Image-based Auto-positioning Brush for LCD Displays+

Jun-Ren Ding, Jiun-Yu Chen, Fu-Chun Yang, and Jar-Ferr Yang

Institute of Computer and Communication Engineering
Department of Electrical Engineering
National Cheng Kung University, Tainan, Taiwan
jfyang@ee.ncku.edu.tw

ABSTRACT

The interactive devices, which help humans to easily access the computer and video game player, become an important technology to provide interactive multimedia services and entertainments in the 21st century. Considering the cost and the effectiveness of the human machine interface (HMI) devices, in this paper, we design a low cost image-based auto-positioning brush (IA-Brush), which can automatically locate the position of the window and modify the affection of angle displacement of camera. The proposed IA-Brush based on a low cost video camera can be easily implemented for low cost liquid crystal display monitor by using image processing techniques figure with a designated background grids. Simulation results with exhibition of interactive painting games show that we can achieve a low cost and effective HMI by using a video camera only.

Index Terms— *IA-Brush, Video Camera, Grid Image.*

1. INTRODUCTION

With more and more needs of offered interactive multimedia services from digital electronic products, the technologies of natural human interactive inferences become very important gradually [1], [2]. In recent years, the processing speed of the interactive game increases year by year, and the demands of digital amusement in consumer markets also increase continuously. Under the trend of digital life, various human machine interface (HMI) technologies not only promote the convenience of life but also reduce the stress in interactive behaviors among science, technology and the humans. A good example, the invention of Nintendo Wii has already gained a lot of attention in the game market.

From relevant articles in recent years, the research of Input/Output Brush (I/O-Brush) proposed by Media Lab, Massachusetts Institute of Technology (MIT) has greatly promoted professional researches in painting game for children [3]-[8]. The I/O-Brush has looked forward to make over the past impression such as costliness of high-tech products has difficulty in the operational interface at present. However, it is still unable to be popularized to the consumers due to the expensive cost. The I/O-Brush uses the projectors and the infrared camera which generates the following issues as the Microsoft Surface [9]. First, it needs larger space to install the projectors. Second, it makes use of an expensive infrared camera to detect the positions on the screen. Finally, the projectors and infrared camera easy be influenced by environmental light, to cause lower robustness of positioning and need a darker operational environment.

In this paper, we suggest that the interactive devices should be operated with the general low cost liquid crystal display (LCD) to replace the overhead projector to solve the above shortcomings. Instead of an infrared camera, we use an inexpensive video camera cooperated with a specially-designated background grid image to determine the interactive position. The image-based auto-position brush (IA-Brush) has a simply operational interface to achieve the similar painting game as the I/O-Brush. We believe that the proposed IA-Brush could become a popularly visual interactive device for digital life in video entertainment and education systems. The rest of this paper is organized as follows. In Section 2, we present the design concept and the system flow diagram of IA-Brush. In Section 3, the technology of image processing for auto-position detection is presented in detail. Finally, the simulation results with some discussions and the conclusions are addressed in Sections 4 and 5, respectively.

2. DESIGN OF IA-BRUSH

The I/O-Brush has been applied several interactive game and education systems. For painting classes in the kindergarten, the pictures, which are established by I/O-Brush, include various kinds of applications. The processes of painting are colorful and flexible such as color paints, image, video and all the objects which can be captured by the camera, all can be painted into the painting work. For instance, the teacher's stapler, a picture in a book, a classmate's doll, a piece of fruit or a favorite shirt, can all be stored and painted by the interactive I/O-Brush. With a single camera to achieve similar functions as I/O-Brush, in this section, the designed concept and the operational processes of the proposed IA-Brush are described as follows:

A. Designed concept of IA-Brush

Actually, the hardware of proposed IA-Brush is a typical general personal computer (PC), a LCD monitor and an inexpensive video camera. The software only adopts the visual C++ to implement the image processing and interactive painting game. As shown in Fig. 1, the camera lens is installed by 10 (cm) in the IA-Brush, because the distance of lens affects the captured image size. Besides, the focal length must be adjusted to capture the image or video in the short distance to obtain the

This research was partially supported by the National Science Council under Grant Number NSC 95-2218-E-006-021

