Development of an intuitive Man-machine interface using facial special feature points

顔特徴点を利用した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

Back ground

In Japan

Over 65 yeas old people = 29 millions

（22.7% of Japanese population）

Aging Society with fewer children

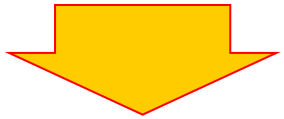
→ Demand of Auto-wheelchair is higher in recent years

Existed interface for Auto-Wheelchair

→ Joystick is mainly utilized

Theme

Physical handicapped persons needs other interface.



Non-contact interface is available

Intuitive operations

Up

Down

Left

Center

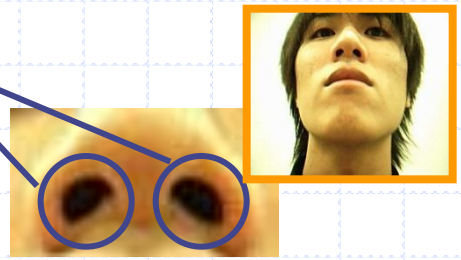
Right

In this study

Face orientation was used as an interface

Changes in nostril area

- Both areas are increased

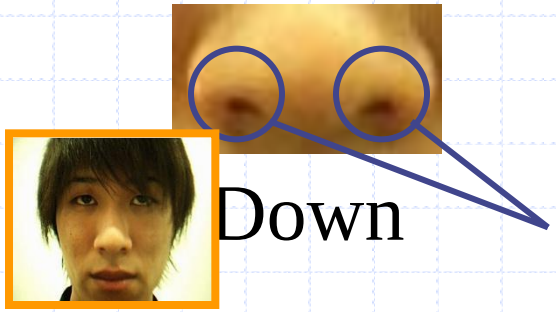


Up

Left area is decreased

Right areais decreased

Left Center Right

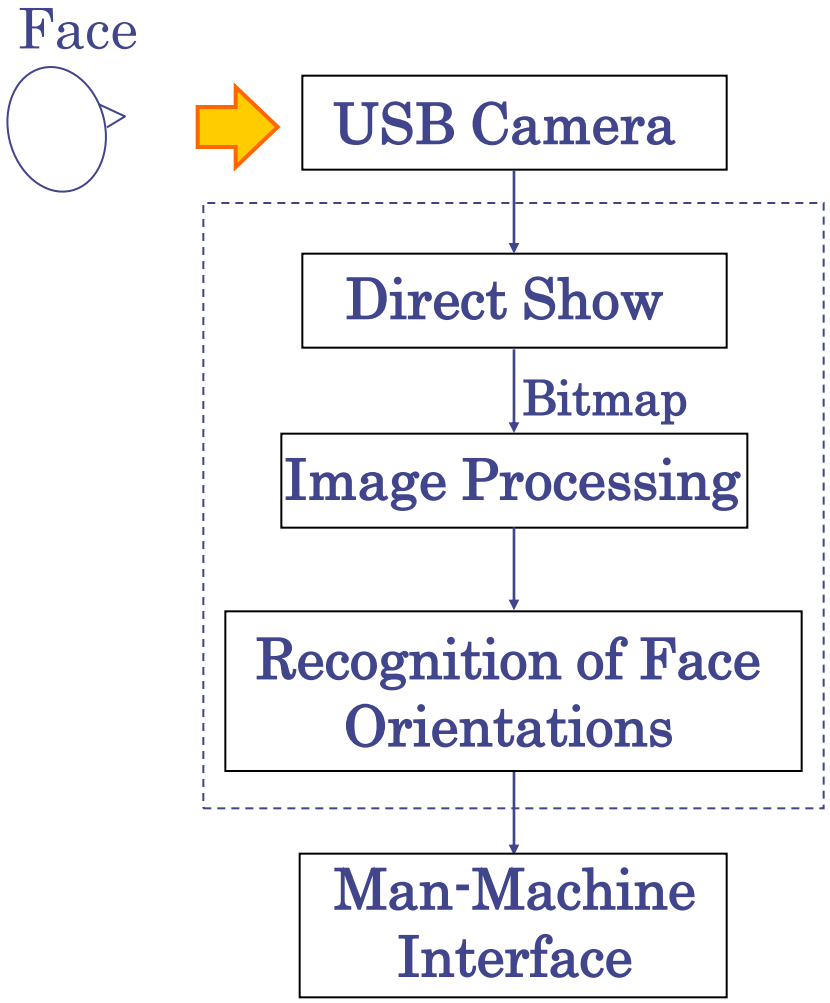


Down

Both areas are decreased

Nostril areas were reflected on recognition

Flow of image processing



USB camera

- 320 × 240 [dots]
- RGB24
- 30 [fps]

