Viewing Tablet: A Pointing System Applicable to any Sheet Object

Hiroshi Usuda[*,**] **and Masanori Idesawa**[*]

*Graduate School of Information Systems, The University of Electro-Communications
1-5-1, Chofugaoka, Chofu-shi, Tokyo, 182-8585 Japan
**Sony Corporation
6-7-35, Kitashinagawa Shinagawa-ku, Tokyo, 141-0001 Japan
E-mail: usuda@arch.sony.co.jp

We discuss a pointing system, the viewing tablet, that enables input or instructions to be given to information system by the operator viewing a sheet object and pointing out its position in the field of vision. The operator has a small video camera that picks up an image of the partial area including the viewing position and points out an object in the field of vision. The viewing tablet processes the partial area image on the object including the viewing position to detect the position in a part pointed out with a finger and gives input or instructions to information system. A transparent space code sheet is overlapped for use that is added with position information on the sheet object to determine the position in the object from the partial area image. We studied the basic technique required for this pointing system and confirmed its feasibility.

Keywords: human interface, information system, digital devide, pointing system, CHI

1. Introduction

Information systems have progressed dramatically and are now widely disseminated from business to the home, providing a wide range of applications to many different users.

Information systems are now indispensable to everyone, but a serious problem exists concerning on the digital divide between users and nonusers.

To solve this problem, information systems should enable users to express intentions or instructions in a way close to accurate, natural motion.

Being able to give input or instructions to information systems by pointing in the user's field of vision is expected to help solve this problem and lead to new applications. We propose a pointing system called the **Viewing Tablet.**

2. Communication between People and Information Systems

People communicate through gestures and language to smoothly convey their intentions. An example is directly pointing out an object in a person's field of vision using words and gestures such as "this" or "that".

This implies the naturalness of this communication. In other words, pointing to a sheet object in the field of vision directly with a finger is familiar to everyone and useful in communication between users and information systems.

The mouse and keyboard are representative of input and instructions widely used with information systems. However, since operations using the keyboard or mouse involve a pattern in which the point of view differs from the operating position, it is difficult to get natural operation and requires training.

Another typical pattern of pointing out an object with a finger for input or instructions is the touch panel, which lets the point of view agree with the operating position, leading to natural operation. It does not require training but it is limited to specific places or conditions for use and is difficult to apply to a variety of real sheet objects.

To overcome the difficulty of the touch panel and to real sheet objects (e.g., catalogs or books), some video tablets have been developed that add a one- or two-dimensional code to a sheet object, picked up with a video camera as video information and processed as an image for input and instructions[3-7].

For these input or instructions, devices are fixed in a specific environment and users cannot give input or instructions without this environment, preventing random or free use from a view of vision at any location.

"A Letter Input System of Handwriting Gesture"[8] extracts changes in the finger position and recognizes them as characters from finger movement and input as code information. The concept of this approach differs our, which targets input or instructions by pointing out a position in a sheet object with a finger.

Other approaches are considered that use a transparent tablet as a method to give input or instructions by pointing out a sheet object with a finger in the user's field of vision.

The transparent tablet requires position detection in advance, which requires a position detection sensor, an arithmetic unit for coordinate positions and a power supply. This method enables input or instruction to be given on a sheet object in the field of vision with a finger, but there are limitations on the range of use and time. It has different setup conditions from we.

We propose implementation of input or instructions that enables natural operation where the viewing point of the user agrees with the operating position, leading to the development of the **Viewing Tablet** enabling input or instructions to be given by pointing out a sheet object in the user's field of vision.

For this **Viewing Tablet**, the operator has a small video camera that picks up a partial area including the viewed location and points to a particular area with a finger on a sheet object within the user's field of vision.

The viewing tablet processes the partial area image on the sheet object including the picked up viewed location and detects the position pointed out with a finger in the object to give input or instructions to information system. It is overlapped with a transparent **Space Code Sheet** for position information added to the sheet object to determine the position in the object from the partial area image.

3. Viewing Tablet

The **Viewing Tablet** deals with the inside of the user's field of vision just like a tablet and is a pointing system that enables the user to give input or instructions to information system by pointing out the viewing area on a sheet object in the user's field of vision.

3.1. Overview of Viewing Tablet

As a specific pattern for use, the viewing tablet is used to point out information stored in information systems in relation to the position in the page of brochures or books. It makes it easy to relate information in information systems to the position in existing catalogs or brochures.

The configuration below is typical of implementation patterns of this system.

