An Automatic Door Sensor Using Image Processing

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1. Introduction

Automatic door is equipped at the entrance of many buildings and inside the buildings.

- It opens when persons approach to the door.
- very useful for persons with large luggage & disabled persons.

Very useful because the door is automatically opened.

On the other hand, there is another aim

Regulated Society of the building

Keep Security of the building

and

Save the air-conditioning cost

Automatic door should be closed as long as possible.

Many kinds of sensors (infrared ray sensor & supersonic sensor), applied for the automatic door, sometime, fail to detect approaching object.

- ✘Persons without will to enter the door,
- ✘Snow, rain or falling leaves,
- ✘*NOREN* (Japanese usual clothes hang in front of entrance of shops)

To solve these difficulties

Automatic door sensor system using image processing

Continual images In front of the door is taken by the CCD camera. → Image processing → Open and close control

As a first step, we develop a technique to classify the current image.

2. Open and Close Control System of Automatic Door Using Image Processing

CCD Camera Data

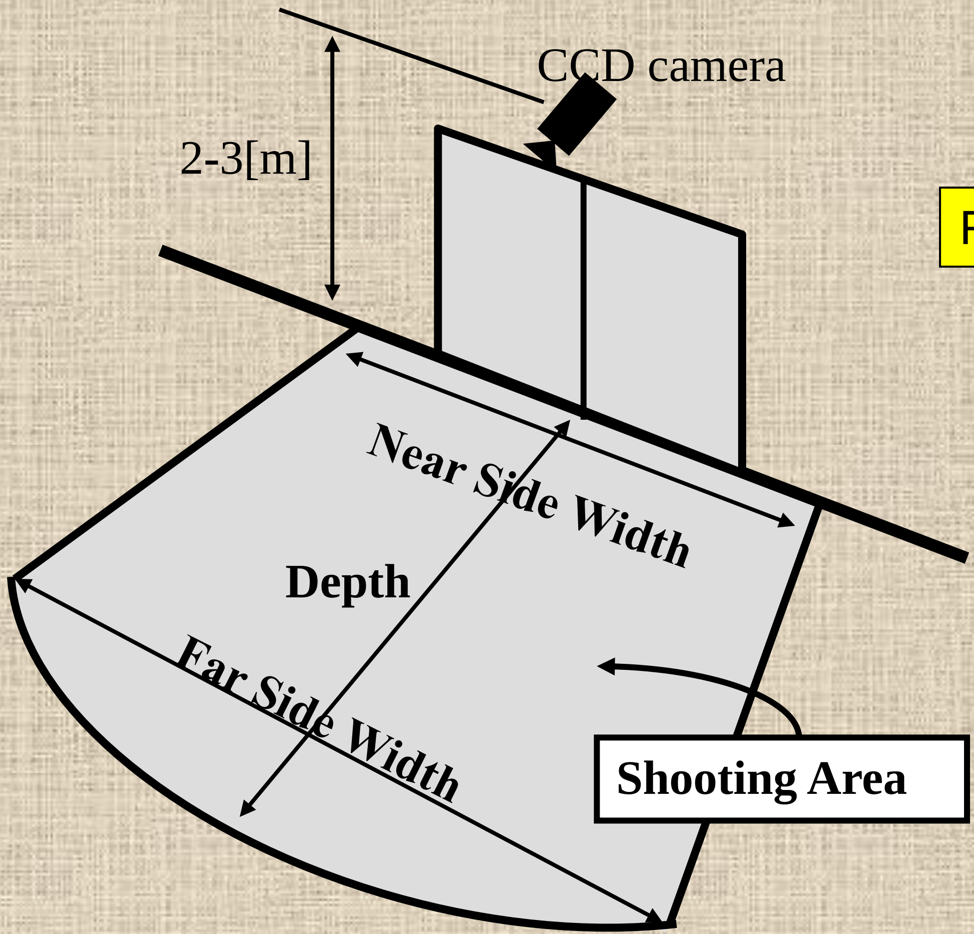


Fig.2.1 Shooting area and its measure.

Requirements of the CCD camera

- Depth :10 [m]
- Near side width:20 [m]

In order to get this shooting area, necessary angle ranges of the CCD camera (installed at a position 3.0 [m] high) is:

- Horizontal angle range: 147.2[deg]
- Vertical angle range : 73.3 [deg]

2. Open and Close Control System of Automatic Door Using Image Processing

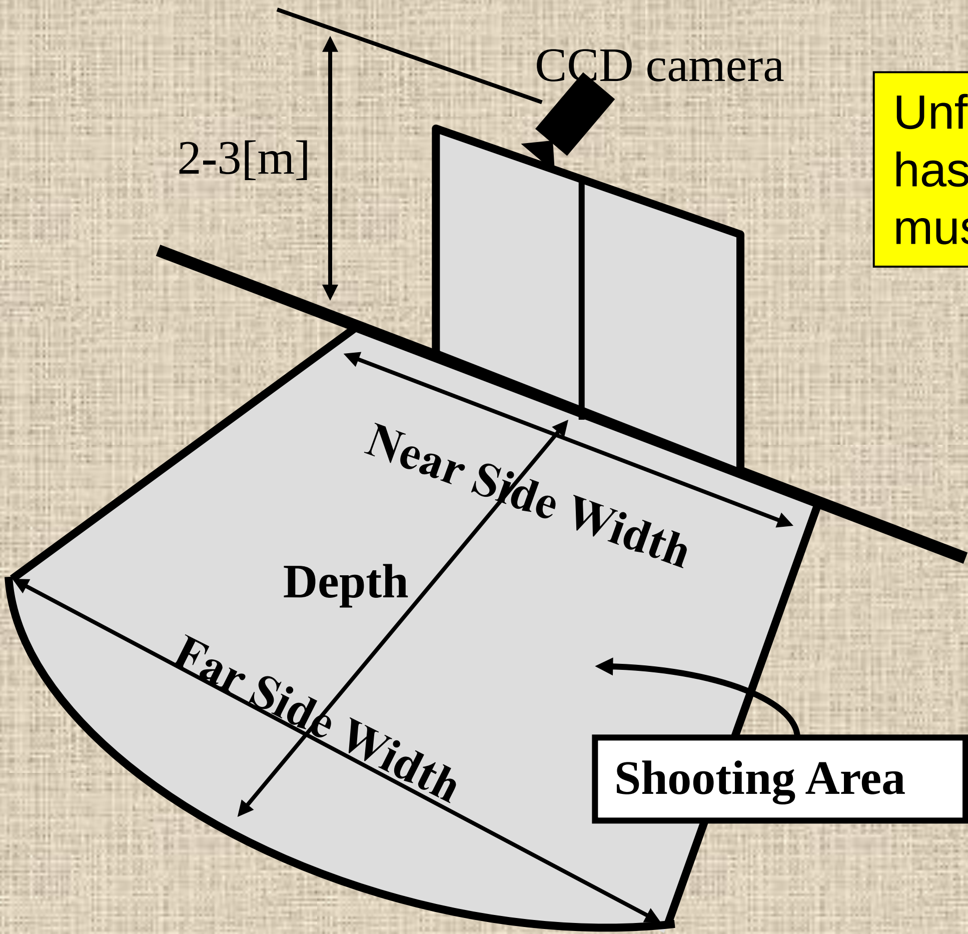


Fig.2.1 Shooting area and its measure.

Unfortunately, the camera we could acquired has poor spec as follows. Then an experiment must be done by using this camera.

Angle ranges of our CCD camera

- Horizontal angle range : 42.4 [deg]
- Vertical angle range : 32.0 [deg]

Then we installed this camera at a position of 3.2 [m] high for experiments of this research.

Fig.2.2 An example image taken by the CCD camera installed at a position 3.2[m] high.

The classification based on the normalized correlation matching

The optical flow estimation requires long computation time.

↓

The flow only in partial regions including moving object should be computed.