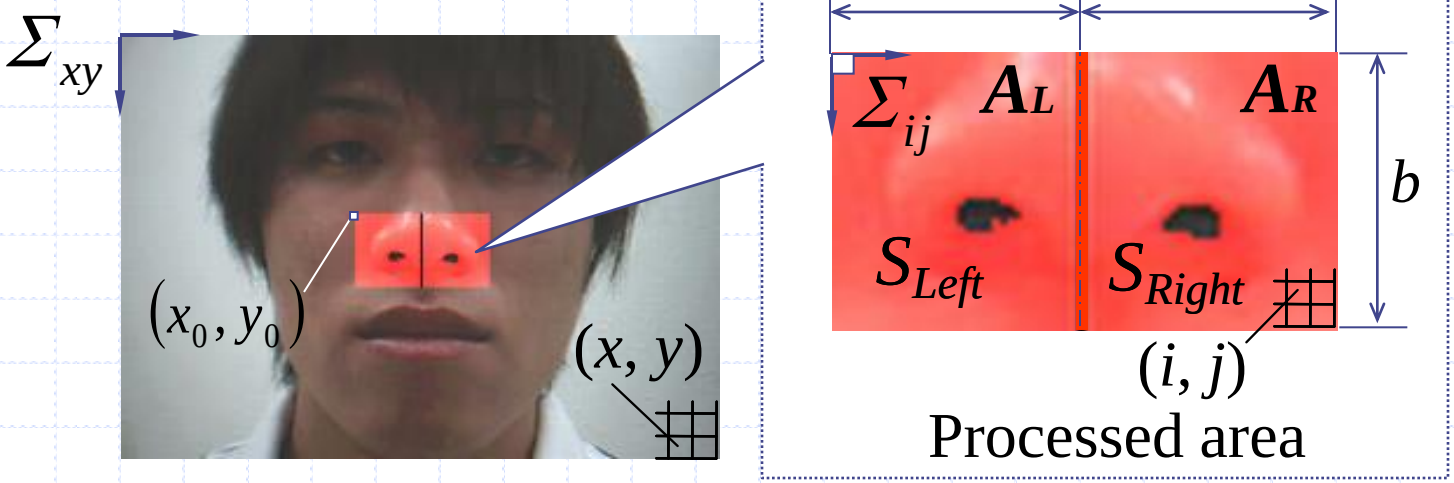
PC

- Windows XP
- CPU core 2duo 2.4GHz

Development

Microsoft C#2007

Nostril image



Nostril area

$$S_{Left/Right} = \sum_i \sum_j g[i, j] \quad \cdots(1)$$

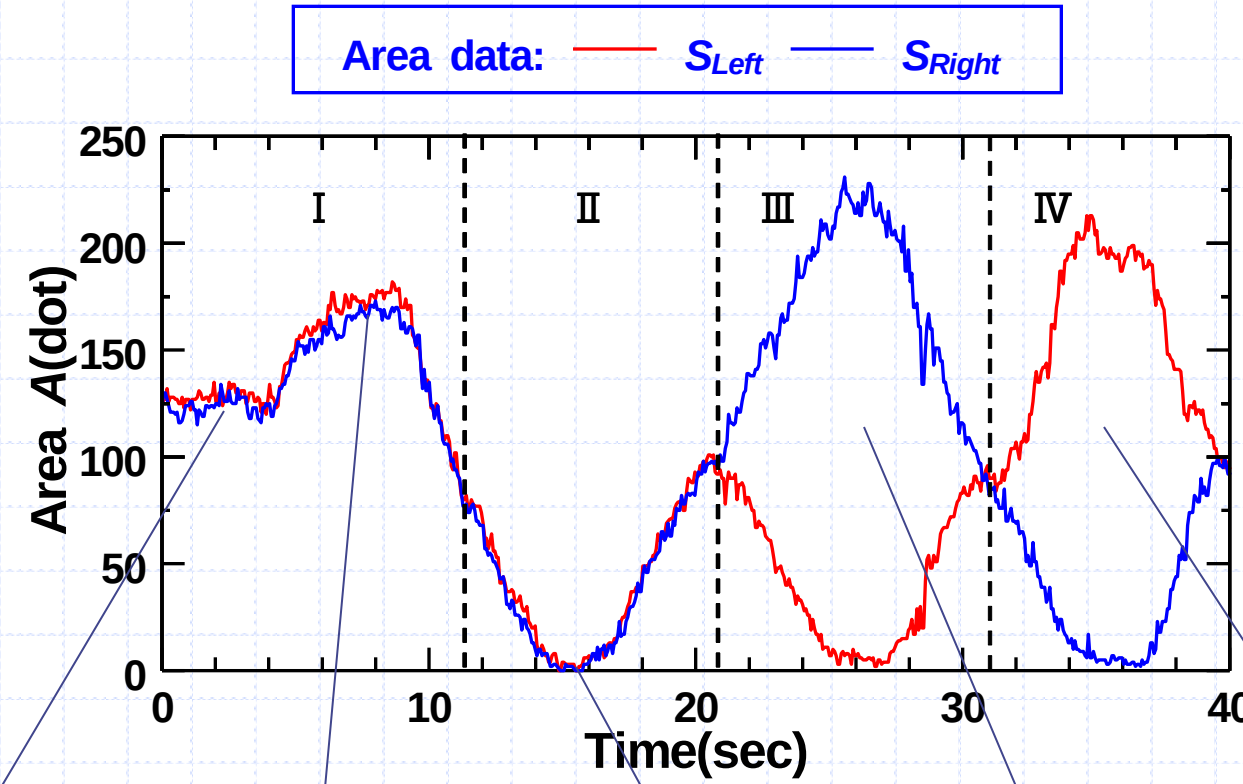
Where

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

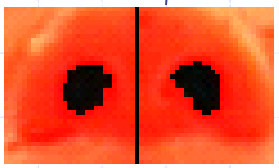
$R[i,j]$: 8 bit brightness of R

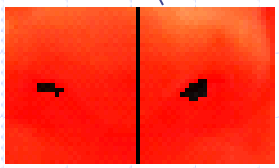
ε : Threshold

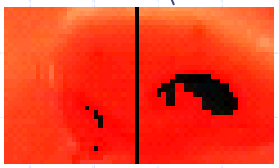
Both nostril areas

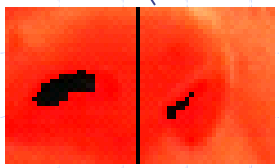



Center

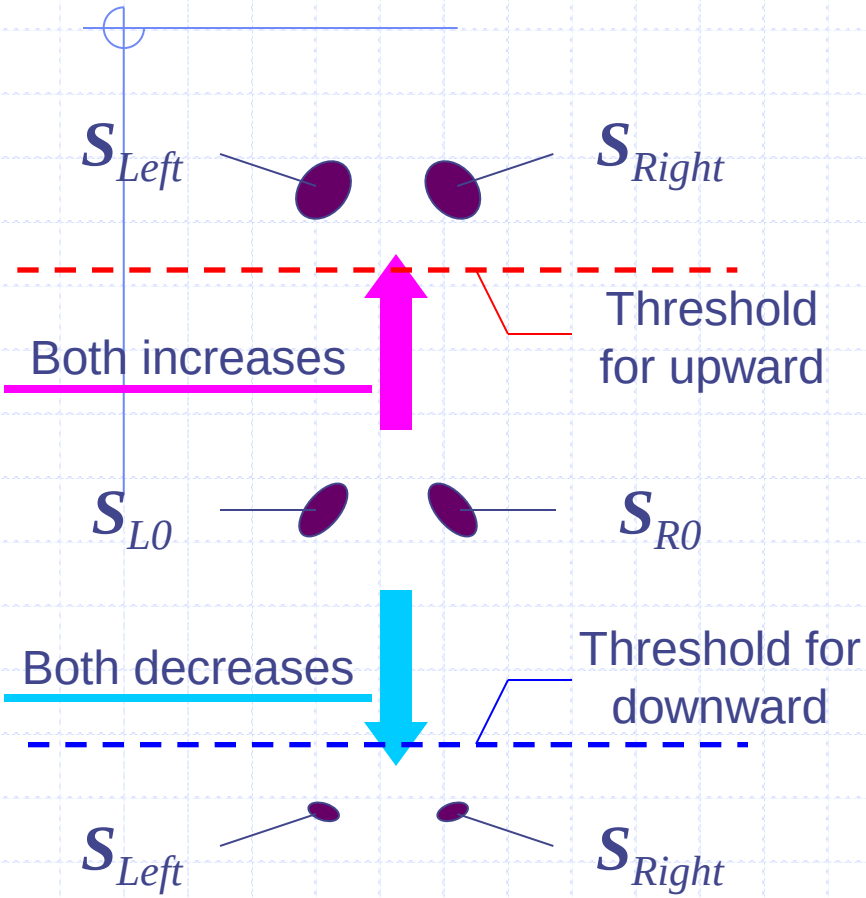

Up


Down


Left


Right

Up and down recognitions



Upward recognition

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

$$(y_L < u_{UL}) \cap (y_R < u_{UR})$$

Where S_{L0} : Initial left nostril area

S_{R0} : Initial right nostril area

u_{UL} u_{UR} : Threshold of position

Downward recognition

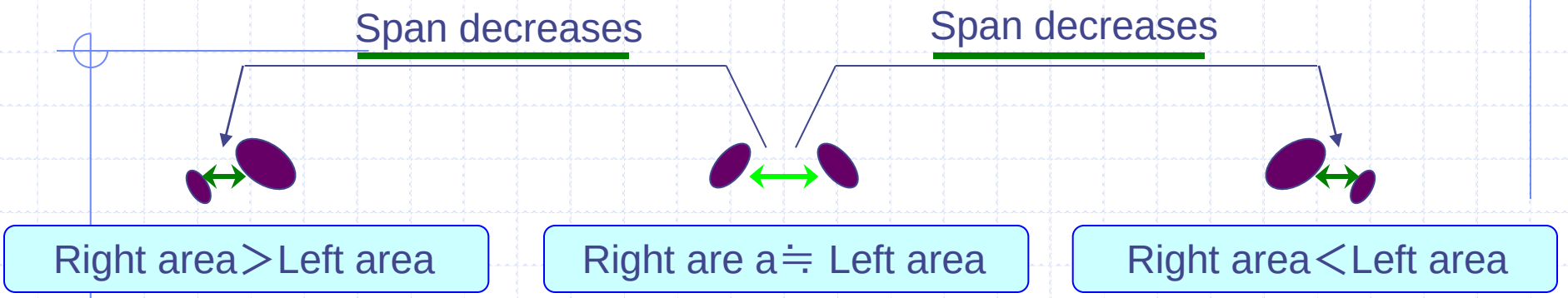
$$(S_{L0} - S_{Left} > t_{DL}) \cap (S_{R0} - S_{Right} > t_{DR})$$

$$(y_L > u_{DL}) \cap (y_R > u_{DR})$$

Where

u_{DL} u_{DR} : Threshold of position

Left and right directions



Left directin

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

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}
x_{R0} : Initial position

Right direction

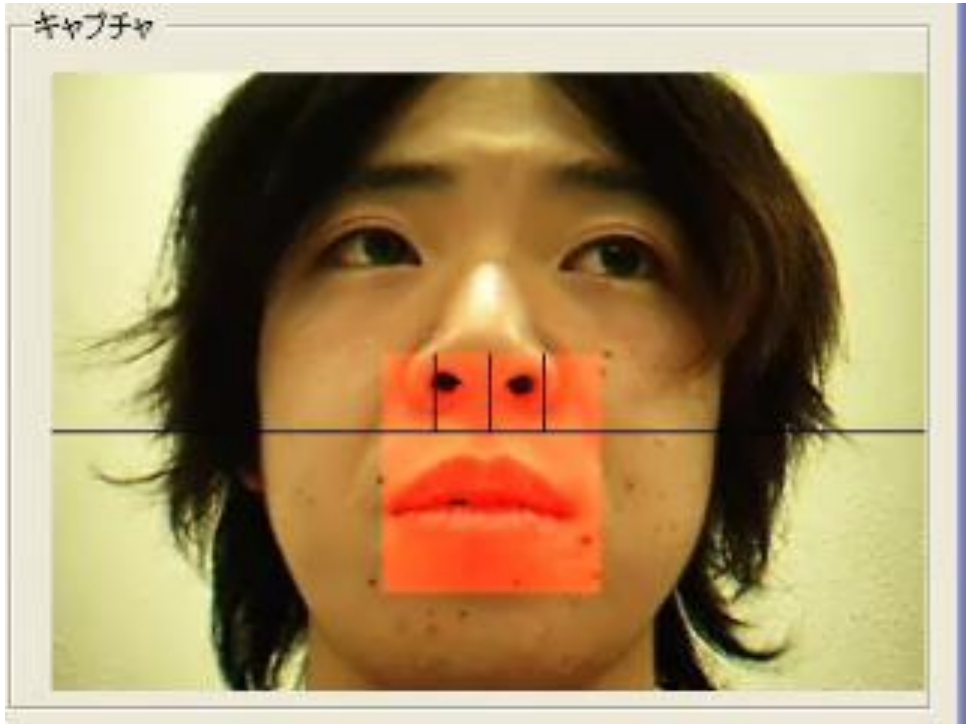
$$(S_{L-R} > v_r) \cap (x_{dis} > w_{dis})$$