The first component is a pickup means of capturing the video of a part on a sheet object that is of interest to the user. This uses a CCD camera on the head or eyeglass frame of the user to obtain the video of the central field of vision (view of interest and surroundings). Even if the user moves the point of view, the CCD camera picks up an area including the position of the sheet object. When the user points out a sheet object in the user's field of vision with a finger, the obtained video contains the area image containing the viewing position in the object and the finger image. Thus, it is possible to detect the area containing a part of interest to the user on the sheet object and information on the motion pointed (**Fig.1**).

The second component is a means of detecting the position in a sheet object pointed out with the user's finger. To implement pointing, the system must detect the position of the pointing point on coordinates fixed to a sheet object. The video by the above pickup means is a partial area around the viewing point of the user. By doing this, it is normally difficult to specify the position of a sheet object. We devised how to use a transparent **Space Code Sheet** with space codes arranged so they is extracted and recognized by simple image processing without impairing visibility of an object even if the code sheet is overlapped and the quality of the image obtained with the CCD and that they can easily specify the position in the entire sheet object from the partial video (**Fig.2**).

The third component is an additional code to identify a viewing sheet object. For example, catalog sheets or book pages are assumed as a viewing sheet object. It is also assumed that an additional code has been given to these pages individually for identification of a sheet object (category) by labeling when they are related to information in information system. The additional code for the identification of the category is used to detect and recognize processing simply and easily. In this sense, **Umark**[1,10], a system we previously developed, is effective and the system is discussed using it as an example.

3.2. Operating Procedures and Features

The **Viewing Tablet** operates as follows:

(1) The user overlaps and sets up a transparent **Space Code Sheet** on a given page of a sheet object such as a target page of a book or a catalog sheet added with a sheet object identification (category) code.

(2) The user looks at the category code and points it out with a finger. The **Viewing Tablet** processes the video information picked up by the mounted camera. It extracts and recognizes the finger of the user and the category code pointed out with the finger to specify a sheet object.

(3) The user moves the point of view to a part of interest on the sheet object and pints out the additional required information in the field of vision with a finger. The **Viewing Tablet** processes the video picked up by the camera and recognizes the finger of the user and multiple space codes placed around the finger. Then it specifies a part on the sheet object to which the pickup part corresponds and sets up sheet object coordinates. The position pointed out with the finger is determined in sheet object coordinates and contents are accessed that are prepared to correspond to the particular part to show information specified by the user on a contents display (**Fig.1**).

The user has access to intended information and uses it by combining and repeating the above operations.

The surface of a sheet object is assumed to be distorted when the user holds a catalog or brochure and looks at it while pointing out the required information in it.

The viewing tablet does not require distortion correction for the entire sheet object, only for the viewed pickup area. There is no problem even if the viewing pickup area is treated as almost flat. Thus, if only turning or rotation is corrected for the pickup image, distortion is corrected.

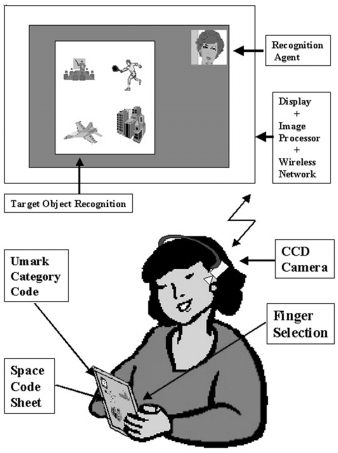

Fig. 1. Viewing tablet.

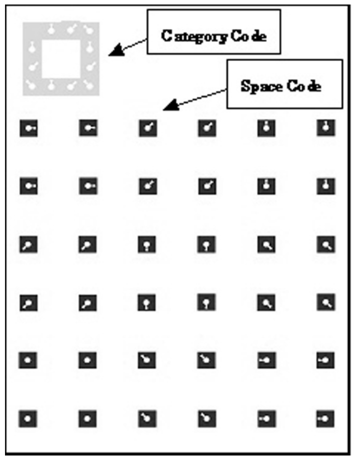

Fig. 2. Space Code Sheet (example of **Umark** added).

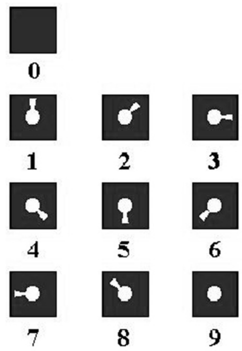

Fig. 3. Umark code number.

The **Viewing Tablet** eliminates conventional cutout because only the area to which the user pays attention is picked up but also the capability of obtaining detailed video information on the viewing area because it is picked up by the whole CCD area.