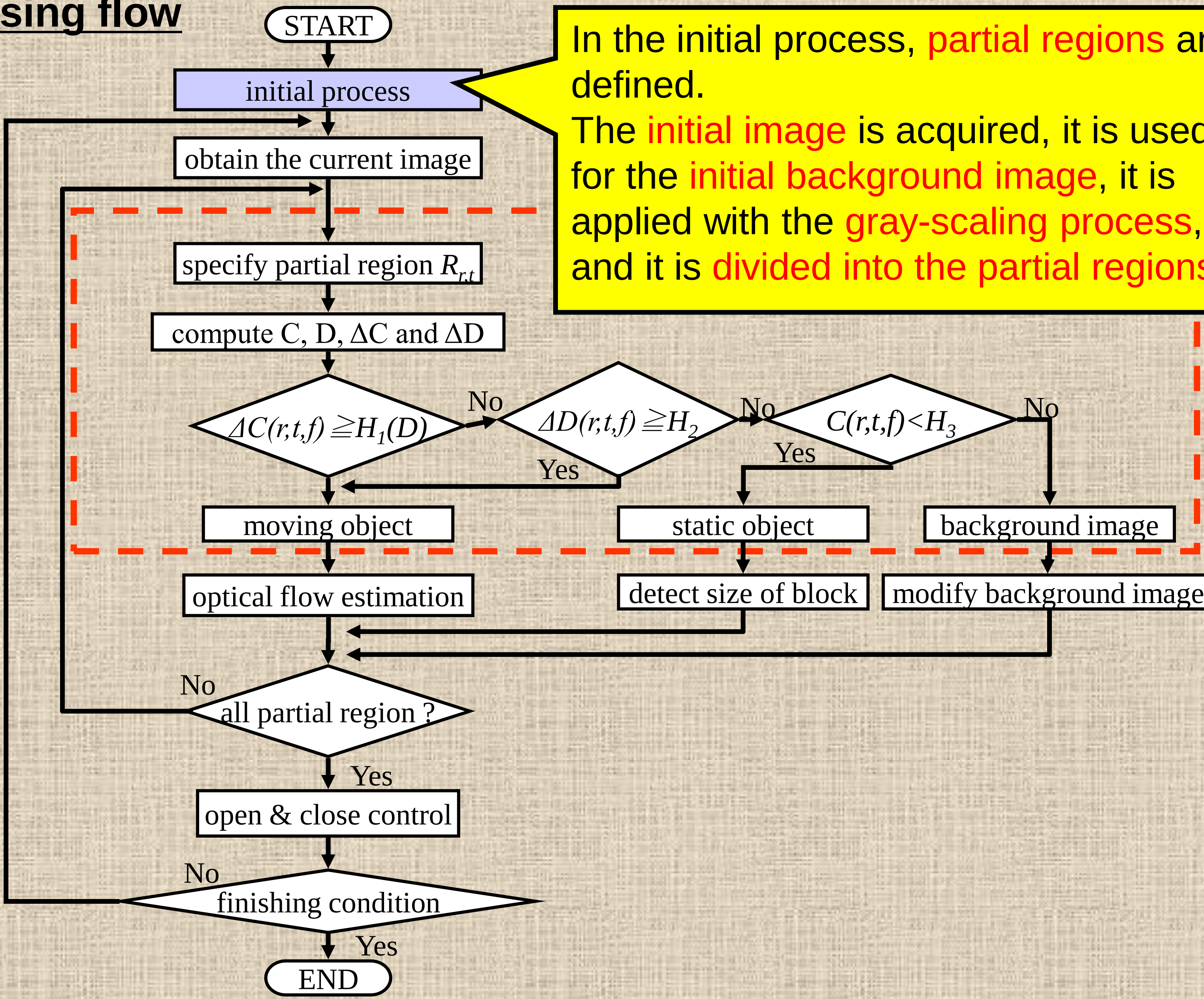
The system classifies the current image at each partial region into…

- containing moving objects.
- containing a static object.
- containing the background image only.

Classification

Based on the normalized correlation matching value (between the background image & the current frame image) and other 3 parameters.

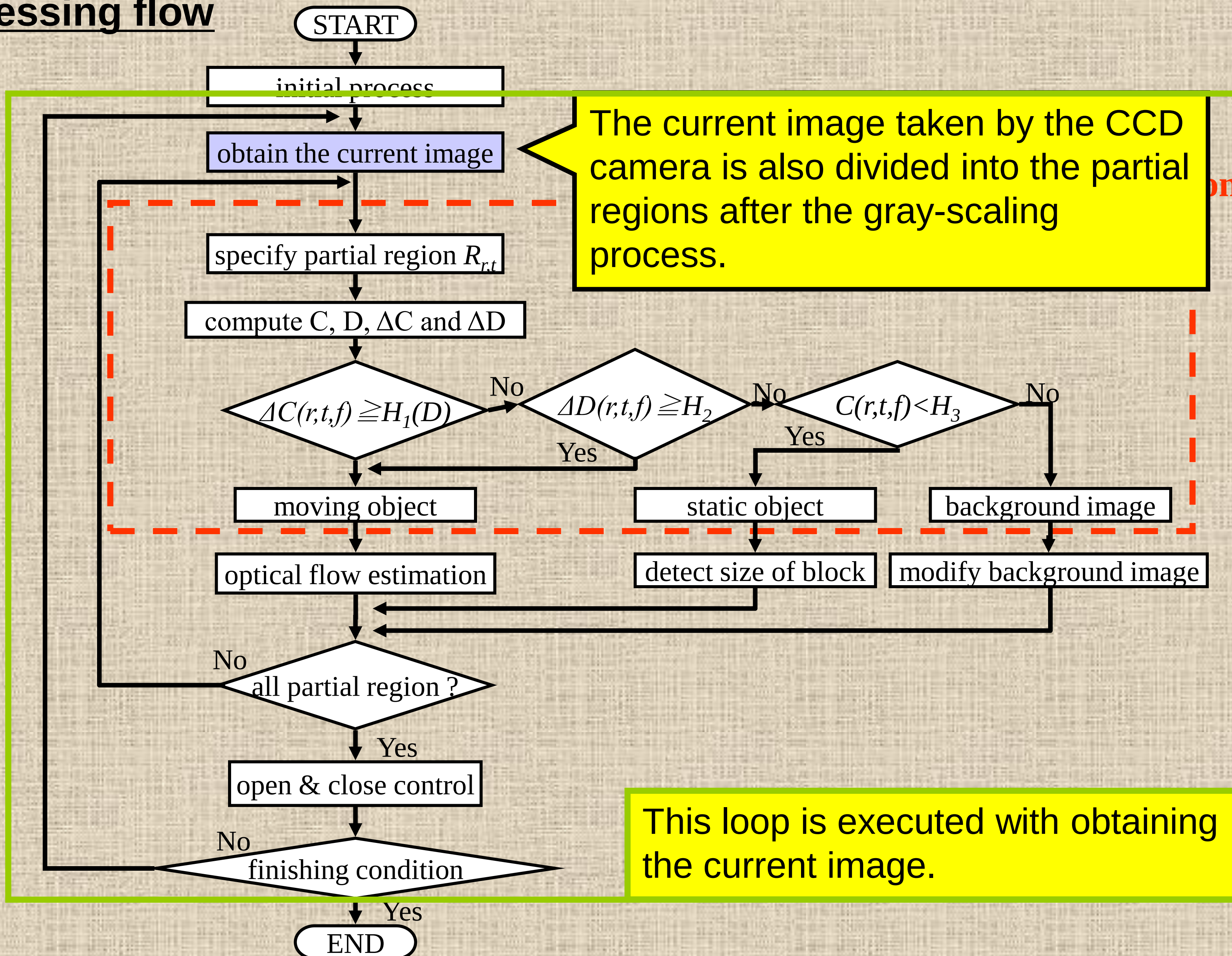
The processing flow



In the initial process, partial regions are defined.
The initial image is acquired, it is used for the initial background image, it is applied with the gray-scaling process, and it is divided into the partial regions.

Fig.2.3 A processing flow of the classification.

The processing flow

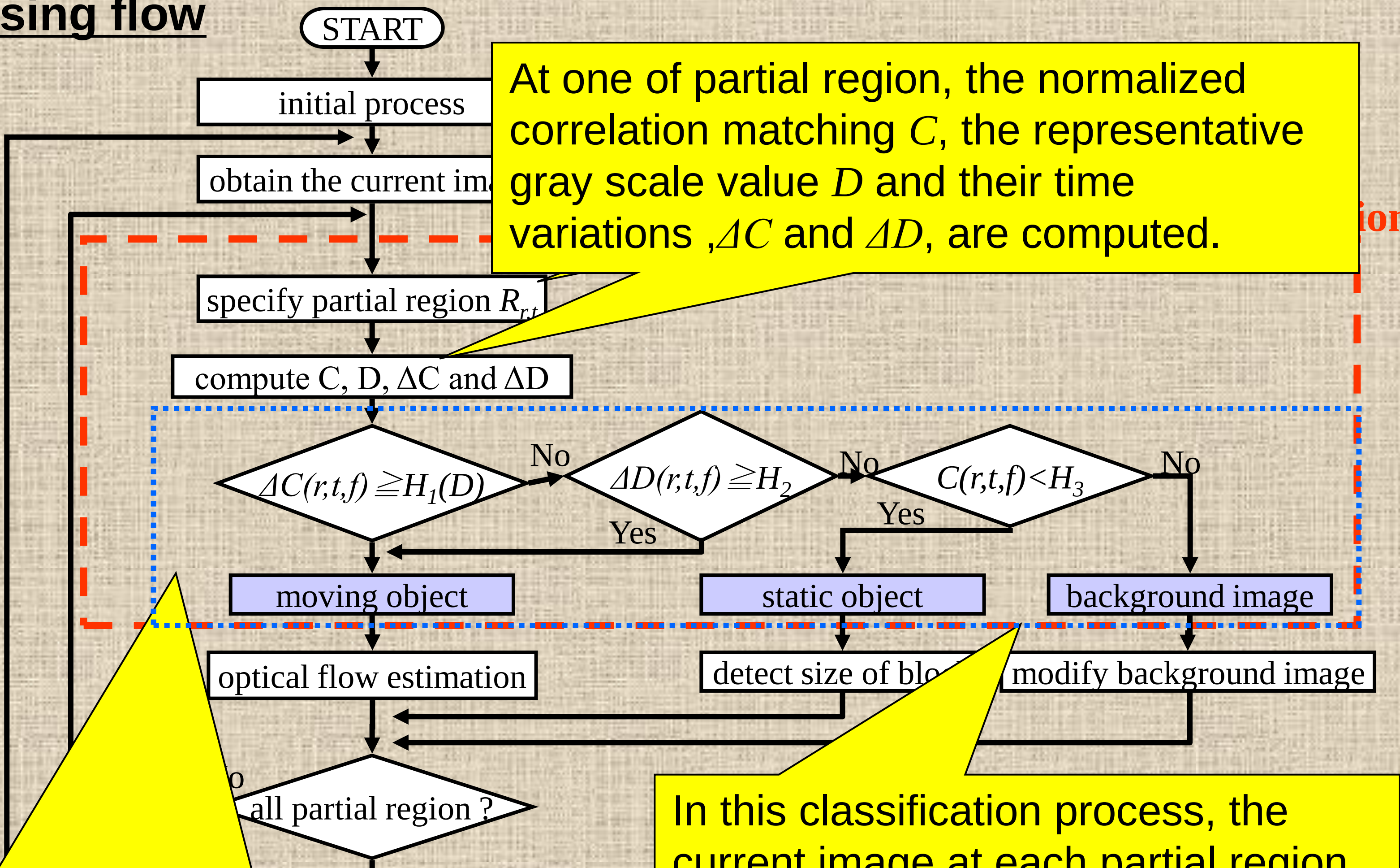


The current image taken by the CCD camera is also divided into the partial regions after the gray-scaling process.