Where

$$S_{L-R} = S_{Left} - S_{Right}$$

v_r : Threshold of area difference

Procedure field



VTR Problem 1

User's face
wasn't constrained

Problem

Nose protrudes
beyond rectangle

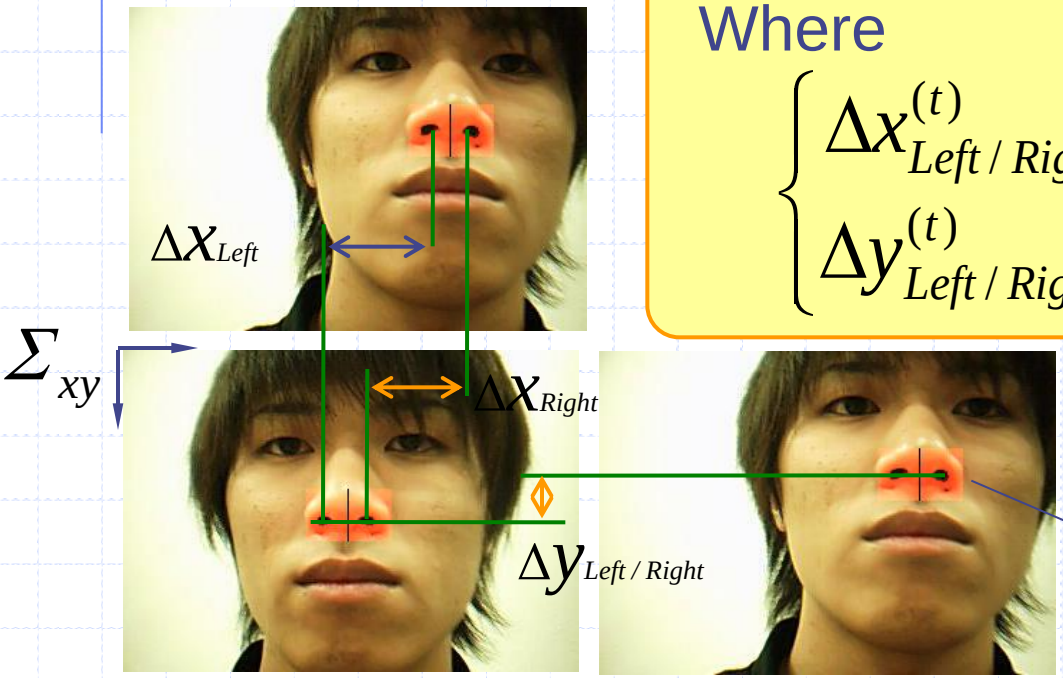
Tracking for nostrils

Movement of origi Σ_{ij}.

$$\begin{cases} x_0^{(t)} = x_0^{(0)} + \Delta x_{Left/Right}^{(t)} \\ y_0^{(t)} = y_0^{(0)} + \Delta y_{Left/Right}^{(t)} \end{cases}$$

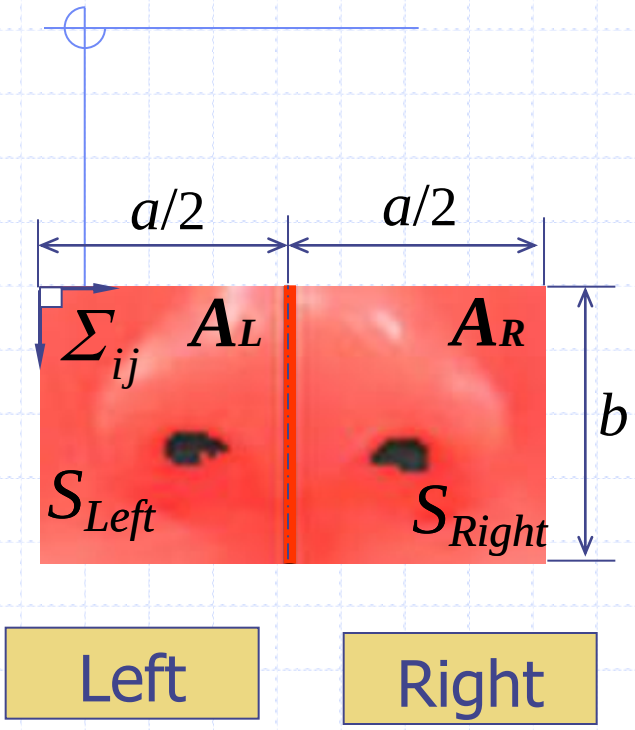
Where

$$\begin{cases} \Delta x_{Left/Right}^{(t)} = x_{Left/Right}^{(t)} - x_{Left/Right}^{(0)} \\ \Delta y_{Left/Right}^{(t)} = y_{Left/Right}^{(t)} - y_{Left/Right}^{(0)} \end{cases}$$



Initial state

Positions of both nostrils



Coordinates of left nostrils

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

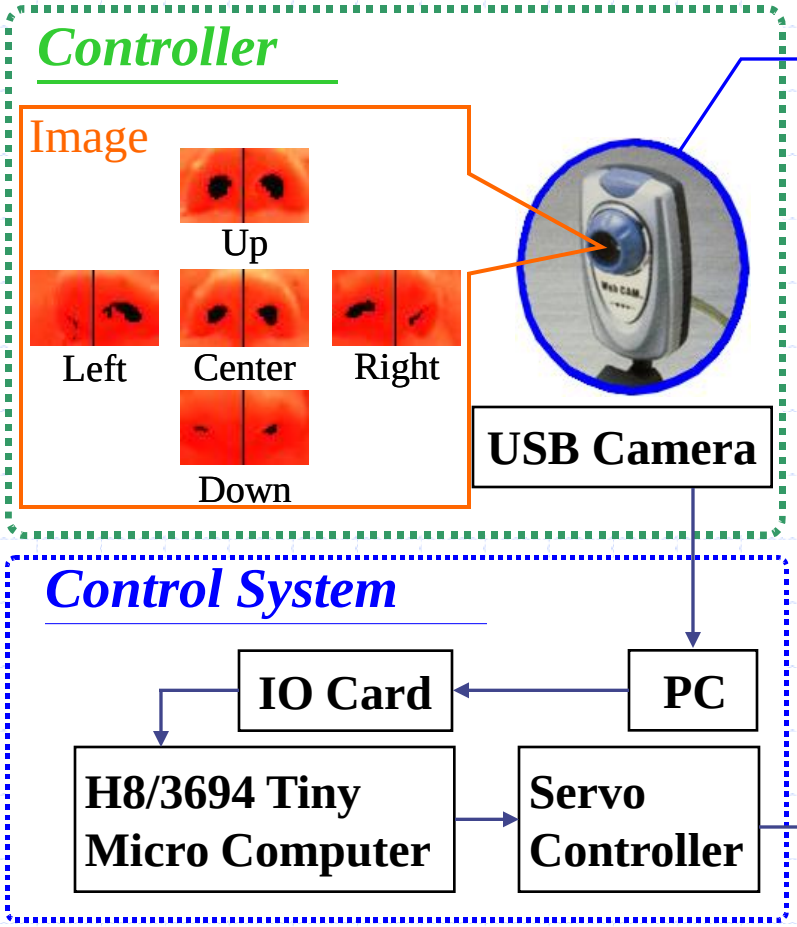
Coordinates of right nostrils

$$\begin{cases} x_{Right}^{(t)} = \sum_{i=a/2}^{a}\sum_{j=0}^{b} i \cdot g[i,j] \Big/ \sum_{i=a/2}^{a}\sum_{j=0}^{b} g[i,j] + x_0^{(t)} \\ y_{Right}^{(t)} = \sum_{i=a/2}^{a}\sum_{j=0}^{b} j \cdot g[i,j] \Big/ \sum_{i=a/2}^{a}\sum_{j=0}^{b} g[i,j] + y_0^{(t)} \end{cases}$$