The point worth noting is that the CCD specifies the position in the CCD image, and the position in the entire sheet object from the partial image of the sheet object even though the image of the entire sheet object is not obtained.

The **Viewing Table** has no problem with the lack of pickup resolution during recognition and provides precise analysis because good-quality image data is used for processing.

3.3. Category Code

The category code specifies a category intended by a book or catalog. If it is new, it is attached to a page of the book and does not interfere with page print information.

It should be simple and extracted and recognized easily and surely.

As an implementation pattern with the specification of a book or catalog category kept in mind, an attempt was made to use the graphic code **Umark** as a category code added to a sheet object.

The feature of a numerical value represented by **Umark** is that the unit of basic numerical code is a decimal and that, unlike other widely used one- or two-dimensional binary code, recognition by the information system is easy, and generated and recognized by people (**Fig.3**).

3.4. Space Code Sheet

Because the position of a sheet object is specified by the partial image, the **Space Code Sheet** is printed so it is overlapped on a transparent sheet for use (**Fig.2**).

The space code sheet is built up so the position in the entire sheet object is easily specified from the code on the sheet partially picked up on the sheet. The code is extracted and recognized by simple image processing without interfering with visibility of the sheet object.

If the sheet contains all different codes, it will be able to be built up so only recognizing one code that uniquely specifies the position in the entire sheet object. However, this increases the number of codes and complicates operation, so the visibility of a sheet object may be compromised and there may be a burden on extraction and recognition processing. For these reasons, we used a configuration to specify the position in the entire sheet object from multiple adjacent codes rather than from a single code.

The configuration uses **Umark** as used for the category code as a space code.

As shown in **Fig.2**, space codes are placed sequentially from the origin of the XY coordinates (served as the sheet object coordinates) located right upwards on the **Space Code Sheet** left downwards. Thus, each space code is placed in advance at a given coordinate position in XY coordinates on the sheet and its position is determined from multiple adjacent space codes.

If multiple adjacent spaced codes (**Umark**) is accurately recognized with the CCD camera, the position is specified in XY coordinates (sheet object coordinates) of the pickup partial image.

By using the principle of this **Space Code Sheet**, the **Viewing Table** is implemented based on the operation in the user's field of vision.

The sections that follow discuss how the position (XY coordinates) on the **Space Code Sheet**, that is, the posi-

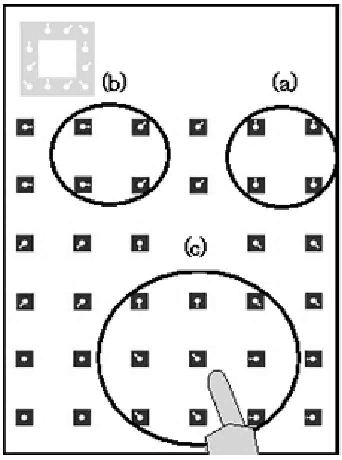

Fig. 4. Detection area of space code.

tion on the sheet object coordinates, is specifically determined from multiple adjacent codes detected in the pickup partial area of the **Space Code Sheet**, based on the **Space Code Sheet** in **Fig.2**.

Assuming that four codes are detected from the pickup image as in **Fig.4(a)** or **(b)**, it is possible to determine that each of these codes corresponds to a specific partial area on the **Space Code Sheet** and to set up the coordinate value of each code from the preregistered table of coordinate values. Even if only three of four codes are detected, it is uniquely determined which position in the **Space Code Sheet** corresponds to them.

In short, the **Space Code Sheet** corrects errors so it can uniquely determine the position on the sheet.

The area picked to implement the actual system is assumed to contain 3×3 codes on the **Space Code Sheet** in **Fig.4(c)**.

The application of the above algorithm is (1) to determine the coordinate value on the pickup image of the detected codes and (2) to make reference to the preregistered table of coordinate values to determine the coordinate value on the **Space Code Sheet** corresponding to the table.

This enables calculation in relation to the conversion from pickup image coordinates to coordinates on the **Space Code Sheet**. This leads (3) to the conversion from the finger position detected in the pickup image to that in coordinates on the **Space Code Sheet**. This enables the position pointed out by the user to be detected and the operation or instruction to be conducted accordingly (**Fig.4(c)**).

The code pattern is arranged experimentally in the form of responding to the pointing resolution from the size of a finger. It is not essential to follow the code arrangement, pattern or size , which is set based on the type of sheet object to be handled.

If a particular code pattern is required, it is implemented by a combination of multiple code pattern[1,2,10]. Of course, the user may add a different code pattern.

