Input and Display of Hand Drawn Pattern Onto Planar Board of Arbitrary Position and Pose Utilizing a Projector and Two Cameras

Hideo Saito and Hitoshi Ban

Department of Information and Computer Science, Keio University
3-14-1 Hiyoshi Kohoku-ku, Yokohama 223-8522, Japan
`saito@ozawa.ics.keio.ac.jp`
`http://www.ozawa.ics.keio.ac.jp/Saito/index.html`

Abstract. In this paper, we propose a system for inputting hand drawn pattern and displaying it on a hand-held planar rectangle board by utilizing two cameras and a projector which are installed above the user. In this system, the cameras and the projector are related by projective geometry. The cameras capture the user's hand-drawing motion. From the captured images, the tip of the user's pen and the corners of the board are tracked for detecting the status of pen's up/down and displaying the drawn pattern at a fixed position on the surface of the board. For demonstrating the validity of the proposed system, we show that the user can draw pattern on the board with arbitrary pose and position, while the pattern is simultaneously displayed on the board in real-time.

1 Introduction

There are a lot of interface devices for using computers. One intuitive interface is using hand-drawn patterns, such as from a pen-tablet interface [1,2]. Hand drawn pattern can also be captured with camera based on computer vision techniques [3,4,5,6,7].

For capturing hand-drawn pattern, we need to detect up/down status of the pen, that is, if the pen is touching on the drawn surface for drawing or leaving for moving to the next drawing stroke. In MEMO-PEN [5], a stress sensor detects the up/down status of the pen. In [7], the length of the stopping time of the pen is used for the detection. In [6,3,4], the pen should actually write the pattern on the surface, so that the camera can detect the locus of the tip of the pen.

In this paper, we propose a system that enables an user to input a hand-drawn pattern on a hand-held surface with arbitrary position and pose, and simultaneously display the input pattern on the surface, by utilizing just two cameras and a projector. In this system, the tip of the pen and the hand-held surface are tracked by two cameras. From the tracked position of the tip of the pen, up/down status of the pen is detected by considering the projective geometry between two cameras and the hand-held surface. The drawn pattern is also captured according to the tracked locus of the tip of the pen, which can be displayed on the surface with arbitrary pose and position by the projector according to the projective geometry between the cameras and the projector. Since the projective geometry among the cameras and the projectors can easily be obtained from the captured images without measuring 3D position/shape of the captured markers/objects, the
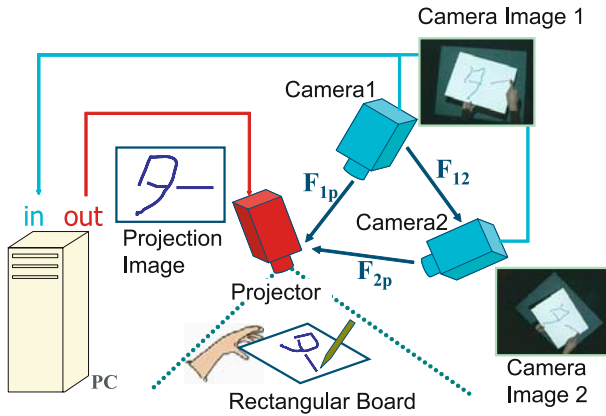
Fig. 1. System configuration

system can easily be built-up without time-consuming calibration of the cameras and the projector with markers and/or reference object with known position and shape.

2 System Setup

Figure 1 shows the overview of the proposed system. By using this system, the user can input arbitrary hand-drawn pattern by drawing with a pen on a board held by his/her hand, while the system simultaneously display the drawn pattern on the board. For realizing such functionalities, the system consists of two cameras for capturing the space of hand-drawing, a projector for displaying the pattern, a rectangular white board held by the user's hand, and a pen for drawing.