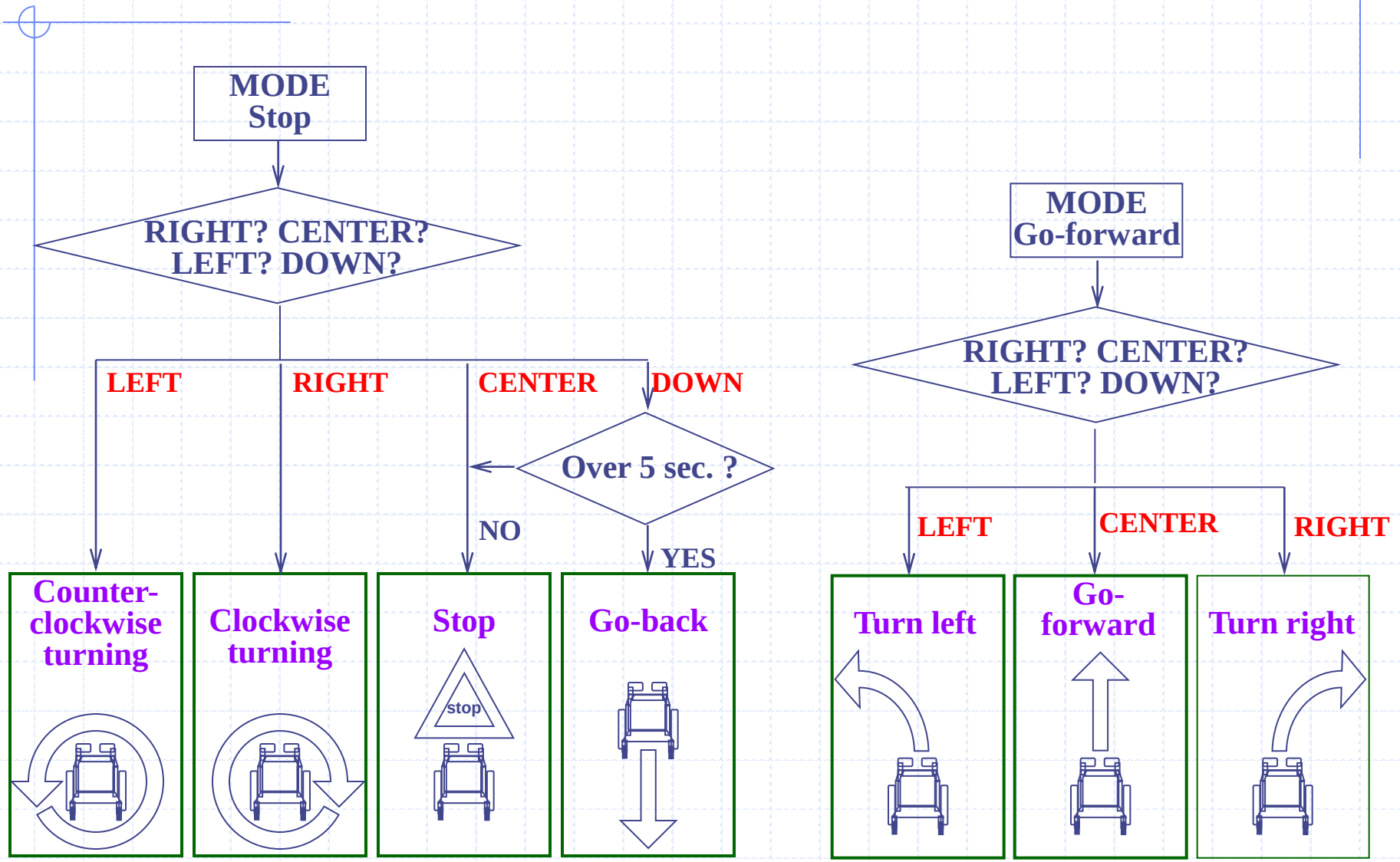
VTR (Test trial)

Application of Auto-Wheel chair

Control system



Assignment of operations



Scene1(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)

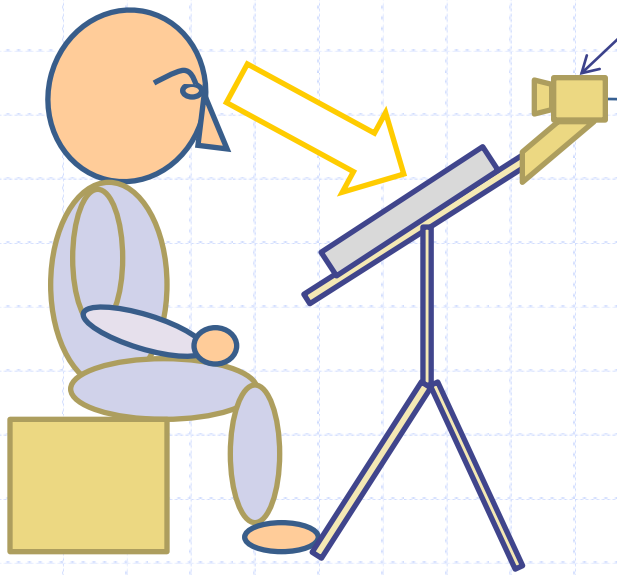
Dorsal position (on the bed)
friction between a pillow and user head
→ Physical burden

In this research

Development of an intuitive interface for page tuner control

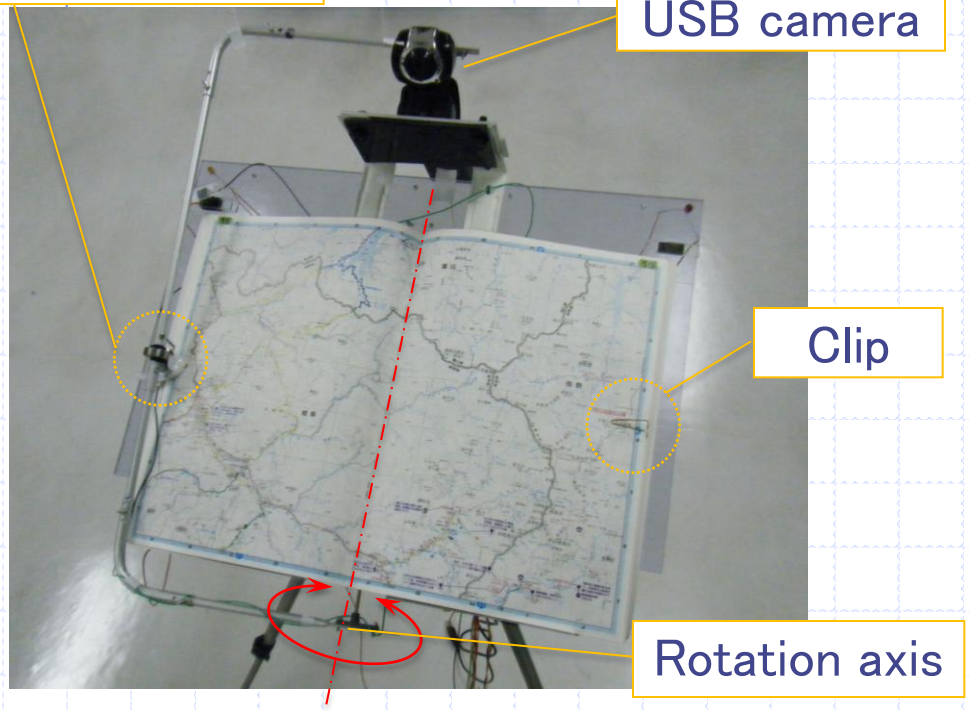
Gazing action was used for operation

Concept

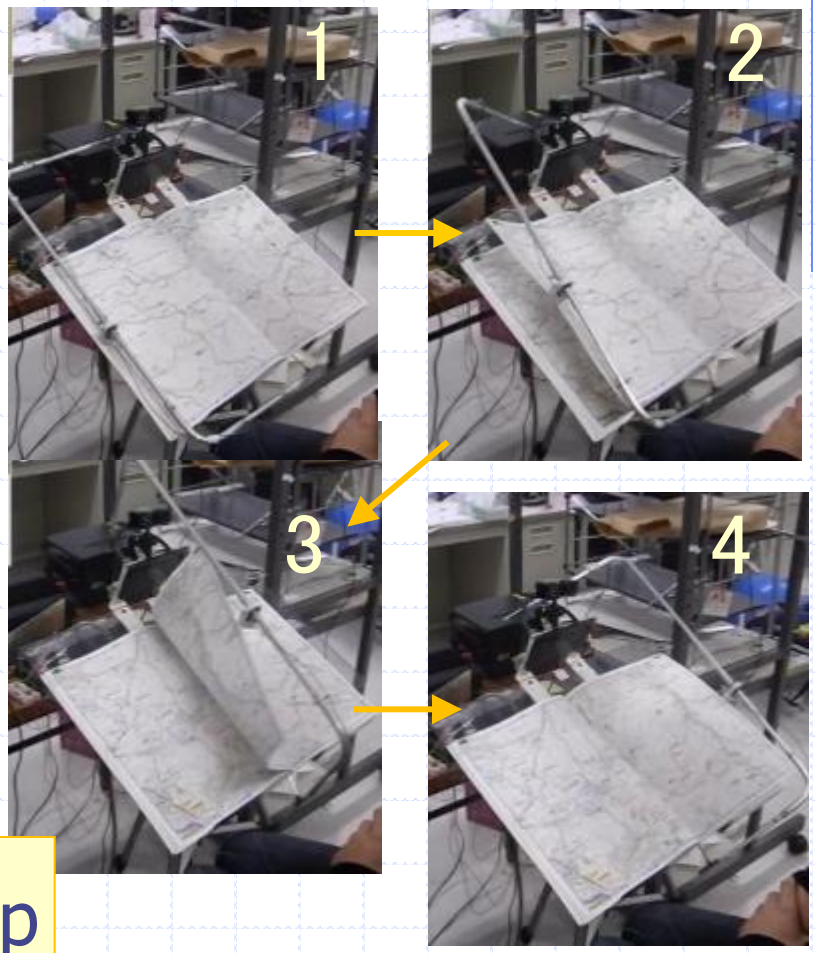


- Printed book is treated
- User doesn’t touch a book
- Machine turns over a page according to user’s sign