4. Image Processing of Space Code

To specify the position in the entire **Space Code Sheet** from a partial image, it is necessary to extract and recognize a space code from **Space Code Sheet** images entered through the CCD camera. To do this, images entered through the CCD camera must be digitalized first by the optimum threshold.

4.1. Digitalization

The threshold must be a proper value for digitalization. The following are examples that set this digitized threshold up automatically.

- P tile

If the approximate area ratio P of the image section in the image of a sheet object is known, this method determines threshold T so the ratio of white to black pixels in a binary image becomes P.

- Discrimination analysis

This determines the optimum threshold in a statistical sense from the density histogram of an image. Interclass dispersion $\sigma^2(k)$ becomes the maximum by Eq.(1.1) if the histogram is divided into classes based on a certain threshold and threshold k should be selected.

$$\sigma^2(k) = \omega_0(\mu_0 - \mu_r)^2 + \omega_1(\mu_1 - \mu_r)^2 \quad (1.1)$$

n_i = Number of pixels at level I

N = Total number of pixels

$$\boldsymbol{Pi} = \boldsymbol{ni} / \boldsymbol{N} \quad (1.2)$$

$$\omega_0 = \sum_{i=1}^{k} Pi \quad (1.3)$$

$$\omega_1 = \sum_{i=k+1}^{L} Pi \quad (1.4)$$

$$\mu_0 = \sum_{i=1}^{k} iPi / \omega_0 \quad (1.5)$$

$$\mu_1 = \sum_{i=k+1}^{L} iPi / \omega_1 \quad (1.6)$$

$$\mu_r = \sum_{i=1}^{L} iPi \quad (1.7)$$

Eq.(1.1) assumes that the density level {1,2, ...L} and that threshold divides pixels into two classes C_0 and C_1, that is, level [1,k] and level [k+1,L].

Pi, ω_0, ω_1, μ_0, μ_1, μ_r is described as in Eqs.(1.2) through (1.7).

The system used discrimination analysis to determine the digitalized threshold.

4.2. Conversion from Pickup Coordinates to Space Code Sheet Coordinates

To specify a sheet object position in the field-of-vision image picked up by the CCD camera, it is necessary to determine the position in pickup coordinates. Because the sheet object in pickup coordinates is the one that a sheet object including the part watched by the user in three-dimensional space that is projected on the two-dimensional pickup surface, it contains distortion such as turning or rotation. As described in Section 3.4, it is necessary to convert the position of a user finger that was detected in the pickup image to the coordinate position in the **Space Code Sheet** for the operation or instruction in accordance with the finger position.

It is necessary to correct a pickup image including turning or rotation distortion to the two-dimensional rectangular coordinates.

To correct the distortion of coordinates on a sheet object in three-dimensional space, a method is proposed in "Matrix"[9] that the posture in three-dimensional space is capture by calculating eight parameters for the perspective conversion from specific four vertexes for the coordinate conversion and correction of an image.

If the CCD camera picks up two-dimensional code on a sheet object, a coordinate detection error on the pickup screen may not be large, but a different error may occur such that the sheet object is bent so that it is outside the pickup plane.

Because very few images are picked up without distortions in the real environment, "Matrix" conversion requiring 4 specific vertexes to be detected is insufficient as conversion for this system.

The sections that follow explain conversion applicable to this system. If two or more space codes are detected that are adjacent to the partial image of the **Space Code Sheet**, their positions corresponding to the sheet, that is, a set of coordinate values at a point indicated two coordinates is given.

Coordinate conversion on the two-dimensional plane is generally described as in (2.1) and (2.2). Assuming that the positions of n space codes that were detected on the pickup surface are (x_i, y_i) (i=1, ...,n) and that coordinate values on the **Space Code Sheet** corresponding to these positions are (X_i, Y_i), respectively, the relationship between (X_i, Y_i) and (x_i, y_i) becomes Eqs.(2.1) and (2.2). If a_x, b_x c_x and a_y, b_y, c_y are determined, any points on the pickup surface is converted by this conversion to coordinate values on the **Space Code Sheet**.

$$X_i = a_x \cdot x_i + b_x \cdot y_i + c_x \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2.1)}$$

$$Y_i = a_y \cdot x_i + b_x \cdot y_i + c_y \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2.2)}$$

If the values of (X_i, Y_i) and (x_i, y_i) are given by any three or more space code points (n ≧ 3), the parameters $\{a_x, b_x, c_x\}$ and $\{a_y, b_y, c_y\}$ is found.

In other words, find the parameters ax, bx, cx and ay, by, cy that minimize the error of mean square J indicated by Eq.(2.3).