This loop is executed with obtaining the current image.

Fig.2.3 A processing flow of the classification.

The processing flow



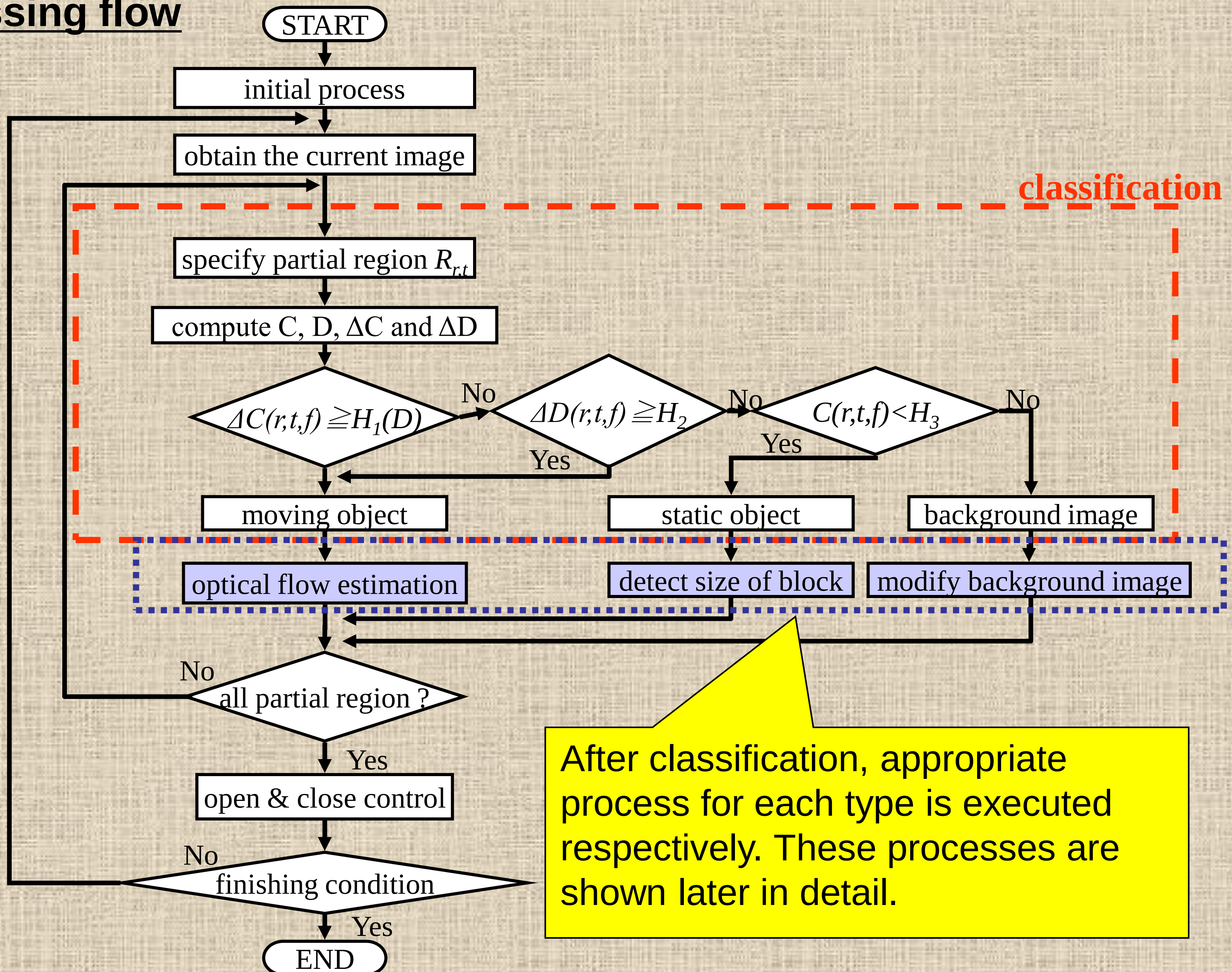
At one of partial region, the normalized correlation matching C, the representative gray scale value D and their time variations ,ΔC and ΔD, are computed.

In this classification process, the current image at each partial region ...ed into three types.

By means of these 4 parameters, the current image of the partial region is classified as

- ●“containing moving object”,
- ●“containing static object” or
- ●“containing background image only”.

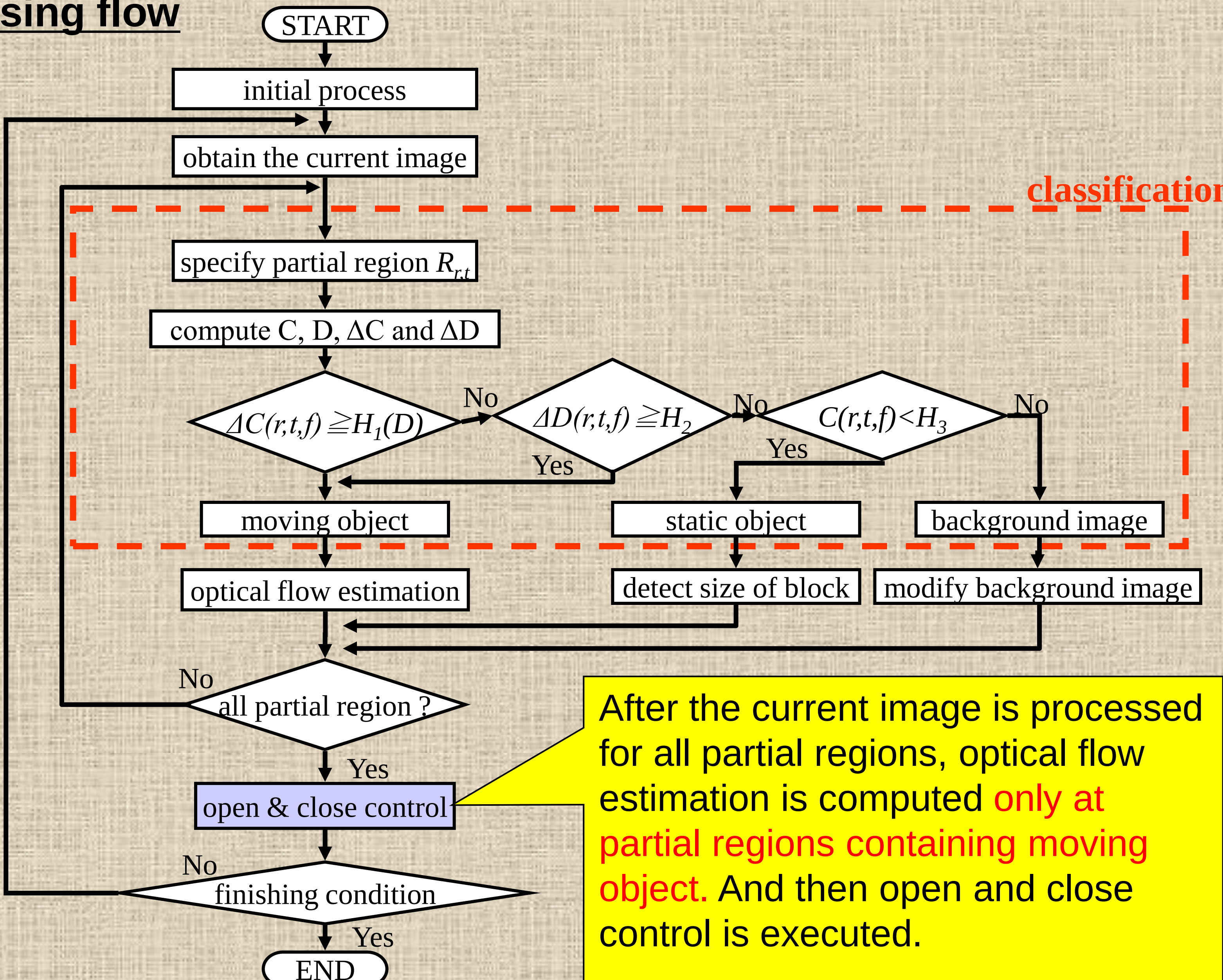
The processing flow



After classification, appropriate process for each type is executed respectively. These processes are shown later in detail.