Page turner machine

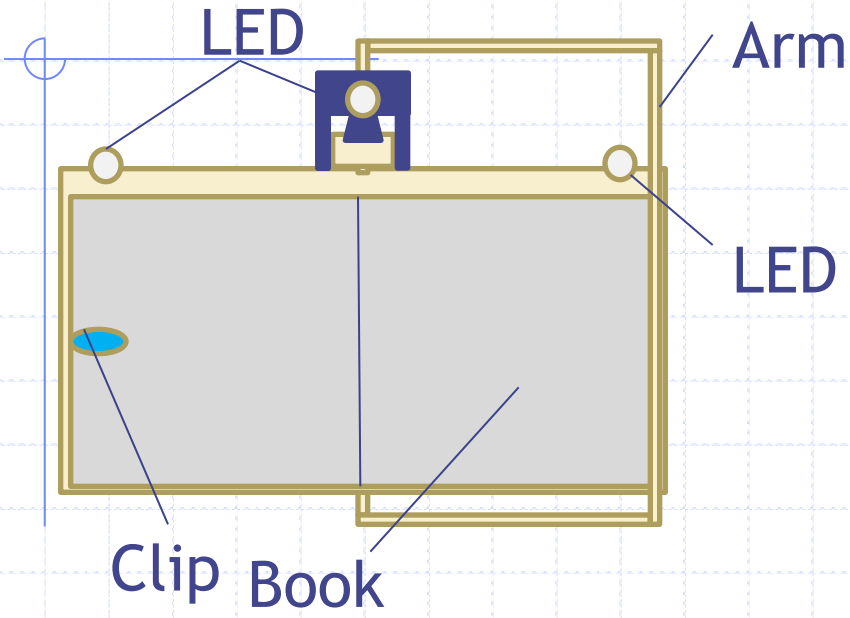


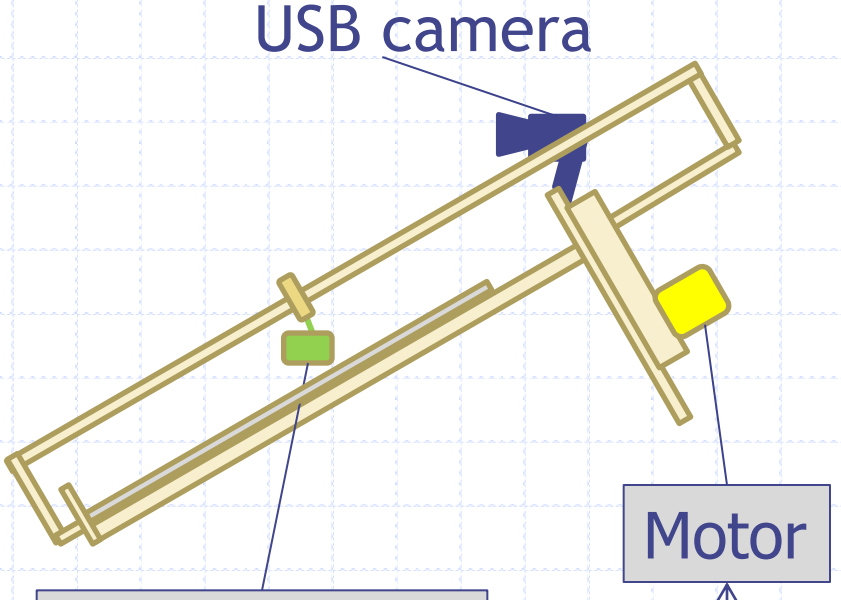
Electro magnet picked up a clip and turned over a page