(Assuming $\sum = \sum_{i=1}^{n}$)

$$J = \sum\{(a_x \cdot x_i + b_x \cdot y_i + c_x - X_i)^2 + (a_y \cdot x_i + b_y \cdot y_i + c_y - Y_i)^2\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2.3)}$$

To find the parameters $\{a_x, b_x, c_x\}$ and $\{a_y, b_y, c_y\}$ that this J takes the minimum value (extremal value), obtain Eqs.(2.4) and (2.5) by setting the result of each parameter by partial differential to be 0.

$$\begin{pmatrix} \sum x_i^2 & \sum x_i y_i & \sum x_i \\ \sum x_i y_i & \sum y_i^2 & \sum y_i \\ \sum x_i & \sum y_i & n \end{pmatrix} \begin{pmatrix} a_x \\ b_x \\ c_x \end{pmatrix} = \begin{pmatrix} \sum X_i x_i \\ \sum X_i y_i \\ \sum X_i \end{pmatrix} \ldots\ldots \text{(2.4)}$$

$$\begin{pmatrix} \sum x_i^2 & \sum x_i y_i & \sum x_i \\ \sum x_i y_i & \sum y_i^2 & \sum y_i \\ \sum x_i & \sum y_i & n \end{pmatrix} \begin{pmatrix} a_y \\ b_y \\ c_y \end{pmatrix} = \begin{pmatrix} \sum Y_i x_i \\ \sum Y_i y_i \\ \sum Y_i \end{pmatrix} \ldots\ldots \text{(2.5)}$$

The coordinate conversion parameters $\{a_x, b_x, c_x\}$ and $\{a_y, b_y, c_y\}$ is found by solving Eqs.(2.4) and (2.5) as above.

That is,

$$\begin{pmatrix} a_x \\ b_x \\ c_x \end{pmatrix} = \begin{pmatrix} \sum x_i^2 & \sum x_i y_i & \sum x_i \\ \sum x_i y_i & \sum y_i^2 & \sum y_i \\ \sum x_i & \sum y_i & n \end{pmatrix}^{-1} \begin{pmatrix} \sum X_i x_i \\ \sum X_i y_i \\ \sum X_i \end{pmatrix} \ldots\ldots \text{(2.6)}$$

$$\begin{pmatrix} a_y \\ b_y \\ c_y \end{pmatrix} = \begin{pmatrix} \sum x_i^2 & \sum x_i y_i & \sum x_i \\ \sum x_i y_i & \sum y_i^2 & \sum y_i \\ \sum x_i & \sum y_i & n \end{pmatrix}^{-1} \begin{pmatrix} \sum Y_i x_i \\ \sum Y_i y_i \\ \sum Y_i \end{pmatrix} \ldots\ldots \text{(2.7)}$$

$(\ )^{-1}$ is an inverse matrix.

5. Verification Experiments

If the viewing position in the entire **Space Code Sheet** is detected from the partial image picked up by the CCD camera, the following (1) and (2) that are its basic techniques must be checked for their performance.

(1) Method determine the position in the entire section from the partial image

(2) Method to correct the relationship between the positions of the sheet object and the camera that is not constant (due to turning or rotation)

To check (1) and (2) for their performance, we made verification experiments on the algorithms in 4.1 and 4.2. A video camera installed on eyeglasses is used in the

Fig. 5. Video camera for experiments.

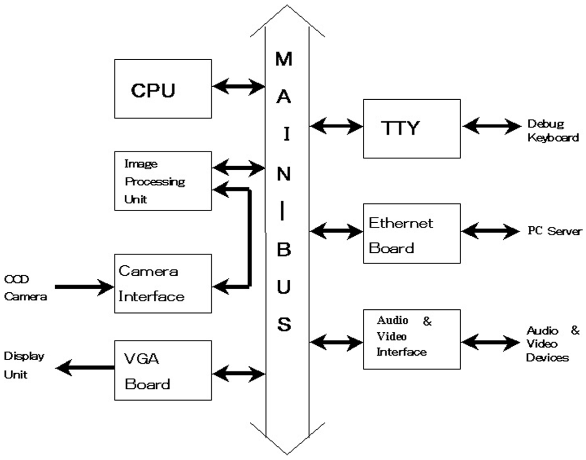

Fig. 6. Hardware configuration for experiments.