Fig.2.3 A processing flow of the classification.

The processing flow



After the current image is processed for all partial regions, optical flow estimation is computed only at partial regions containing moving object. And then open and close control is executed.

Fig.2.3 A processing flow of the classification.

Definition of partial regions

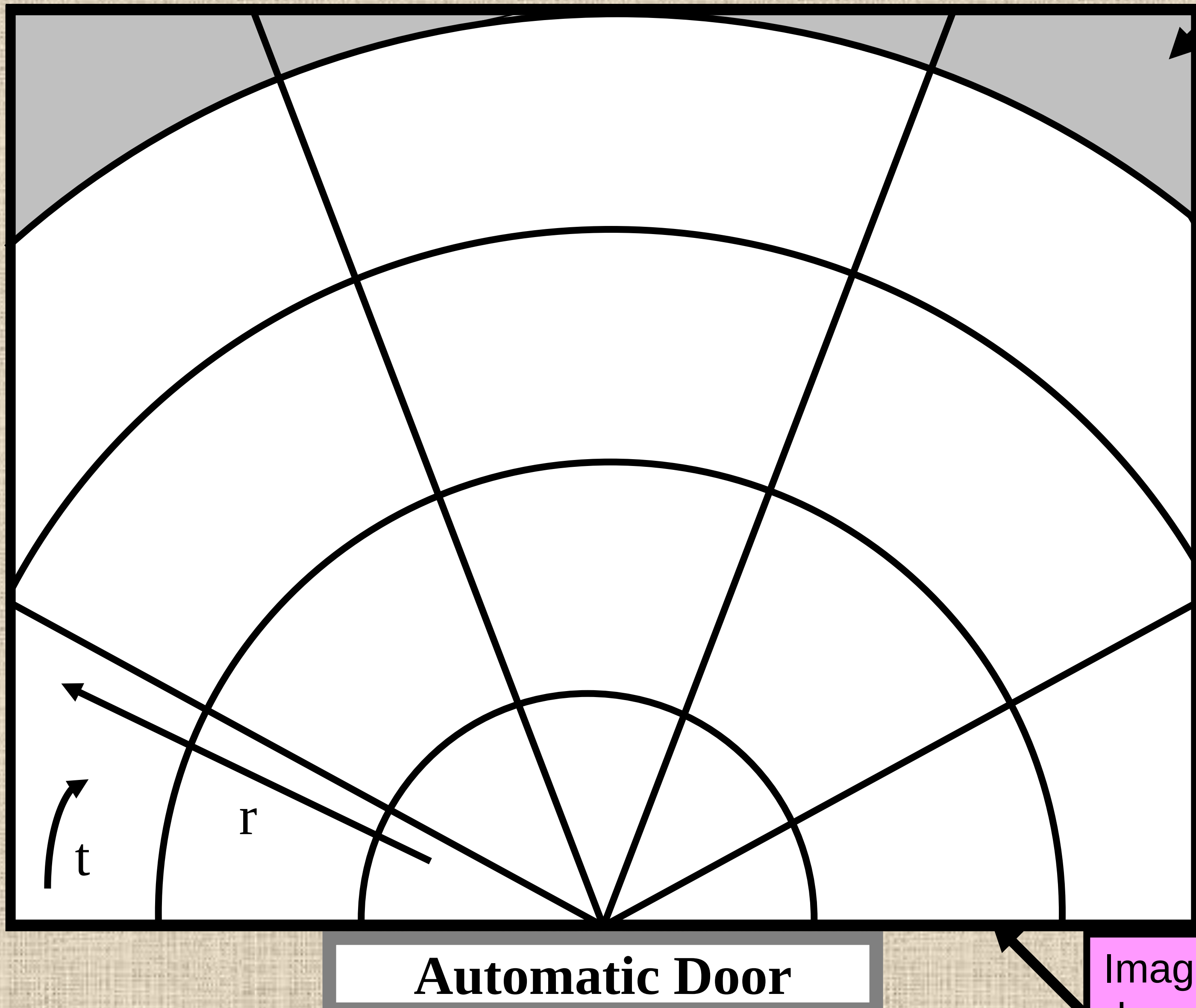


Fig.2.4 Definition of the partial regions.

Each partial region is formed as a sector defined by the polar coordinate system.

The range on the argument *t* is equally divided into five parts, and the depth on the radius r is equally divided into four parts.

Totally, 18 partial regions are defined .

Gray-scaling process

For the image processing, the original color image is converted to the gray-scale image.

$$P(i,j) = 0.299 \times P_R(i,j) + 0.587 \times P_G(i,j) + 0.114 \times P_R(i,j) \quad (1)$$

$$Q(i,j) = 0.299 \times Q_R(i,j) + 0.587 \times Q_G(i,j) + 0.114 \times Q_R(i,j) \quad (2)$$

(i, j)	:position of image pixel
P	:grayscale value of the background image
P_R, P_G, P_B	:color elements of the background image
Q	:grayscale value of the current image
Q_R, Q_G, Q_B	:color elements of the current image

Fig.2.5 Gray-scale process.

Four parameters

① $C(r,t;f)$: The normalized correlation matching

$$C(r,t;f)=\frac{\sum_{(i,j)\in R_{r,t}} P(i,j)\cdot Q(i,j;f)}{\sqrt{\sum_{(i,j)\in R_{r,t}} P(i,j)^2}\sqrt{\sum_{(i,j)\in R_{r,t}} Q(i,j;f)^2}} \quad (3)$$

② $D(r,t;f)$: The representative gray scale value

$$D(r,t;f)=\sqrt{\sum_{(i,j)\in R_{r,t}} Q(i,j;f)^2} \quad (4)$$

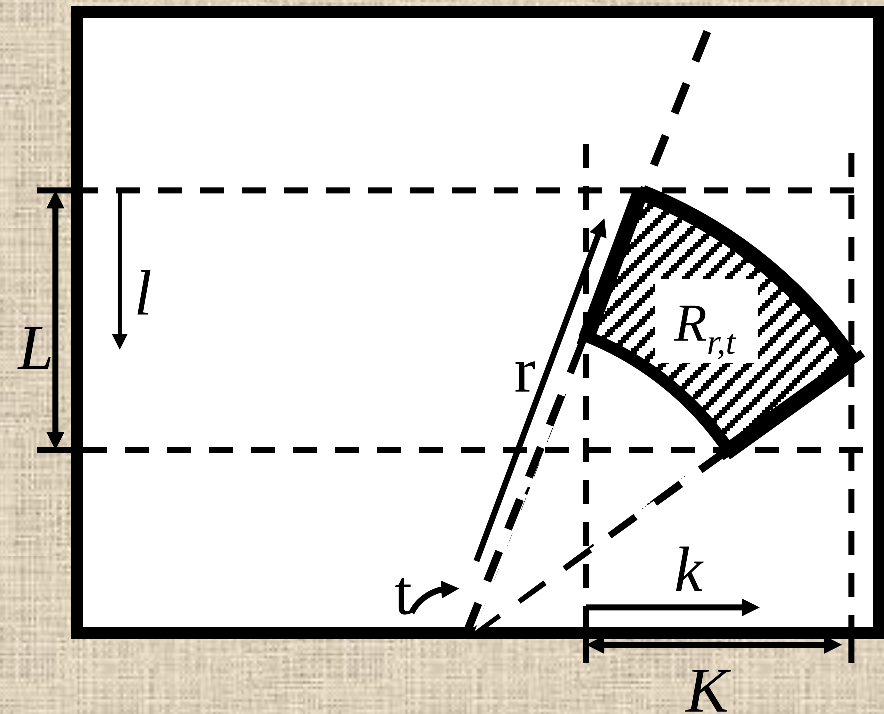


Fig.2.6 Definition of the partial regions $R_{r,t}$.

③ $\Delta C(r,t;f)$: Time variation of the value of C

$$\Delta C(r,t;f)=C(r,t;f)-C(r,t;f-1) \quad (5)$$

④ $\Delta D(r,t;f)$: Time variation of the value of D

$$\Delta D(r,t;f)=D(r,t;f)-D(r,t;f-1) \quad (6)$$

f :an index of the current frame.

Classification 1

When one of those two conditions is satisfied, the partial region is decided as **containing moving objects**.

Condition 1

$$\Delta C(r,t;f) \geq H_1(D) \qquad (7)$$

$H_1(D)$**:** A threshold function of $\boldsymbol{D}$ defined by

$$H_1(D) = \alpha D(r,t;f) + \beta \qquad (8)$$

α, β **:**constant values.

Condition 2

$$\Delta D(r,t;f) \geq H_2 \qquad (9)$$

H_2 **:** A constant threshold value.

In this region, the **direction of the moving object** is determined by the **optical flow estimation**.

Classification 2

When the previous conditions about the moving object are **not satisfied**, and when the condition 3 is satisfied, the partial region is decided as **containing a static object**.

Condition 3

$$C(r,t;f) < H_3 \tag{10}$$

H_3 : A constant threshold value.