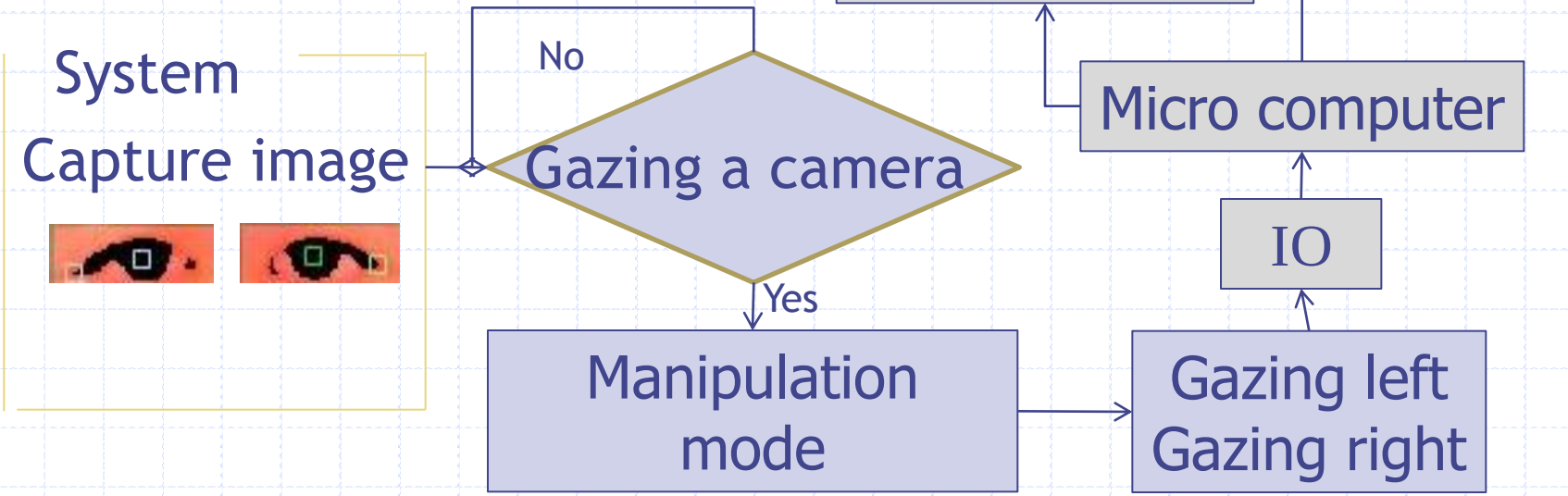


Page turning scene

Control system







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

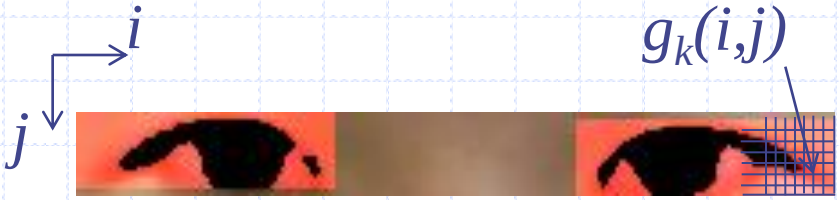
Development software

Microsoft
Visual C# 2010

Image processing

Equation

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



Measurement field

$r[i,j]$: Brightness t : Threshold

Influence of threshold

t = 10 t = 40

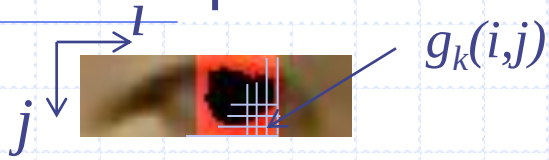
t = 50 t = 80

Pupil Inner and outer corner

Detection of feature points

Variable threshold

Pupil

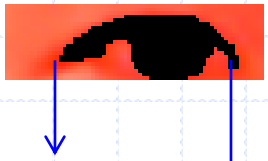


Center of gravity

$$x_{pl/pr} = \frac{\sum_i \sum_j i \cdot g(i,j)}{\sum_i \sum_j g(i,j)},$$

$$y_{cl/cr} = \frac{\sum_i \sum_j j \cdot g(i,j)}{\sum_i \sum_j g(i,j)}$$

Inner and outer corner



Outer corner

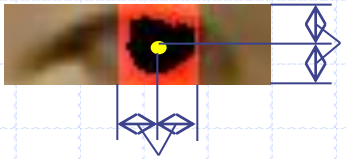
$x_{cl/cr}, y_{cl/cr}$

Inner corner

$x_{hl/hr}, y_{hl/hr}$

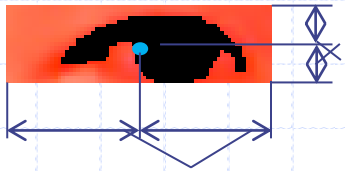
Procedure field

Limited



10 pixels

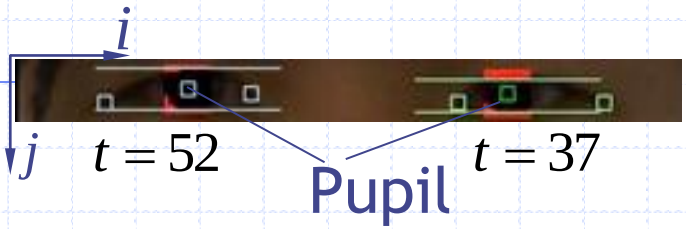
10 pixels

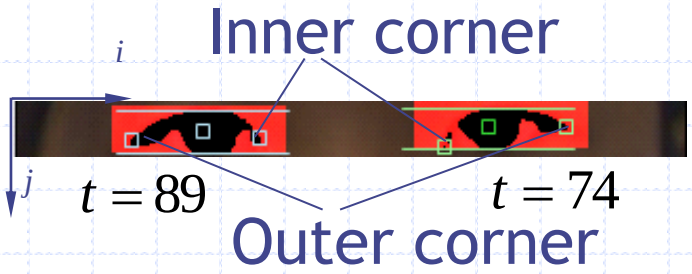


10 pixels

40 pixels

Detected example





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

Blinking problem

Blinking disturbs feature points detection

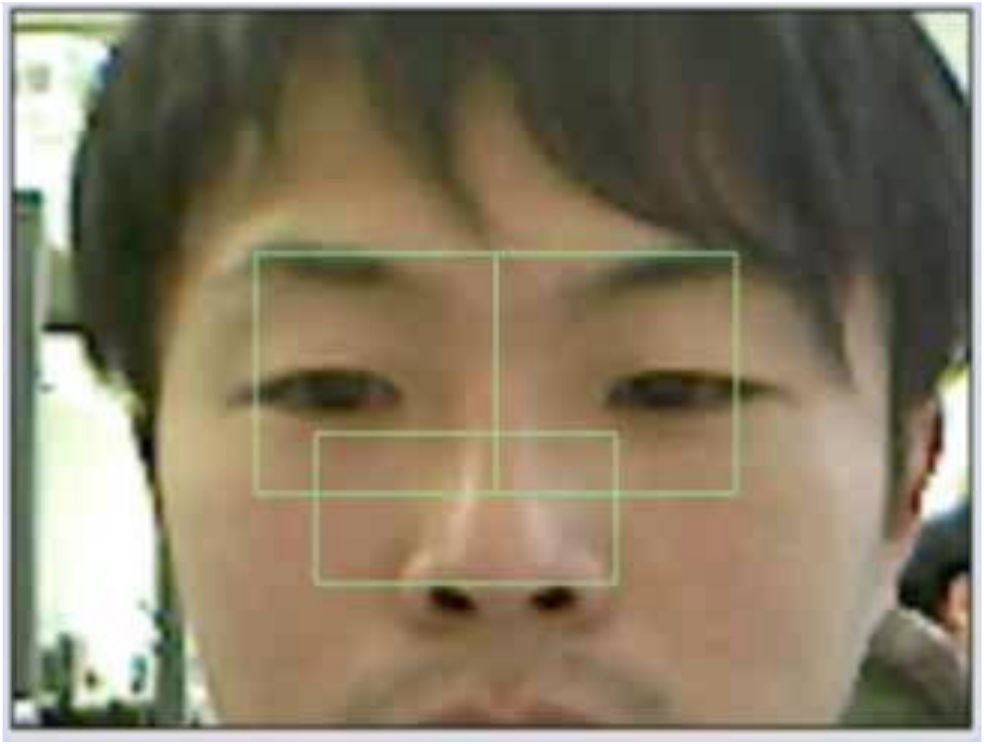
$$x_{pl/pr} = \frac{\sum_i \sum_j i \cdot g(i,j)}{\sum_i \sum_j g(i,j)},\ y_{cl/cr} = \frac{\sum_i \sum_j j \cdot g(i,j)}{\sum_i \sum_j g(i,j)} \quad (A > a)$$