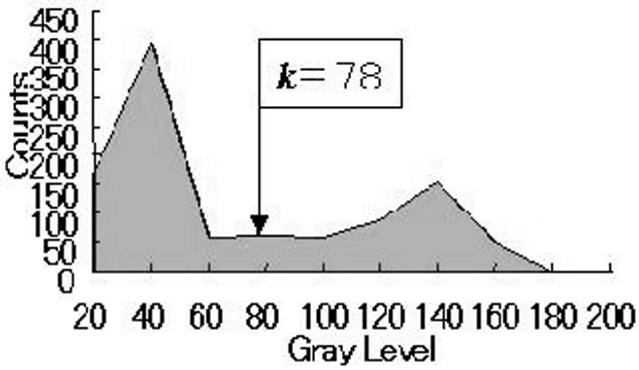

Fig. 7. Results of determining digitalized threshold.

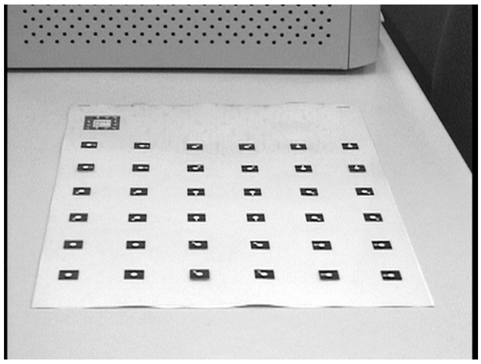

Fig. 8. Space Code Sheet and sheet object (paper added with category codes).

actual system, but we used the one as shown in **Fig.5** containing the CCD device with S-video output.

We used an NTSC color EIAJ, a 1/3-inch color CCD (380,000 pixels), a motor-driven 12-magnification zoom lens, F1.8-F2.7, a horizontal field angle of 4.4° to 48.8°, the nearest pickup distance of 10 mm, the lowest subject illumination of 7 lx, a horizontal resolution of 460 TV pieces, and a pan tilt function (horizontal±100°, vertical ±25°) as the specifications of the CCD camera. (Motor-driven zoom CCD camera EVI-D30 made by Sony)

Input images were stored in video memory in the video image-processing unit as in Fig. 6 and CCD image data (640×480 pixels) was taken sequentially from the video memory and processed by each coordinate conversion program based on digitalization and the method of least squares.

The NEC VR4131 was used as the CPU, the IP90MS800 made by Sumitomo Metal Industries as the image input and output unit, and WindRiver VxWorks as the operating system. The VxWorks program development environment was mounted on the PC server and the generated code was downloaded into memory via the network.

5.1. Digitalization

The **Space Code Sheet** has the space code display portion treated as opaque with a white correcting fluid from the back of the sheet. Thus, it is designed to prevent a mixture of contents with codes even if it is overlapped on a book page. This design enables a pickup space code image to be detected by digitalization.

The digitalization program is mounted in CPU memory as shown in **Fig.6** and is operated sequentially by the command line.

If the camera in **Fig.5** is actually used to process a digitalized threshold under the room environment (about 180 lx) with the algorithm in section 4.1, the digitalized threshold k=78 is found as shown in **Fig.7**. This threshold is used for digitalization. The execution time of the digitalization program is 17 ms.

5.2. Conversion from Pickup Coordinates to the Space Code Sheet Coordinates

We made experiments on the verification of the precision of converting pickup coordinates to the **Space Code Sheet** coordinates using the **Space Code Sheet** assumed for practical use.

The program for this conversion is mounted in CPU memory as shown in **Fig.6** and made available by the command line for sequential operation.

This program calculates coordinate conversion parameters ax, bx, cx and ay, by, cy by substituting the values of (X_i, Y_i) and (x_i, y_i) of three or more points ($n \geqq 3$) in Eqs.(2.6) and (2.7) based on the method of least squares in Section 4.2.

As the experimental setup conditions, a turning distor-

Table 1. Conversion rate of sheet object (category codes).

Rotation Angle	Number of Right Transformation	Number of NO Transformation	Number of Miss Transformation	Ratio of Right Transformation
(+) 30°	100	0	0	100%
(+) 25°	97	1	2	97%
(+) 20°	100	0	0	100%
(+) 15°	97	2	1	97%
(+) 10°	97	3	0	97%
(+) 5°	96	1	3	96%
(+/-) 0°	97	1	2	97%
(-) 5°	98	0	2	98%
(-) 10°	96	4	0	96%
(-) 15°	94	6	0	94%
(-) 20°	95	3	2	95%
(-) 25°	99	0	1	99%

Table 2. Examples of coordinate conversion coefficients found by method of least squares.

