\)

Inner corner

\(x_{hl/hr}, y_{hl/hr}\)

Limited

10 pixels

10 pixels

40 pixels
Proposed system is independent of changes in the brightness of surrounding environment

Blinking problem

Blinking disturbs feature points detection

\[
\begin{align*}
\sum_{i} \sum_{j} (i \cdot g(i, j)) & = \sum_{i} \sum_{j} j \cdot g(i, j) \quad (A > a) \\
x_{pl/pr} = u_{pl/pr}, \quad y_{cl/cr} = v_{pl/pr} \quad (A \leq a) \\
A & : \text{Pupil area} \quad u_{pl/pr}, v_{pl/pr} : \text{previous time position} \\
a & : \text{Threshold}
\end{align*}
\]
Recognition in horizontal direction

Pre-experiment

Subject gazed ten targets in order

Evaluation

\[ J_H = \frac{\Delta x_l}{\Delta x_r} \]

Left eye  Right eye

Subject

Panel

USB camera

Subject

500 mm

200 mm

130 mm
Value $J_H$ according to gazing direction

Horizontal gazing direction was easily judged
Recognition in vertical direction

(a) Gazing the USB camera

(b) Reading a book

Eye shape is changed by gazing direction
Recognition in vertical direction

Evaluation

\[ Q = \frac{a - bf - \frac{bd}{e} + bc}{1 - \frac{b}{e}} \]

\[ a = \frac{y_{cl} + y_{pl}}{2} \]
\[ b = \frac{x_{cl} + x_{pl}}{y_{cl}y_{pl}} \]
\[ c = \frac{x_{cl} + x_{pl}}{2} \]
\[ d = \frac{y_{pl} + x_{hl}}{2} \]
\[ e = \frac{x_{pl} + x_{hl}}{y_{pl} - y_{hl}} + 0.00001 \]
\[ f = \frac{x_{pl} + x_{hl}}{2} \]

Reading mode

\[ J_v = Q - y_{pl} \leq 0 : \text{Gazing lower} \]

Operation mode

\[ J_v = Q - y_{pl} > 0 : \text{Gazing upper} \]
Time trajectory of operation

Camera

- upper
- lower
- right
- center
- left

Recognition

- Gazing camera
  \( (J_V > 0) \cap (0.75 < J_H < 1.15) \)
- Gazing left
  \( (J_V > 0) \cap (J_H \leq 0.75) \)
- Gazing right
  \( (J_V > 0) \cap (1.15 \leq J_H) \)
- Reading book
  \( (J_V \leq 0) \)

Page tuner operation

Camera

- Left
- Right
- Lower camera

Time trajectory of operation
Operation method

1. Reading
2. Gazing camera
3. Waiting for input (LED is illuminated)
4. Gazing
5. Operation execution

Gazing zone
USB camera
LED

Gazing over 2 sec

Gazing

① Reading
② Gazing camera
③ Waiting for input (LED is illuminated)
④ 視線で操作
⑤ 操作実行
Conclusions

Development of an intuitive gazing interface for page tuner control

Proposed system

- Recognition of upper and lower gazing was based on eye shape
- Reading and operating states could be judged
- Proposed system doesn't need calibration
Summary

An intuitive Interface can produce a new interactions.

- Not Gazing ➔ Joystick
- Gazing ➔ Ready
- Head tilting ➔ Operating
Thank you!!