This partial region is **joined** to other partial regions similarly containing the static object around this attending region.

→ The size of a block of these partial regions denotes the **size of the static object**.

Especially, if the static object is detected at partial regions **right in front of the automatic door**,

The static object is considered as a **person** standing still at the position.

→ **The door must be always open** while this situation.

Classification 3

When the conditions about moving object and about static object are both not satisfied, the partial region is decided as containing the **background image** only.

If this situation continues for a constant number of frames,

↓

an image giving the maximum C among the frames is substituted for the background image at the partial region.

↓

By means of this technique, the system can always store the exact background image adapting to gray scale change according to weather change and time progress.

3. Detection of Moving Object Direction by Optical Flow Estimation

Although various methods of optical flow estimation has been proposed, …

We have adopted **the Lucas-Kanade method**.

- good accuracy
- short computation time.

$$u(r,t) = \frac{\sum_{(x,y)\in R_{r,t}} \frac{\partial Q(x,y;t)}{\partial x} \cdot \frac{\partial Q(x,y;t)}{\partial t}}{\sum_{(x,y)\in R_{r,t}} \left(\frac{\partial Q(x,y;t)}{\partial x} \right)^2} \quad (11)$$

$$v(r,t) = \frac{\sum_{(x,y)\in R_{r,t}} \frac{\partial Q(x,y;t)}{\partial y} \cdot \frac{\partial Q(x,y;t)}{\partial t}}{\sum_{(x,y)\in R_{r,t}} \left(\frac{\partial Q(x,y;t)}{\partial y} \right)^2} \quad (12)$$

$u(r,t)$: x element of the optical flow estimation at the partial region Rr,t.
$v(r,t)$: y element of the optical flow estimation at the partial region Rr,t.

In the computer program, the optical flow estimation is computed in the discrete coordinate system.

Equation (11)

$$u(r,t)=\frac{\sum_{(x,y)\in R_{r,t}}\{Q(i,j;f)-Q(i-1,j;f)\}\cdot\{Q(i,j;f)-Q(i,j;f-1)\}}{\sum_{(x,y)\in R_{r,t}}\{Q(i,j;f)-Q(i-1,j;f)\}^{2}} \qquad (13)$$

Equation (12)

$$v(r,t)=\frac{\sum_{(x,y)\in R_{r,t}}\{Q(i,j;f)-Q(i,j-1;f)\}\cdot\{Q(i,j;f)-Q(i,j;f-1)\}}{\sum_{(x,y)\in R_{r,t}}\{Q(i,j;f)-Q(i,j-1;f)\}^{2}} \qquad (14)$$

4. Classification experiment

Fig.4.1 Sample images for this experiment.

Experiment Conditions

CCD camera
CCD-CAM(I-O DATA)
Horizontal range**:** 42.4[deg]
Vertical range **:** 32.0[deg]

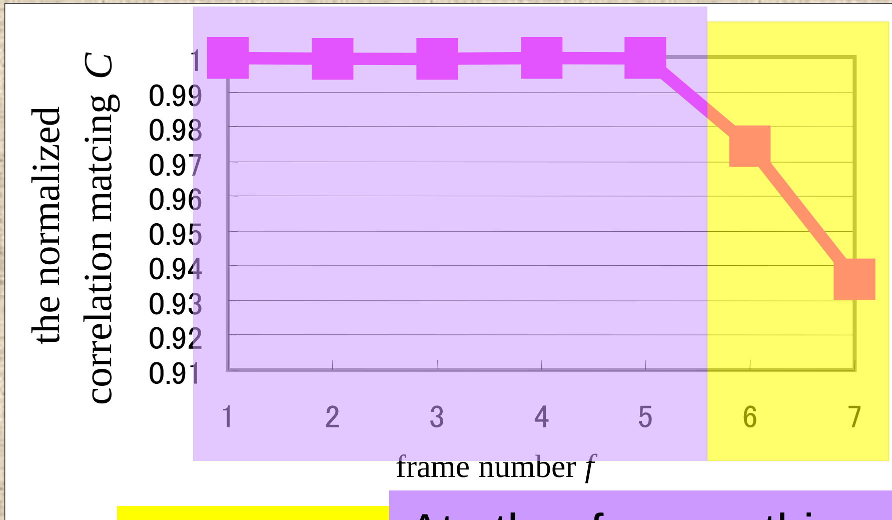
Computer
Dynabook(TOSHIBA)
OS **:**Microsoft Windows Me
CPU **:**celeron 640[MHz]

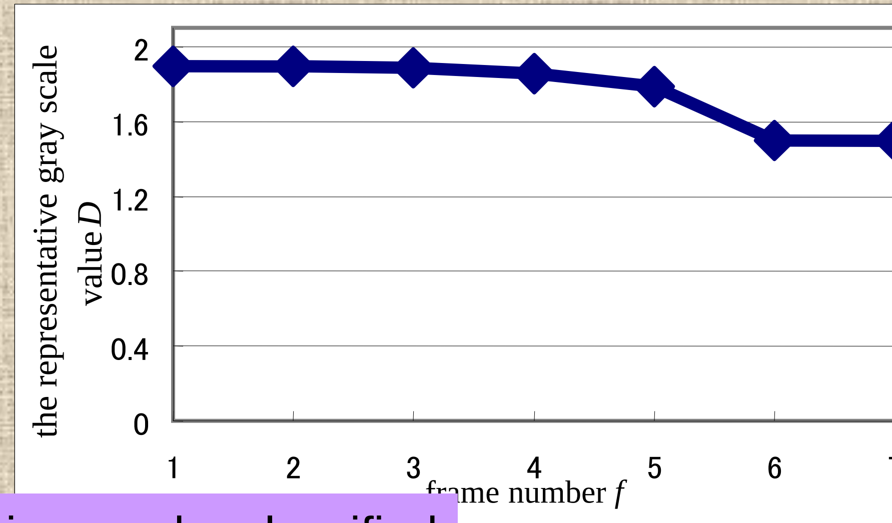
Case1

The partial region $R_{0,0}$ is an example which initially contains the background image only, and after that, contains moving object.

$R_{0,0}$

Fig.4.2 Position of partial region $R_{0,0}$**.**

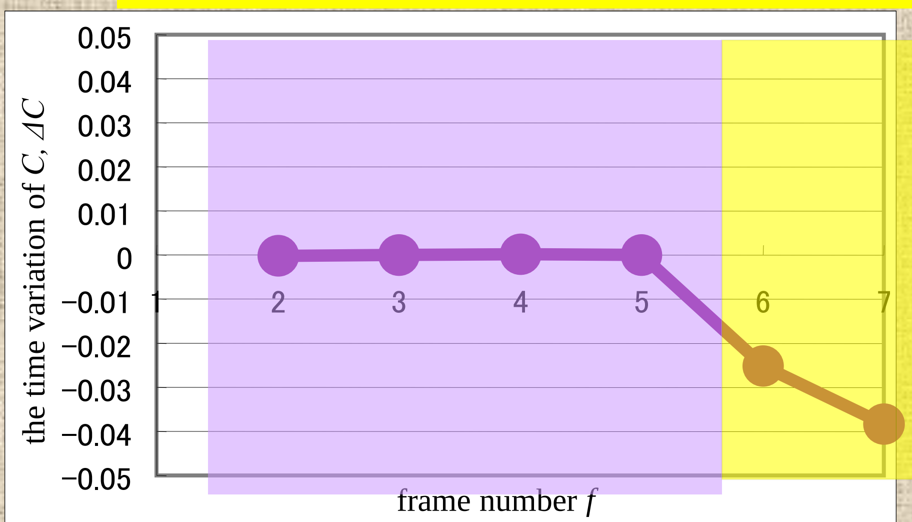


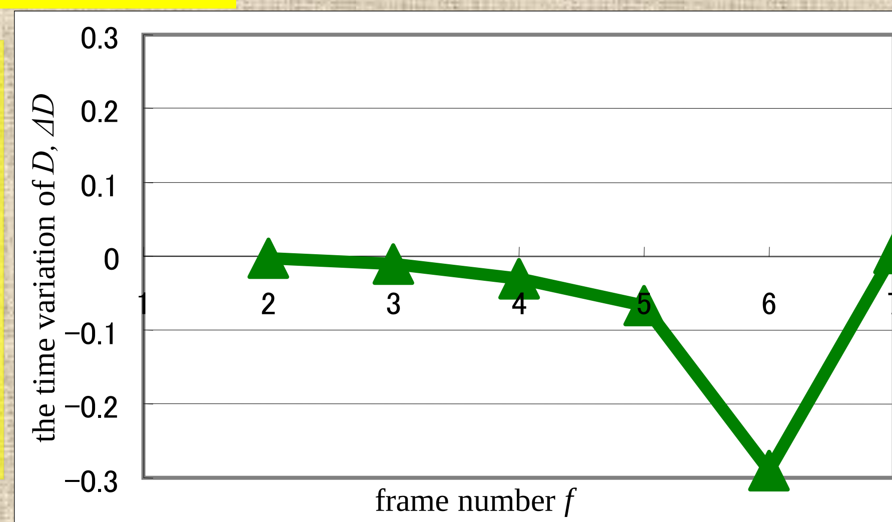


At frames 6
as containin

At other frames, this region can be classified as containing background image only.

ray scale value, D





(c) the time variation of C, ΔC.