$$x_{pl/pr} = u_{pl/pr},\ y_{pl/pr} = v_{pl/pr} \quad (A \le a)$$

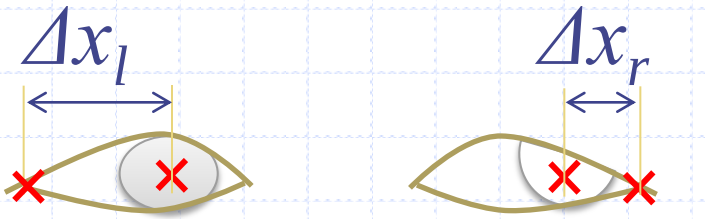
a :Threshold

A : Pupil area $u_{pl/pr}, v_{pl/pr}$:previous time position

VTR



Recognition in horizontal direction

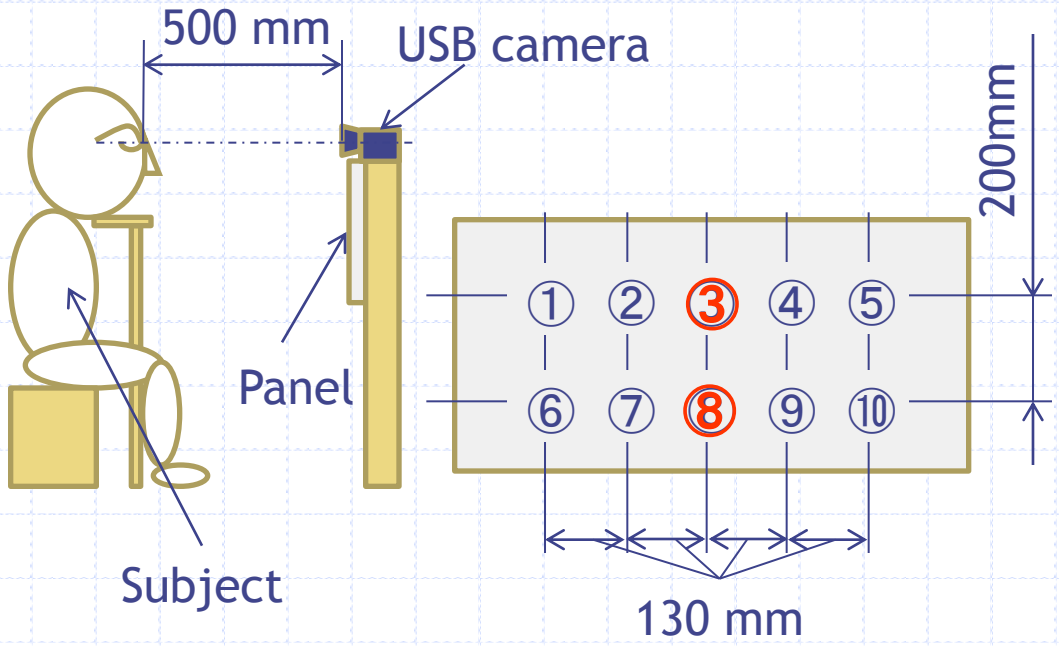


Evaluation

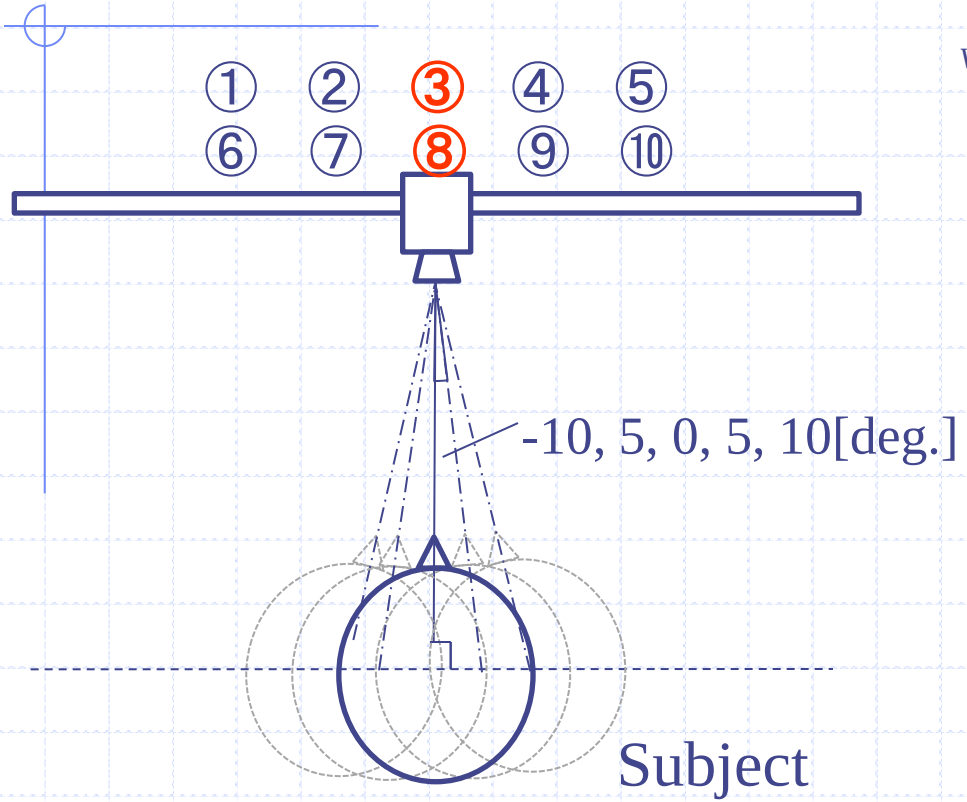
$$J_H = \Delta x_l / \Delta x_r$$

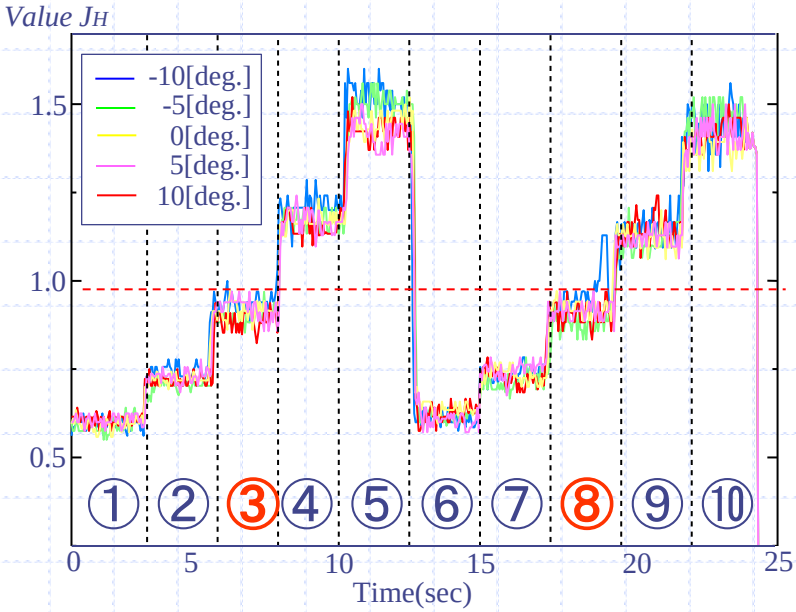
Pre-experiment

Subject gazed ten targets In order



Value J_H according to gazing direction

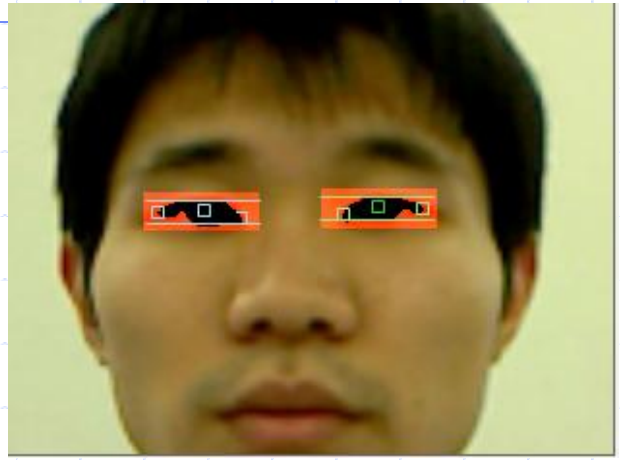




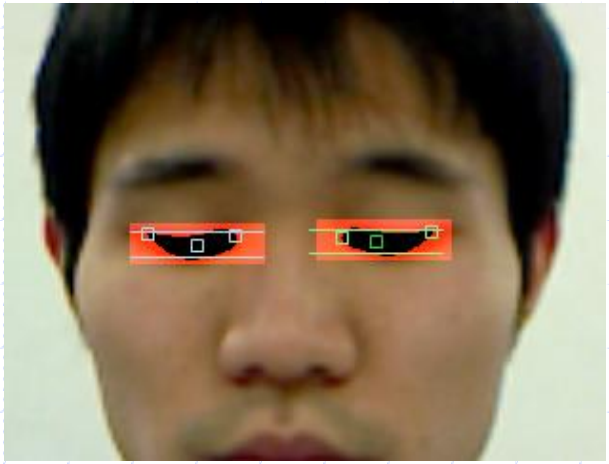
Experimental data of J_H
with respect to the head position

Horizontal gazing direction was easily judged

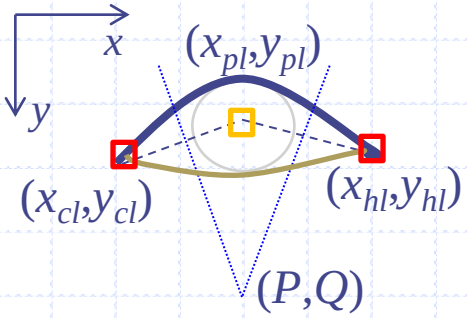
Recognition in vertical direction

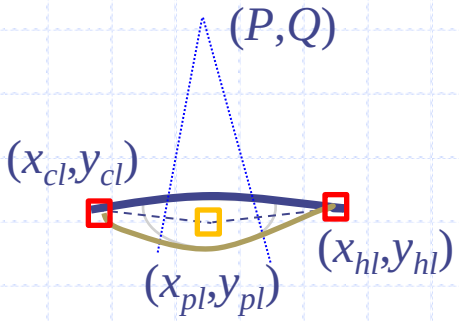


(a) Gazing the USB camera



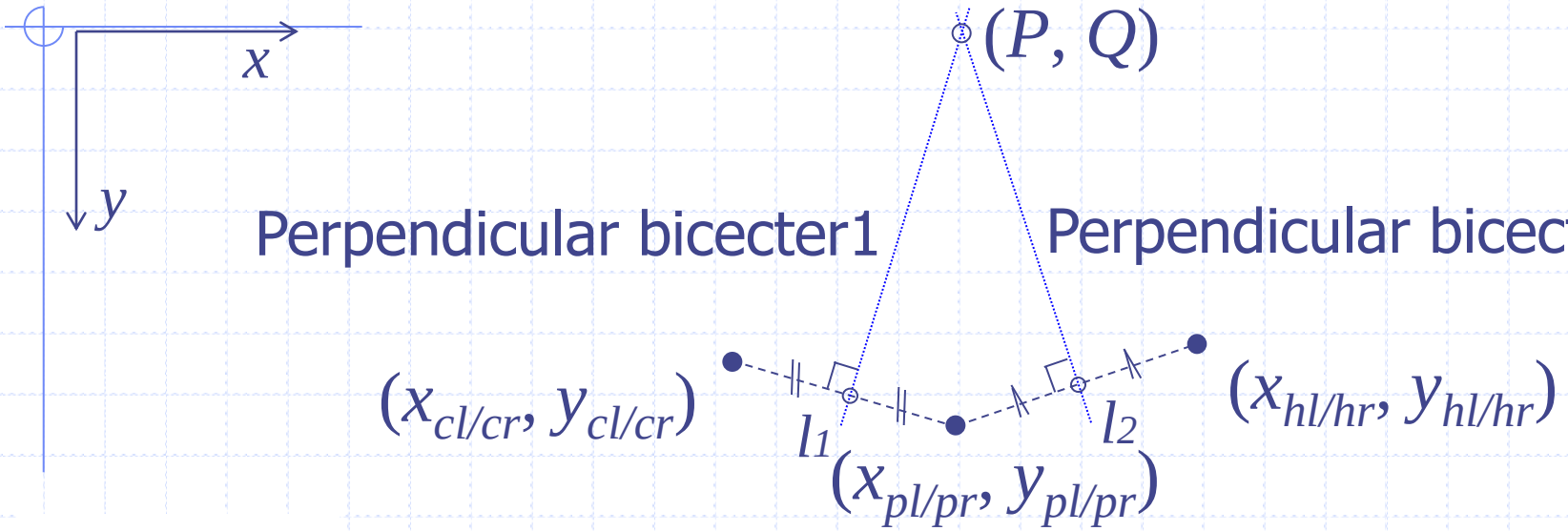
(b) Reading a book





Eye shape is changed by gazing direction

Recognition in vertical direction



Evaluation

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

$$a=\frac{y_{cl}+y_{pl}}{2} \qquad d=\frac{y_{pl}+x_{hl}}{2}$$

$$b=\frac{x_{cl}+x_{pl}}{y_{cl}-y_{pl}} \qquad e=\frac{x_{pl}+xhl}{y_{pl}-yhl}+0.00001$$