Parameter	Case(1)	Case(2)	Case(3)
ax	0.512	0.546	0.576
bx	0.073	-0.339	0.044
cx	0.411	7.707	0.380
ay	-0.120	0.211	0.059
by	0.498	0.315	0.711
cy	12.707	0.473	0.230

tion occurs mostly in cases where the **Space Code Sheet** is put on the desk because the **Space Code Sheet** held by the user or put on the desk is assumed.

Rotation distortion of the **space code sheet** is considered distortion if it is held by the user or put on the desk. Since the allowable angle at which the sheet can be naturally recognized in the user's field of vision is within ±30°, it was set as the upper limit.

A specific setup condition was set to a gradient angle of 25° from the horizontal plane, which is equivalent to a field angle of vision when the **Space Code Sheet** (**Fig.8**) is overlapped on the upper surface of a sheet object (paper added with category codes) and put on the desk, and the camera is mounted on the user to reproduce the environment under which the camera was mounted on the user. (A turning angle of 65° for the object from the pickup surface by the camera).

The height of the desk was set to 70.0 cm, the height of a camera stand to 24.5 cm, the height from the bottom surface of the camera to the center of the lens to 8.0 cm, and the distance between the camera stand to the bottom surface of the **Space Code Sheet** to 52.0 cm. The camera was set to autofocus mode in experiments.

Experiments were made so the **Space Code Sheet** was overlapped and rotated on category codes added to the sheet object from +30° to -30° by five degrees to measure the precision that images picked up 100 times for each angle were properly converted to the **Space Code Sheet**

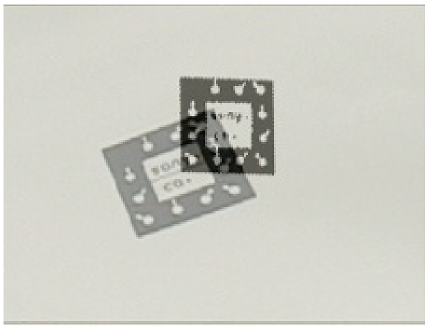

Fig. 9. Case (1): Rotation by (+) 30°.

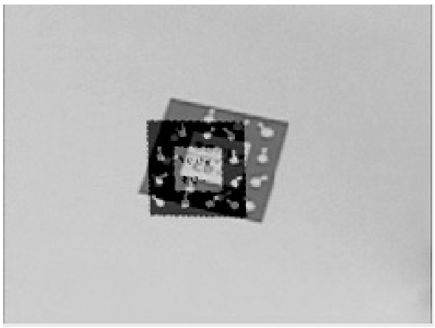

Fig. 10. Case (2): Rotation by (-) 15°.

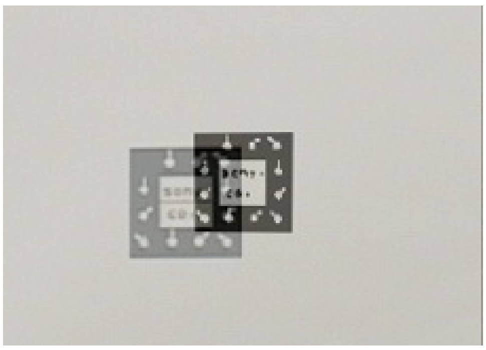

Fig. 11. Case (3): Rotation by (±)0°.

coordinates.

As a result, the processing time of the conversion program was 36.5 ms and the results were obtained as in **Table 1**. The average correct conversion rate was 97.07%.

The following typical cases were used for rotations to the camera.

(1) Rotation by (+) 30°

(2) Rotation by (-) 15°

(3) Rotation by (±)0°

Based on these cases, the conversion images were obtained from pickup coordinates in **Figs.9, 10** and **11** to the **Space Code Sheet** coordinates as the results of the conversion experiments from pickup coordinates to the **Space Code Sheet** coordinates **Table 2** lists the coordinate parameters $\{a_x, b_x, c_x\}$ and $\{a_y, b_y, c_y\}$ in Eqs.(2.1) and (2.2) used for this conversion.

6. Considerations

Results of experiments in **Figs.1**, **10** and **11** showed that accurate conversion is made by correcting turning or rotational distortion from pickup coordinates to the space code coordinates for the following cases with the space code categories pointing to the camera in **Fig.5**.

(1) Rotation by (+) 30°

(2) Rotation by (-) 15°

(3) Rotation by (±)0°

In addition, from **Table 1** and the results as above, it was confirmed that the algorithm and program to convert pickup coordinates based on the least squares method to **Space Code Sheet** coordinates was fully effective in the recognition of category codes, and as coordinate conversion to determine the position in the entire **Space Code Sheet** from the partial image of a space code and also detect the finger pointing position when the user pointed out a sheet object in his field of vision.