(d) the time variation of D, ΔD.

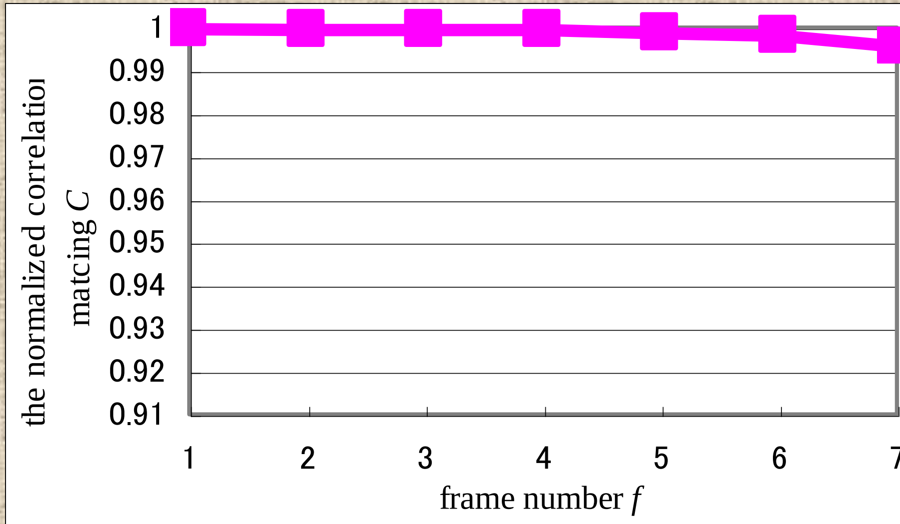
Fig.43 Graphs of C, D, ΔC and ΔD for each frame at the partial region $R_{0,0}$.

Case2

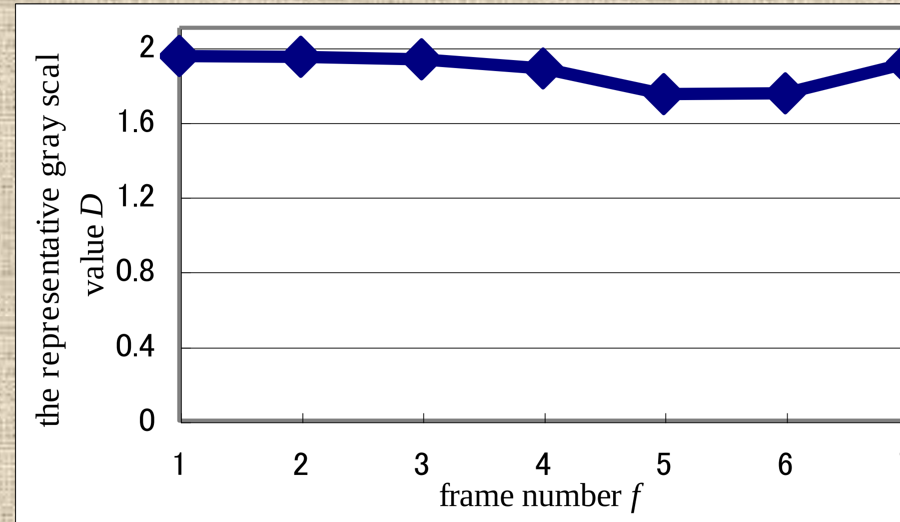
The partial region $R_{0,1}$ is also same example.
But the moving object taken in the region is too small.

$R_{0,1}$

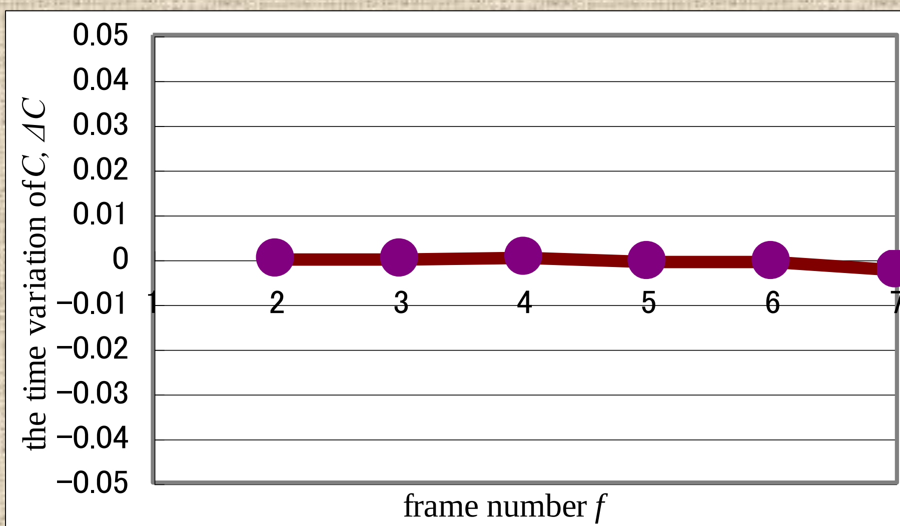
Fig.4.4 Position of partial region $R_{0,1}$.



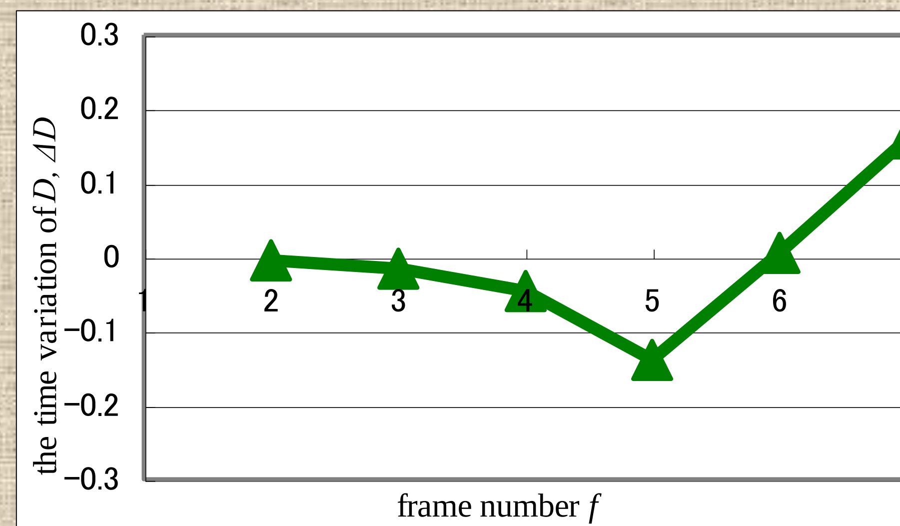
(a) the normalized correlation matching, C .



(b) the representative gray scale value, D



(c) the time variation of C, ΔC.



(d) the time variation of D, ΔD.

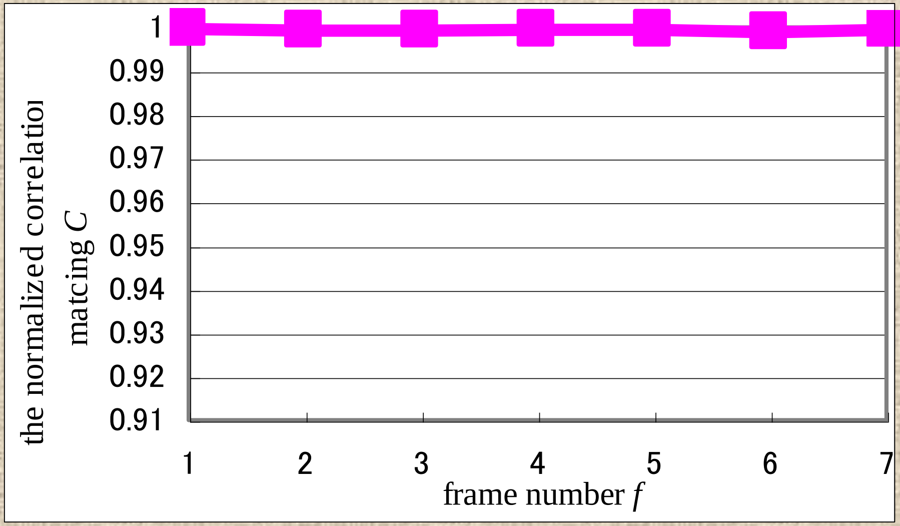
Fig.4.5 Graphs of C, D, ΔC and ΔD for each frame at the partial region $R_{0,1}$.