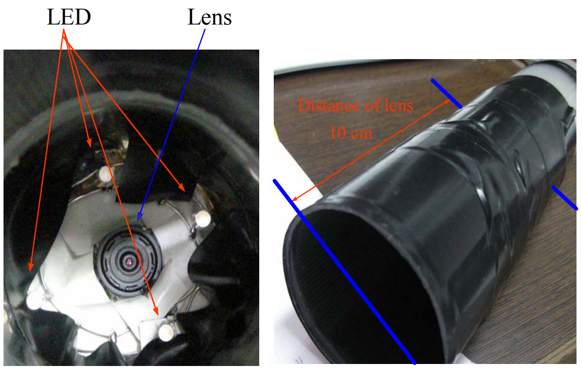


Fig. 1. Lens installed and structure of I-Brush.

clearest image or video. It is noted that the video camera is initially set to capture the long distance video mostly while left the factory.

As shown in Fig. 2, the IA-Brush is first initialized, where the initialization includes the setup of the background grid image. After initializing, the user could capture and keep the image or video for painting. Then, in the next step, the user has to use IA-Brush to search the position and to paint the captured image or video. The IA-Brush stops searching until the system finds the fit position to paint. Therefore, the design of the background grid image certainly is the most important task. If we use wanton lines or full white background image, the system will have difficult to search the matched position and paint the captured image or video.

B. Core Processing of IA-Brush

After painting the captured image or video, the user has to determine whether to stop painting or capture the other source for painting. If the user chooses to stop painting, they have to decide whether to save it or not. For storage, the final result will be compressed by H.264-based lossless image coding with differential pulse code modulation (H.264-LS_DPCM) [10]. As shown in Fig. 3, the detailed explanation about "Positioning and Painting" function of the IA-Brush depicted in Fig. 2 is

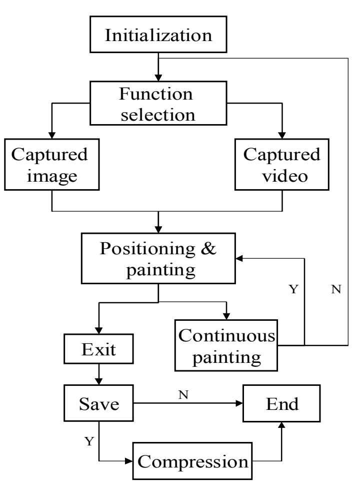


Fig. 2. System flow diagram of the proposed IA-Bruch system.

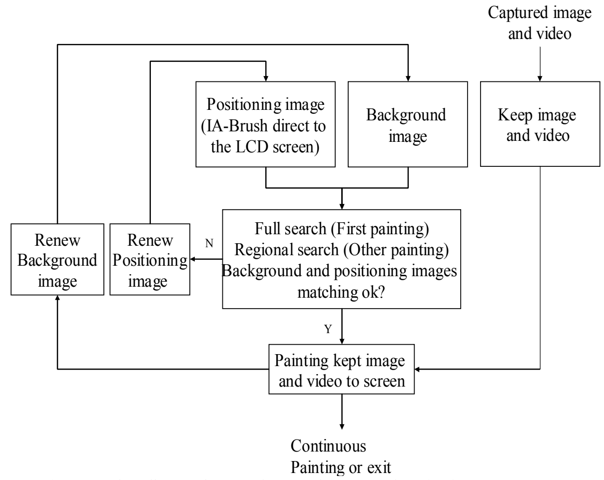


Fig. 3. The flow chart of searching and painting processes.

present. We can clearly learn why the IA-Brush needs a specially-designated background grid image. As shown in Fig. 3, for the initialization of painting, if the positioning image matches to the background image when painting for the first time, we will paint the kept image or video on the LCD screen by full search (background image). If the user wants to continuously paint the kept image or video on the screen, the initial background image will add the painted image or video regarding as a new background image for continuous painting and executing the regional search (positive and negative 32 pixels for last positioning coordinate in the background image). Oppositely, if the background image and positioning image are not matched, then the system will continuously renew the positioning image.