The space code recognition program under the real environment is confirmed to have a recognition precision of about 97% in the condition of the ordinary illumination light (about 180 lx) in the verification results of **Umark**[1,10] and **Ultra Magic Key**[2].

The program to calculate the position in a sheet object pointed out with a finger is installed as the basic program when the **Ultra Magic Key**[2] was implemented based on the endpoint detection method[11,12] by extracting the differential image of the finger motion to provide a recognition precision of about 85% in the condition of an ordinary illumination light (about 180 lx).

The **Viewing Tablet** was verified to be feasible as a pointing system targeting input or instructions given to information systems by the user pointing out a sheet object in the field of vision. This field is handled as if it were a tablet by combing the newly developed conversion program based on the method of least square from pickup coordinates to the **Space Code Sheet** coordinates with the previously developed space code recognition program and the finger pointing position coordinate calculation program.

7. Conclusions

We proposed a **Viewing Tablet** as a pointing system accurately selecting and pointing out a sheet object in the user's field of vision close to natural motion. This provides a flexible means of giving I/O instructions to information system such as a wearable computer that helps prevent generation of a digital divide. We also considered and discussed the feasibility of this proposal experimentally.

The feasibility of input or instructions was confirmed when a sheet object in the user's field of vision is pointed to directly by a finger for input to an information system, which could not be implemented previously by input or instructions to an information system. We verified the viewing tablet principle and experimental considerations of its feasibility.

The **Viewing Tablet** effectively enables smooth communication between people and information systems. This leads to the possibility of developing smoother information to help counter the digital divide.

References:

1) Usuda, H., Idesawa, M., "The Figure Code System Enables interactive Mutual Conversion between ATOM and BIT, SMC'99 Conference Proceedings, IV-pp.47-52, IEEE, 1999.
2) Usuda, H. and Miyazaki, M., "The Multimedia Interface using "Paper": Ultra Magic Key", Proc. of Asia pacific Computer human Interaction 1998 (APCHI'98), pp.393-397, IEEE Computer society Press, 1998.
3) P. Wellner, "The Digital Desk Calculator: Tangible Manipulation on a Desktop Display", Proc. of the ACM SIGGRAPH and SIGGHI Symposium on User Interface Software and Technology (UIST91), November 1991.
4) Wakita T., Nagaya, T. and Terashima, T.: "Uniting of World Wide Web which uses two dimension code and paper media," Information Processing Society of Japan Human Interface Society Research reports: 98- HI- 76 Vol. 98 No. 9 pp.1-6, 1998.
5) Kobayashi, M. and Koike, H., "Enhanced Desk: Integrating Paper Documents and Digital", Proc. of Asia Pacific Computer Human Interaction 1998 (APCHI'98), pp.57-62, IEEE Computer Society Press, 1998.
6) Arai, T., Aust, D. and Huson, E. S., "A technique for hyperlinking from real paper to electronic content", Proc. of the ACM Conference on Human Factors in Computing Systems (CHI'97), pp.327-334, Addison-Wesley, 1997.
7) Johnson, W., Jellinek, S., Klotz jr., L., Rao, R. and Card, S, "Bridging the paper and electronic words: The paper user interface", Proc. of ACM INTERCHI'93 Conference on Human Factors in Computing Systems (CHI'93), pp.507-512, Addison-Wesley, 1993.
8) Sonoda, T. and Muraoka, Y., "A Letter Input System of Handwriting Gesture", Proc. of IPSJ Symposium Series Vol. 2001, No. 5, pp.3-10, IPSJ, 2001.
9) Rekimoto, J: Matrix, "A Realtime Object Identification and Reg-

istration Method for Augmented Reality", Proc. of APCHI'98, pp.63-68, IEEE Computer Society Press, 1998.

10) Usuda, H. and Idesawa, M., "A User Interface using Figure Code and Character", Proc. of The First International Symposium on Measurement, Analysis and Modeling of Human Functions 2001 (ISHF2001), pp.251-256, September 2001, SICE, 2001.

11) Usuda, H. and Miyazaki, M., Japan Patent No. 9608781303, US Patent No. S97P1025US, INFORMATION INPUT METHOD AND APPARATUS, November, 1996.

12) Usuda, H., Miyazaki, M and Kobayashi, M., Japan Patent No. 96083262, US patent No. S97P1028US, INFORMATION INPUT METHOD, INFORMATION INPUT SHEET AND INFORMATION INPUT APPARATUS, November 1996.