The drawing motion is captured by the two cameras. The tip of the pen and the corner of the board are tracked in the captured images. The pen's up/down status is recognized according to the positions of the tip of the pen and the corner of the board
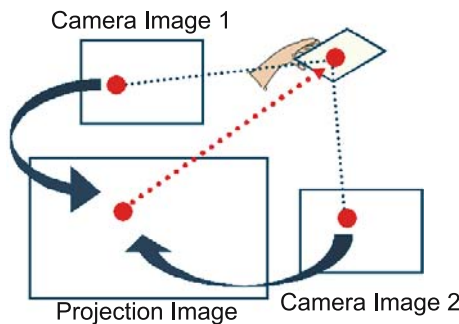

Fig. 2. Computation of Fundamental Matrix

in both images. The locus of the pen is simultanously displayed on the board by the projector.

In this system, projective geometry among the cameras and the projectors should be measured by the following procedure.

The projective geometry are represented by fundamental matrices as $\mathbf{F}_{1p}, \mathbf{F}_{2p}, \mathbf{F}_{12}$. For estimation of fundamental matrices, 2D-2D correspondences between images captured by the cameras and the image projected by the projector should be detected.

For detecting the corresponding points, an image with a marker point is projected onto the board placed at various positions and poses as shown in Fig. 2. Then the image of the board is captured by the both cameras. Since the 2D position of the marker point in the image projected by the projector is previously known, the 2D-2D correspondence between each camera and the projector can be corrected by detecting the 2D position of the marker point in the image of the board captured by the camera. Using the 2D-2D correspondences, fundamental matrices between each camera and the projector, $\mathbf{F}_{1p}, \mathbf{F}_{2p}$, can be computed.

The 2D-2D correspondence between both cameras can also be corrected by the 2D positions of the marking points. The fundamental matrix between both cameras 1 and 2, $\mathbf{F}_{12}$, can be computed from the correspondences.

3   System Behavior

This system takes two images captured with two cameras as input data. The position of the tip of the pen is detected from the input images. For simple and robust performance, we use a pen with a light source on the tip of the pen. The corners of the board are also detected from the input images according to the method in section 3.1.

The pen up/down status can be detected according to the positions of the tip of the pen and the projective geometry of the board, so that the drawn pattern by the user can be captured. At the same time as detecting the positions of the tip of the pen, the projector displays the captured pattern, so that the user can feel as if the user writes the pattern on the board by the pen.

After finishing the hand drawn pattern input/display, the system tracks the corners of the board, so that the captured hand-drawn pattern can always be projected at the fixed position on the board.

Those processes are repeated in the proposed system.

3.1   Detection of Corners of the Board

In this system, the corners of the board are often occluded by the user's hand. Therefore, we find the corners by taking intersection of the line segments of the border of the area of the board.

The procedure is shown in Fig.3. The area of the board is first detected, then the edges are extracted from the board area. The line segments of the edge pixels are are detected by employing the Hough transform. The corners are detected by finding the intersections of the line segments.
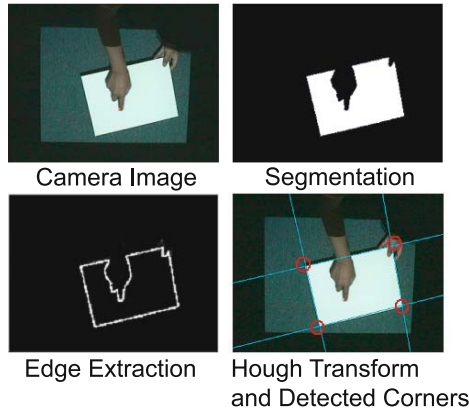
Fig. 3. Flow of corner detection

3.2 Detection of Pen Up/Down Status

For detection of the pen up/down status, projective relationship between two cameras for the board surface, which is represented by homography $\mathbf{H}_{12}$, is considered. For computing the homography $\mathbf{H}_{12}$, the detected corners of the board are corresponded between two camera images as shown in Fig. 4. For determining the corresponding point from detected four corner points, projective relationship between the cameras presented by fundamental matrix $\mathbf{F}_{12}$ is used. As shown in Fig. 4, the closest corner point to the epipolar line is selected as the corresponding point. The use of the fundamental matrix $\mathbf{F}_{12}$ can avoid wrong corresponding points.