If the user wants to capture the image or video and paint it on the LCD screen by the IA-Brush, then, just takes the orientation IA-Brush and captures the image or video from the object, such as a ceaselessly blinking eye or a monotone color. After the red and black color twinkles on the up-right corner, namely IA-Brush starts to capture the image or video. The color twinkles again after the image or video is captured successfully, and the IA-Brush begins to search for the position at this moment. The image or video is painted after the IA-Brush sticks on the screen and finishes searching for the corresponding position on the specially made background image. The user can paint the image or video on the screen continuously when moving the IA-Brush to find corresponding positions on the screen. In respect of the specially made background image and image processing technology, they are described in next Section.

3. IMAGE PROCESSING FOR IA-BRUSH

In this section, the design of background grid image and image processing technologies for auto-positioning are discussed as follows:

A. Design of the background grid image

First, we design a square block as the background grid image. To achieve a unique positioning function for IA-Brush, the block grid background image at (i, j) is normalized as

$$x = 2i/(width-1)\,, \tag{1}$$

$$y = 2i/(height-1)\,, \tag{2}$$

where *width* and *height* denote the width and the height of the image, respectively. Then, we change (x, y) coordinate into the polar coordinate as,

$$r = sqrt(x^2 + y^2) \tag{3}$$

$$\theta = \tan^{-1}(y/x) \tag{4}$$

The warping method defined the new magnitude as

$$r' = \mathrm{sqrt}(r) \tag{5}$$

Finally, we then transfer the new polar coordinate (r',θ) into (x', y'), which transforms the original block grid image into a warping grid image as shown in Fig. 4. The optimum of the background grid image for auto-position should be further discussed in future publications. However, there are 3 key points should be carefully considered: 1) the distribution of texture or edge on the background grid image should be absolutely different for different positions; 2) the density of edge or texture should be adjustable for different LCD sizes; 3) the grid image should achieve less annoying vision for the user as possible.

B. Positioning by full motion search

We adopt the sum of absolution difference (SAD) algorithm for full and regional searches. It is described as follows:

$$SAD_k = \sum_k |BI(i,j) - PI(i',j')| \tag{6}$$

where $BI(i, j)$ and $PI(i, j)$ present the background and positioning images in the k^{th} block pixels, respectively. The size of positioning image is far smaller than background image, because it is the captured image by IA-Brush in a short distance. When the camera points the position on the LCD screen, it means we have achieved the minimum *SAD* and detected the position. The threshold of *SAD* can not be set too low by numerous tests, otherwise the system may have difficulty to find a position to match and paint. Similarly, it can not be set too high, otherwise many positions could be determined that they are all matched. It may cause the system can not operate regularly. For practical operations, there is very little external influence, because the camera is very close to the LCD screen and does not interfere with the orientation of IA-Brush easily.

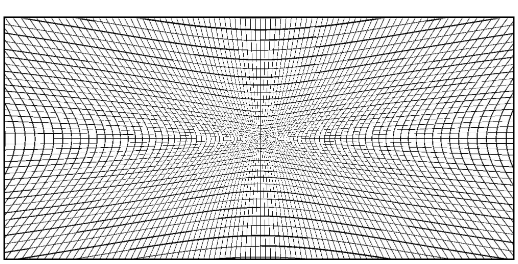


Fig. 4. The designed background grid image

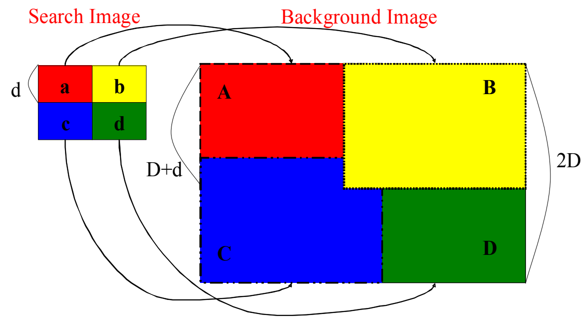


Fig. 5. The diagram of new segmental algorithm

C. Fast positioning method for IA-Brush

Because full search needs a large of computation time to calculate and search all pixels on the background image completely. We need a quick algorithm to reduce the computational time effectively based on the variation of image content of background grid image. We segment the positioning image which is captured from IA-Brush as shown in Fig. 5. First, we have to divide the background image into four blocks, A, B, C, and D and also divide the searching image which is used for positioning into four blocks, a, b, c, and d. We can determine a block on the background by calculating the component of white pixels (refer to Fig. 4.) from the four sub-images, a, b, c and d. If the accumulative value of luminance of "a" image is the largest and that represents the largest number of white pixels, we will determine this block belongs to "A" block of background image. If the accumulative value of luminance of "b" image is the largest and that represents the largest number of white pixels, we will determine this block belongs to "B" block of background image. The equations are also used for calculating the *SAD* and described as follows:

$$V_r = Sum(wp), \text{for } r = a,b,c,d \tag{7}$$

$$Max(V_r) \xrightarrow{\text{Correspond to}} BI_R,\ R = A,B,C,D \tag{8}$$

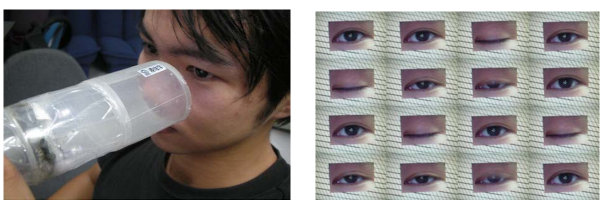
$$SAD = \sum_k \sum |BI_R(i,j) - SI(i',j')| \tag{9}$$

where V_r presents the total number of white pixels (*wp*) for *a*, *b*, *c*, *d* ranges. By using this algorithm of segmentation, we only need to search for one of A, B, C and D blocks to save about 3/4 searching time of full search. The other fast search based on gradient of the grid image is also possible.

4. SIMULATION RESULTS

We make a brief analysis about advantages and drawback of the proposed IA-Brush comparing to Microsoft Surface and MIT I/O-Brush. The compared results are summarized in Table 1. It is obvious that the proposed IA-Brush with low cost should be a valuable and innovative technology for HMI and painting game. The IA-Brush can capture the image and video, and continue painting on the LCD screen. By using the IA-Brush, the whole world will become more vivid and more interesting with a very cheap video camera. Fig. 6 shows some figures related to the operations of the proposed IA-Brush. The user can immediately see the image or video from the background image while picking and capturing the source image or video. The design of such function can be a great help for the user to revise the information immediately and determine the angle or direction that they hope to paint with. The demo video can be downloaded in [11].

(a) Figures show capturing image, positioning, painting, and continuously painting operations.



(b) Captured video continuously showing on the LCD.

Fig. 6. Practical operation of IA-Brush.

Table 1. Comparisons of IA-Brush, Surface and I/O-Brush.

Works	MIT I/O-Brush	Microsoft Surface	Proposed I-Brush
Position and control window (HMI)	Infrared camera		Video camera with a designed background grid image
Display device	Projector		LCD
Service content	Input/output image and paint image and video	1. Pull window 2. Multimedia and communication	Input/output image and paint image and video
Advantages	1. Accurate positioning. 2. The interface of touch sensor. 3. Microsoft has a great ability and service in software.		1. No space limitation 2. Low cost 3. Good for LCD
Drawbacks	1. The infrared sensor is easy to be effected by the reflection of light 2. The projector wastes the space 3. High cost 4. The resolution of projector is easy to be effected by the light of the environment 5. It is hard to move 6. Microsoft does not have I/O-Brush device		1. No touch sensor 2. Positioning ability needs to be improved.
Expansibility	Low	High	High
Technology	Image processing technology, Program design.		

5. CONCLUSIONS

In order to realize a low cost I/O-Brush system, the positioning method is proposed with a designated background grid image associated with motion search mechanism. The IA-Brush uses the low cost video camera to replace the infrared camera, which is really expensive relatively used in the order interactive devices. This research will be a great help to promote the interactive multimedia services, such as interactive painting games. We also expect that IA-Brush system could be very helpful to develop interactive education systems which can bridge the gaps between parents and children as well as teachers and students for preschool children. It will also guide the children getting more interactive and enjoyable learning on an interesting, fresh and relaxing education platform. The continuously developed improvements and capabilities for the proposed IA-Brush are also considered for different interactive multimedia services.

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