Case3

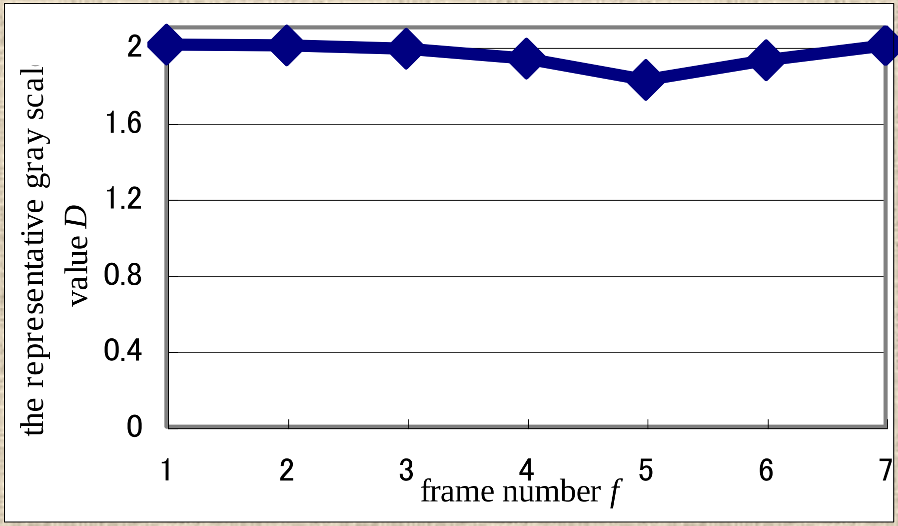
The partial region $R_{0,2}$ is an example which contains the background image only.

$R_{0,2}$

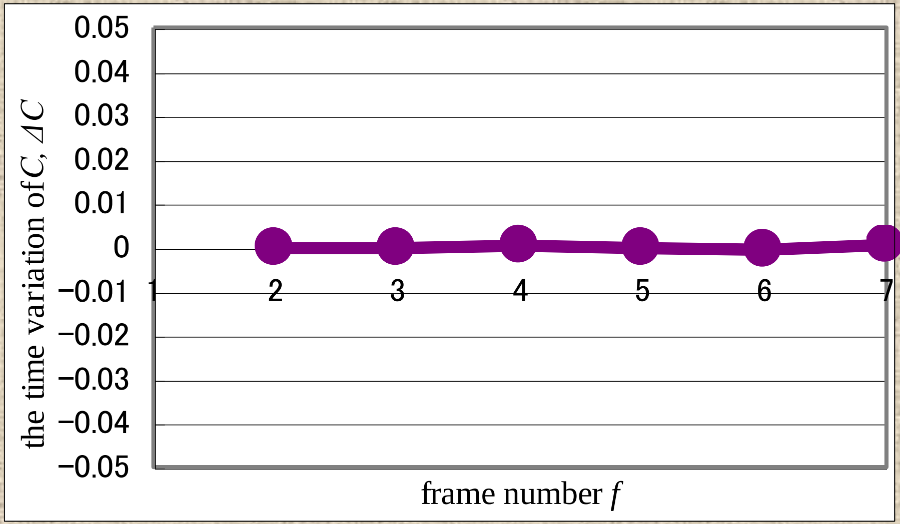
Fig.4.6 Position of partial region $R_{0,2}$.



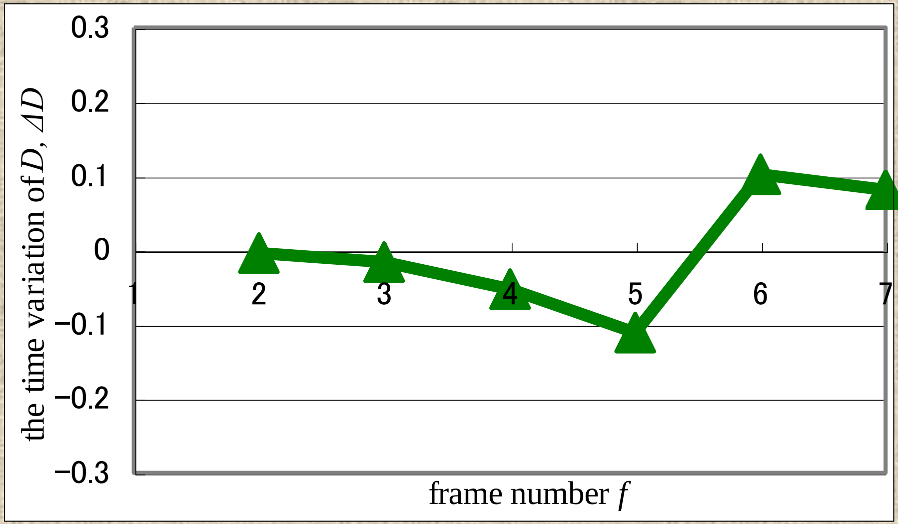
(a) the normalized correlation matching, C .



(b) the representative gray scale value, D



(c) the time variation of C, ΔC.



(d) the time variation of D, ΔD.

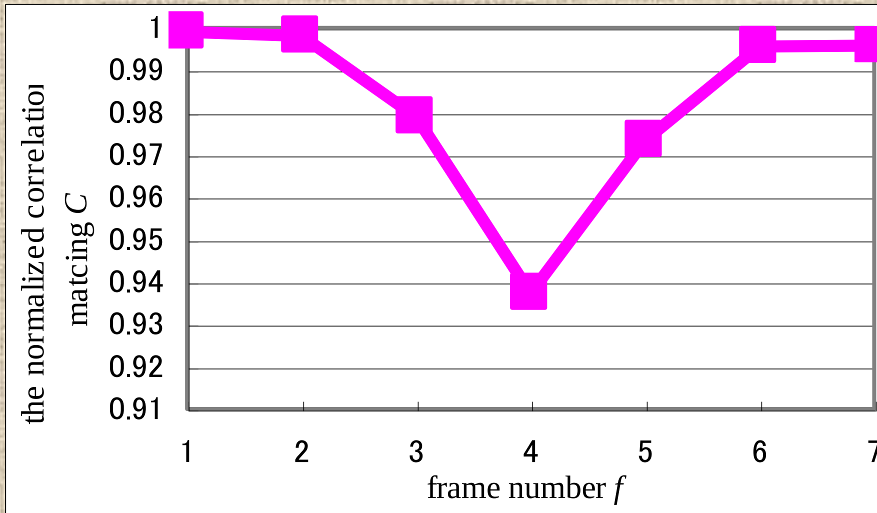
Fig.4.7 Graphs of C, D, ΔC and ΔD for each frame at the partial region $R_{0,2}$.

Case4 The partial region $R_{2,2}$ is an example which initially contains the background image only, and then contains moving object, and after that, contains the background image only.

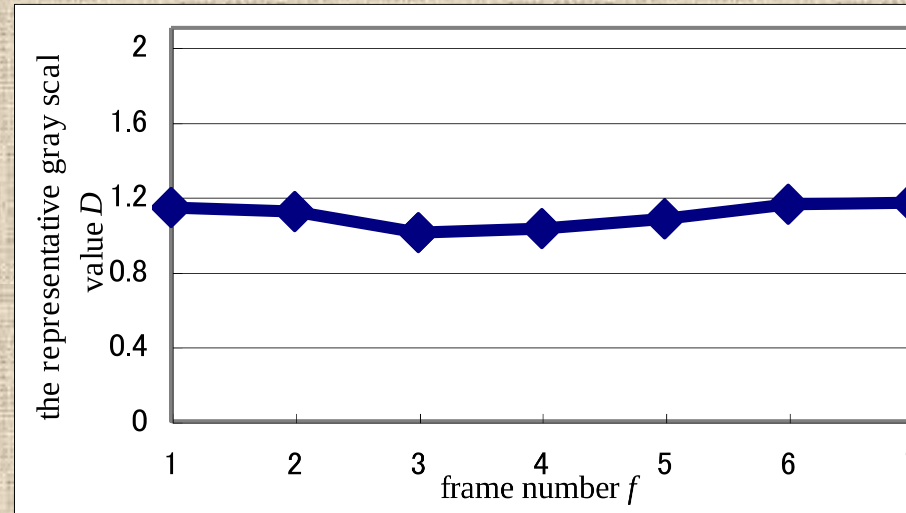
Partial regions such as this case

$R_{2,2}$

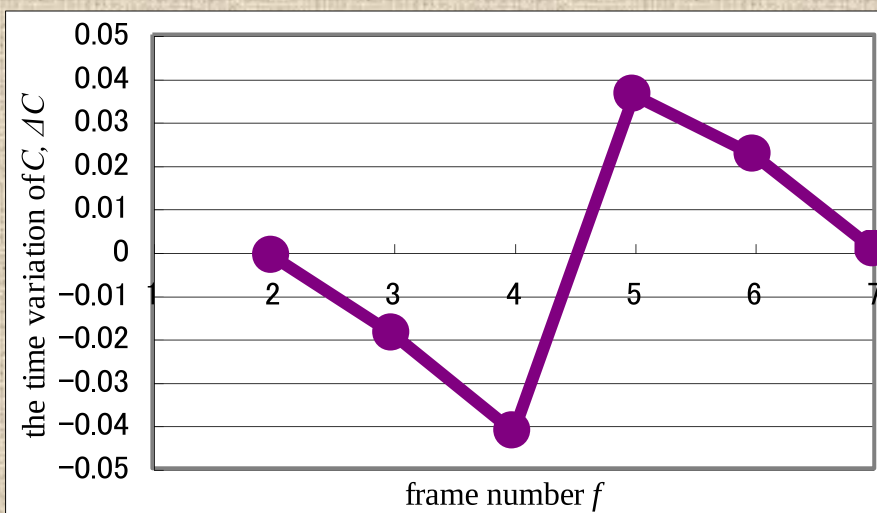
Fig.4.8 Position of partial region $R_{2,2}$.