Let $\mathbf{x}_1$ and $\mathbf{x}_2$ be the positions of the tip of the pen detected in the captured images. If the tip of the pen is down, $\mathbf{x}_1$ and $\mathbf{x}_2$ should satisfy the equation (1). In other words, the position $\hat{\mathbf{x}}_2$ computed from the detected position $\mathbf{x}_1$ according to the equation (1) should coincide with $\mathbf{x}_2$, if the pen is down. Therefore, we evaluate the distance between $\hat{\mathbf{x}}_2$ and $\mathbf{x}_2$, and then detect if the distance is larger than the threshold th for the pen's up/down detection. as shown in equation (2).
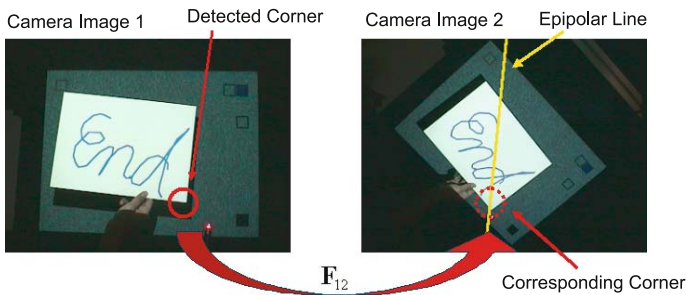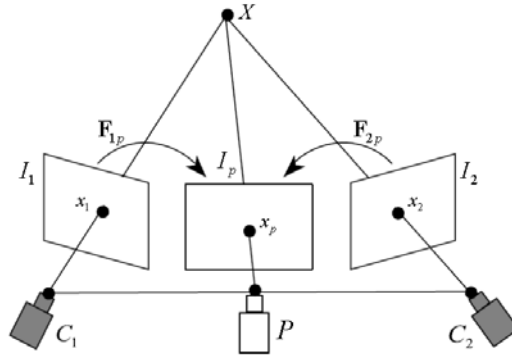

Fig. 4. Calculation of correspondent point

Fig. 5. Making of projection image

$$\tilde{\mathbf{x}}_2 = \mathbf{H}\tilde{\mathbf{x}}_1 \tag{1}$$

$$\begin{cases} \parallel \hat{\mathbf{x}}_2 - \mathbf{x}_2 \parallel \geq th : PenUp \\ \parallel \hat{\mathbf{x}}_2 - \mathbf{x}_2 \parallel < th : PenDown \end{cases} \tag{2}$$

3.3 Projection of Drawing Pattern

In the proposed system, the drawn pattern is simultaneously displayed on the surface of the board using the projector, when the pen is down.

As shown in Fig.5, I_1 and I_2 represent the images captured by the cameras C_1 and C_2. I_p represents the image projected by the projector P. When the pen is down at point X, let $\mathbf{x}_1$ and $\mathbf{x}_2$ represent the detected position of the tip of the pen in images
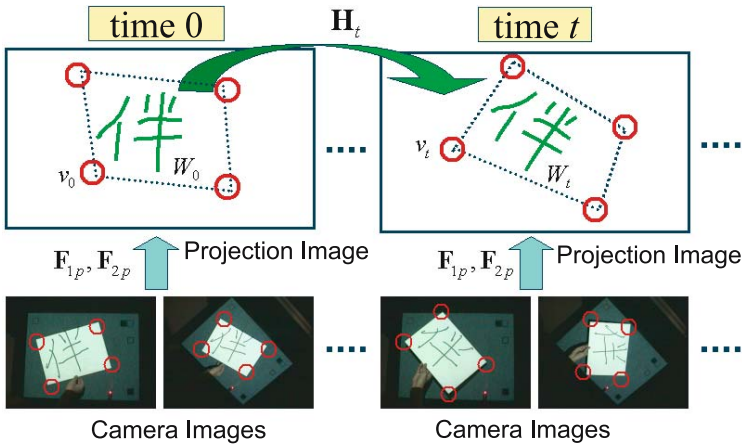

Fig. 6. Warping of hand drawn pattern

I_1 and I_2. Then, two epipolar lines of $\mathbf{x}_1$ and $\mathbf{x}_2$ can be computed on the projection image I_p according to the fundamental matrices $\mathbf{F}_{1p}$ and $\mathbf{F}_{2p}$. The intersection point of the epipolar lines $\mathbf{x}_p$ in the projection image I_p corresponds to the tip of the pen X. Therefore, by projecting the image with a bright point at $\mathbf{x}_p$, the bright point can be displayed at the surface of the board at the point X. In this way, the drawn pattern can be displayed by the projector on the surface of the board.