$$c=\frac{x_{cl}+x_{pl}}{2} \qquad f=\frac{x_{pl}+xhl}{2}$$

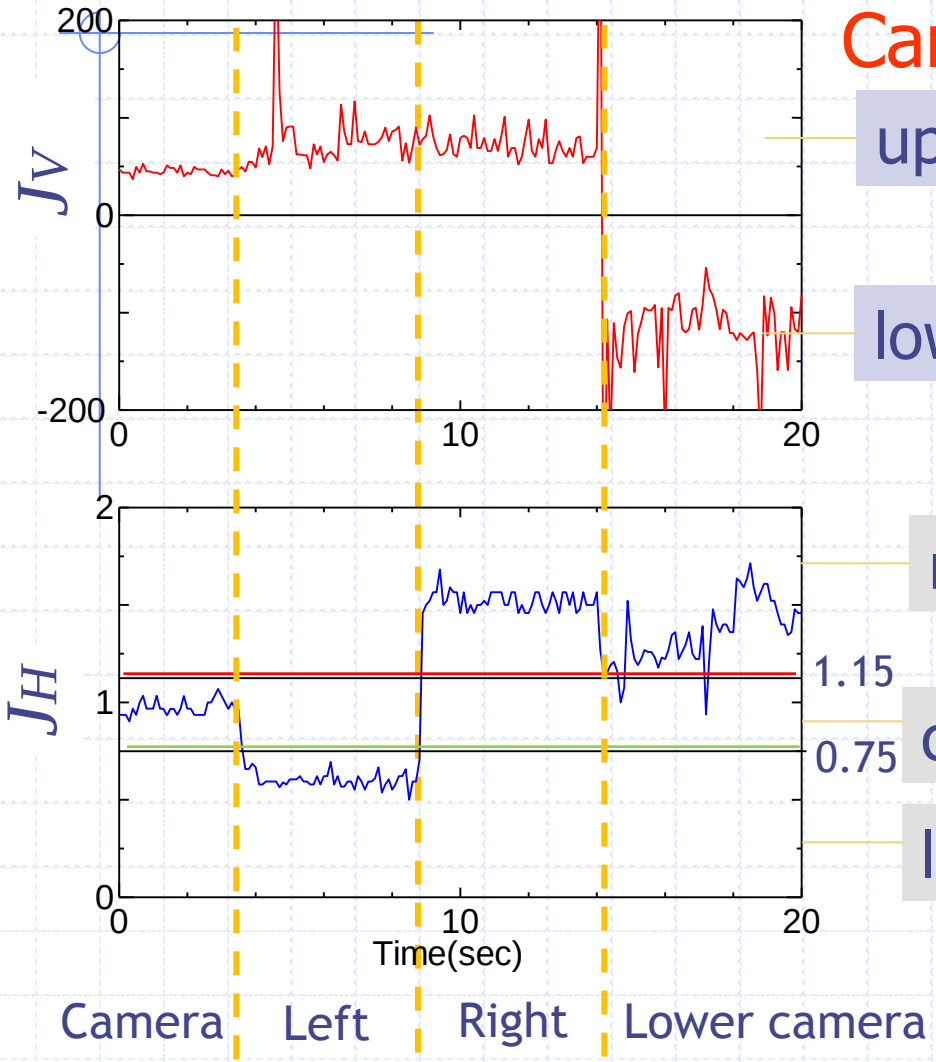
Reading mode

$Jv=Q-y_{pl}\leq 0$:Gazing lower

Operation mode

$Jv=Q-y_{pl}>0$: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

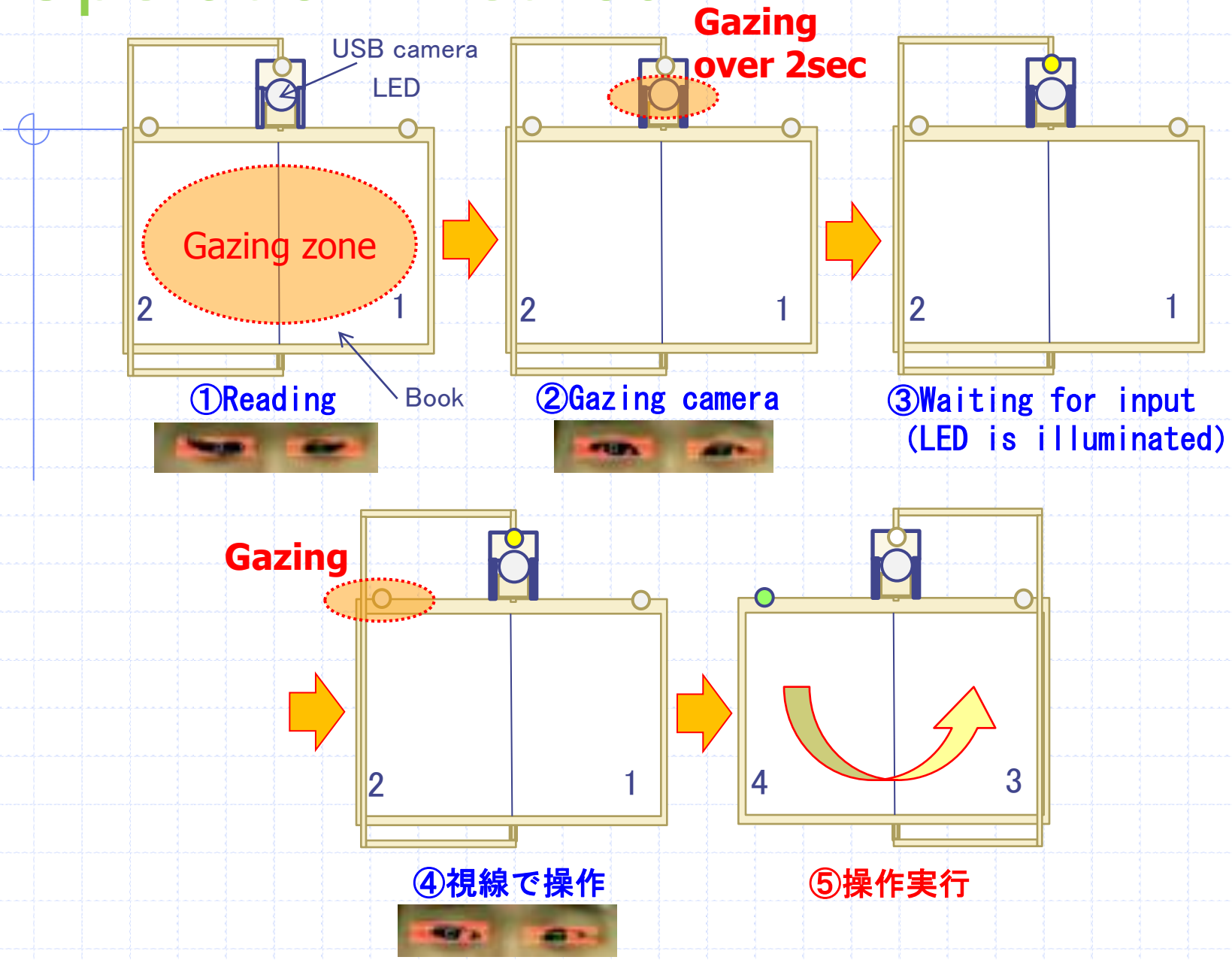
$(J_V>0)\cap(1.15\leq J_H)$

Reading book

$(J_V\leq 0)$

Page tuner operation

Operation method



VTR

Conclusions

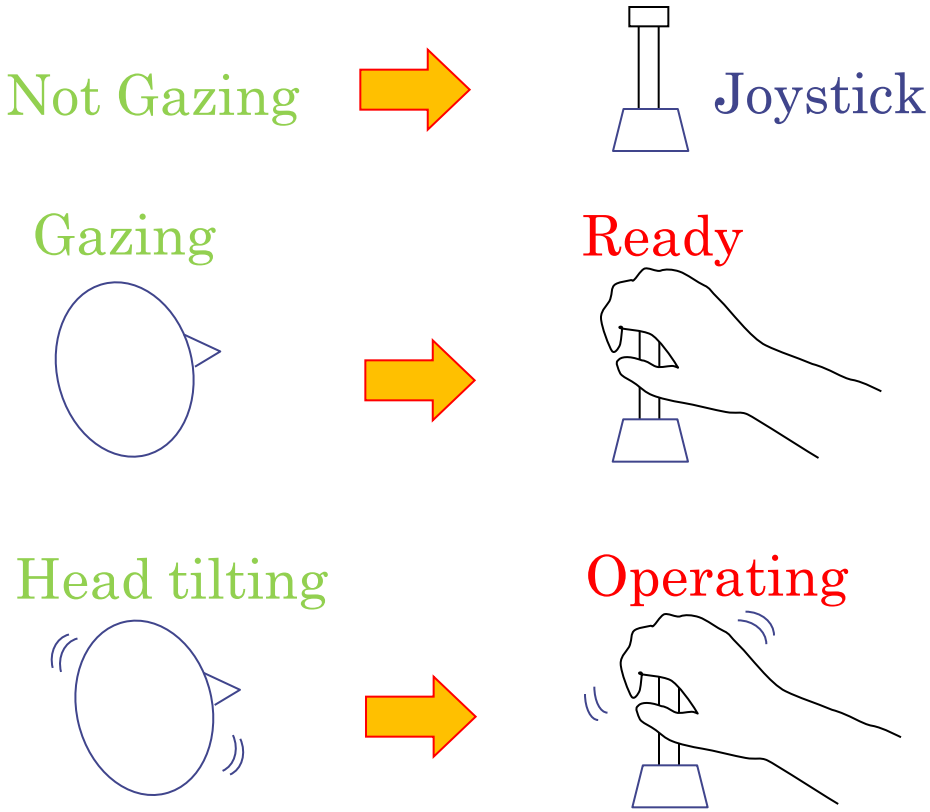
Development of an intuitive gazing interface for page tuner control

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.



Thank you!!