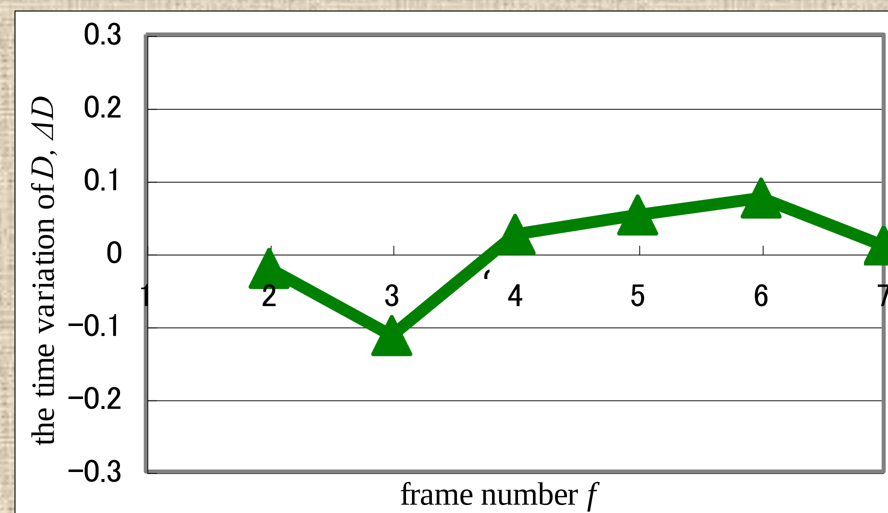
(a) the normalized correlation matching, C .



(b) the representative gray scale value, D



(c) the time variation of C, ΔC.



(d) the time variation of D, ΔD.

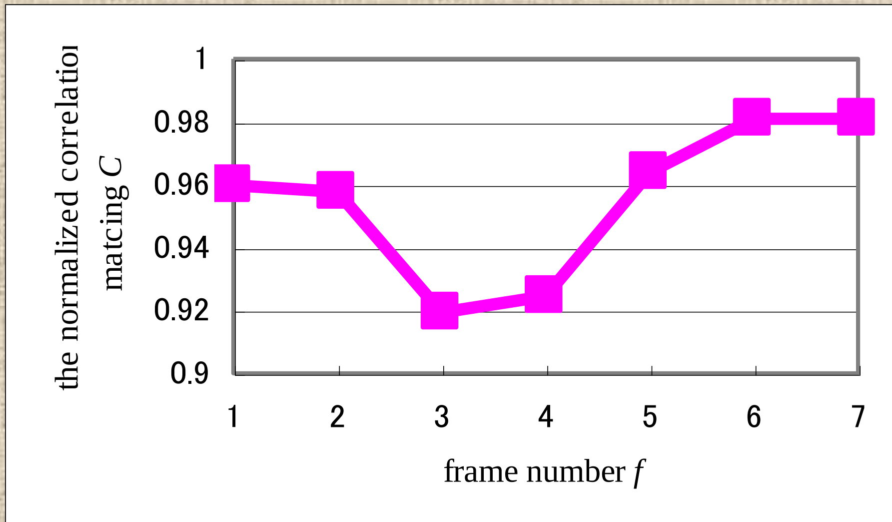
Fig.4.9 Graphs of C, D, ΔC and ΔD for each frame at the partial region $R_{2,2}$.

Case 5

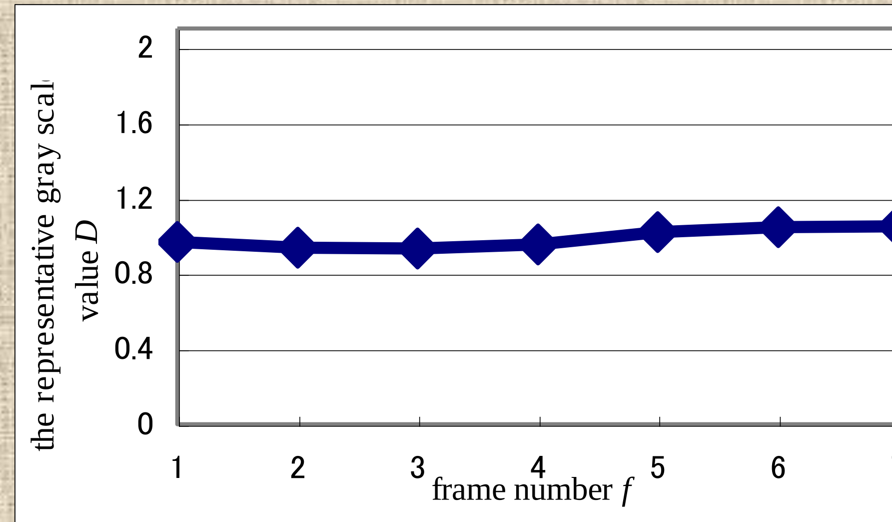
The partial region $R_{3,2}$ is an example which initially contains the moving object, and then contains the background image only.

$R_{3,2}$

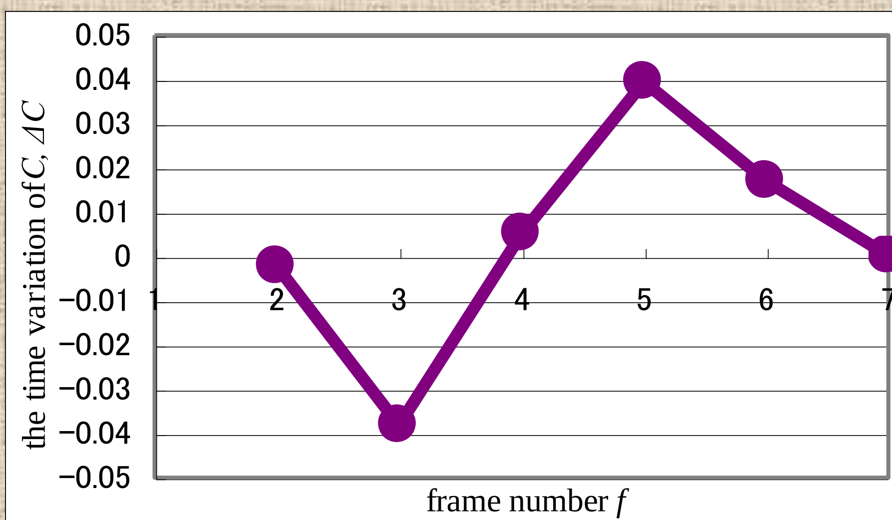
Fig.4.10 Position of partial region $R_{3,2}$.



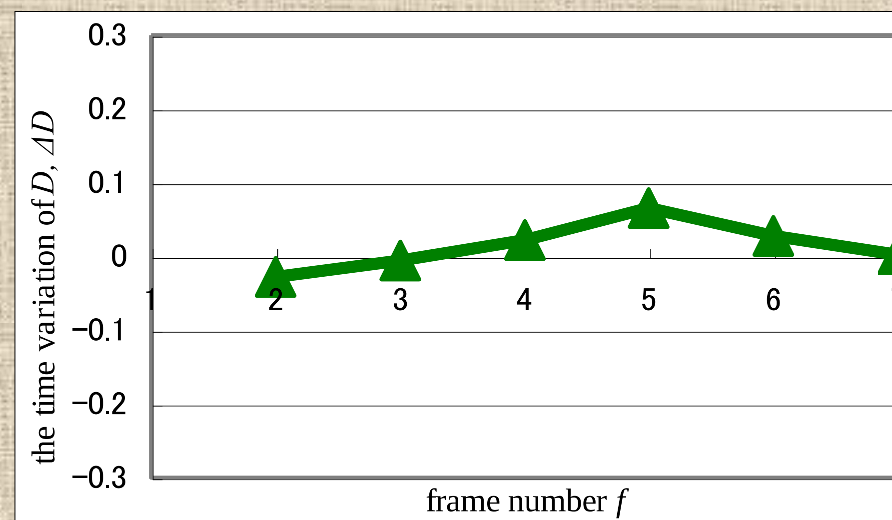
(a) the normalized correlation matching, C .



(b) the representative gray scale value, D



(c) the time variation of C, ΔC.



(d) the time variation of D, ΔD.

Fig.4.11 Graphs of C, D, ΔC and ΔD for each frame at the partial region $R_{3,2}$.

Consideration from the experiment

- From these experiments, the threshold value H_3 should be set as follows.

$$0.978 \leq H_3 \leq 0.980 \quad (15)$$

- When small part of the moving object is taken in the partial region, C does not distinctly change, especially for large sized partial regions. Therefore, different threshold is required according to the size of region.

- The time variation ΔC is effective for recognition of existence of the moving object.

- We could not fined clear effectiveness of parameters D and ΔD.

5. Conclusion

We tried a technique to classify the partial regions for the open-close control system by using image processing.

- The CCD camera takes continual images.
- The continual images are divided into the partial regions.
- The partial region is classified into 3 types by means of 4 parameters.

Experiment of the classification is illustrated.

- It is clarified that the normalized correlation matching and its time variation are effective for the classification.
- Effectiveness of the representative gray scale value and its time variation could not found.

In the future

1. We will find effective parameters for the classification, and develop the rest of the system.
2. We will establish a new technique to compute the optical flow estimation **by using GA**, which we are doing research on.
3. A lens with wide range is also considered to be installed on the CCD camera of the systems.

That’s all !

Thank you!