3.4   Display Pattern After the Drawing

Even after the user finishes the drawing pattern, the system should continue displaying the pattern on the surface of the board. The drawn pattern should be regarded as fixed on the board, the pattern in the projection image needs to be changed according to the motion of the board by user's hand, so that the pattern can be displayed at the fixed position on the board.

Let W_0 represent a projection image of the hand-drawn pattern at time 0. After that, assume that the board moves at time t. If W_0 is still projected at time t, the position and shape of the hand-drawn pattern projected on the board is changed, so the projection image W_0 should be warped to W_t as shown in Fig.6. The warping is performed by shifting all the pixel in W_0 according to the homography $\mathbf{H}_t$ between the board at time 0 and time t.

For computing $\mathbf{H}_t$, the position of the corners detected according to the method in 3.1 are automatically corresponded between time 0 and time, t.

4   Experimental Results

Fig. 7 shows the experimental system. The PC has Pentium4(3.06GHz) and 1024MB memory. The captured images by the cameras are digitized at 320×240 pixels of 24 bit color. The projection image is 1024×768 pixels of 24 bit color. This system runs around 9fps.
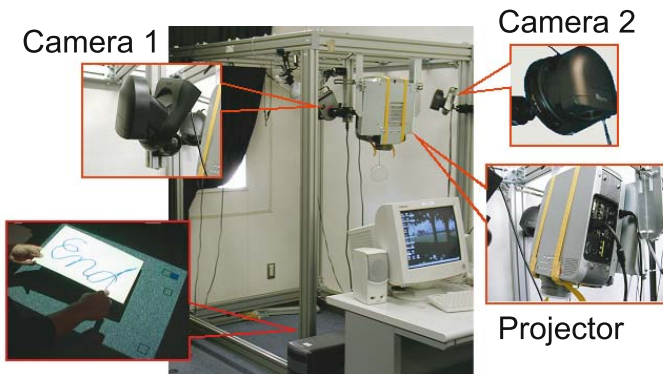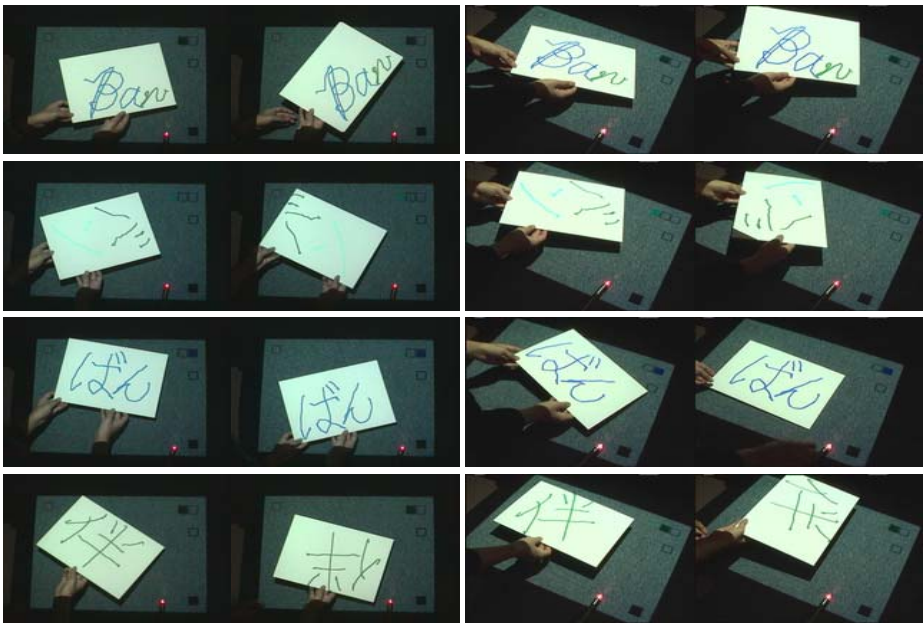

Fig. 7. Experimental system

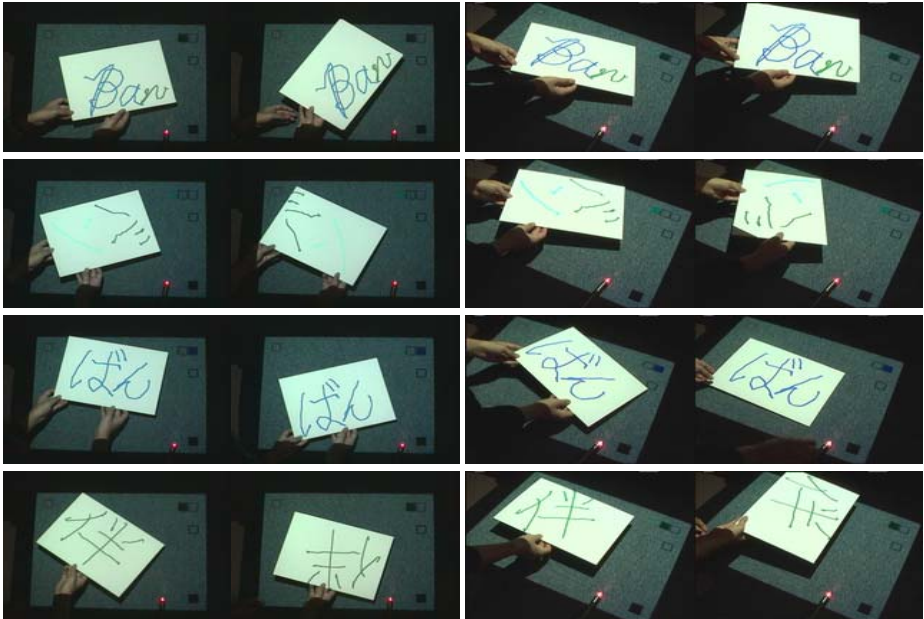**Fig. 8.** The appearance when the user draws a pattern using the experimental system

Fig. 9. The appearance when the user moves the board after drawn pattern

Fig. 8 shows the appearance when the user draws a pattern using the experimental system. As shown in this figure, the status of the pen's up/down is detected, so that the hand-drawn pattern can properly be inputted and displayed on the board.

Fig. 9 shows the appearance when the user moves the board after drawn pattern. As shown in this figure, the drawn pattern can be displayed at the fixed position on the board at arbitrary pose and position.

5   Conclusion

In this paper, we propose a system for input and display of hand-drawing pattern on hand-held board by utilizing two cameras and a projector. In the proposed sysytem, the status of the pen's up/down can be detected, so that the drawn pattern can properly be captured and displayed on the surface of the board. The proposed system does not need any 3D information of the cameras, the projector, and the object board, but only needs the projective relationship among them. Therefore, we do not need to perform so-called "strong calibration"

We also show some experimental results for demonstrating the effectiveness of the proposed system.

References

1. Wacom CINTIQ, http://tablet.wacom.co.jp/pro- ducts/cintiq/
2. InkLink, http://www.siibusinessproducts.com/pr- oducts/link-ir-p.html
3. T. Yamasaki and T. Hattori, "A New Data Tablet System for Handwriting Characters and Drawing Based on Image Processing," Proc. IEEE Int. Conf. Systems, Man and Cybernetics, pp.428-431, 1996.
4. H. Bunke, T. Von siebenhal, T. yamasaki, and M. Schenkel, "Online Handwriting Data Acquisition Using Video Camera," Proc. Int. Conf. Document Analysis and Recognition, pp.573-576, 1999.
5. S. Nabeshima, S. Yamamoto, K. Agusa, and T. Taguchi, "Memo-Pen: A New Input Device," Proc. Int. Conf. Human Factors in Computing Systems(CHI), pp.256-257, 1995.
6. M. E. Munich and P. Perona, "Visual Input for Pen-Based Computers," IEEE Trans. Pattern Analysis and Machine Intelligence, vol.24, pp.313-328, 2002.
7. Z. Zhang, Y. Wu, Y. Shan, and S. Shafer, "Visual panel: Virtual mouse keyboard and 3d controller with an ordinary piece of paper," Proc. of ACM Workshop on Perceptive User Interfaces(PUI), 2001.