Proceeding of the IEEE
International Conference on Information and Automation
Shenzhen, China June 2011

The Design of Infrared Touch Screen based on MCU

Zheng Wei[1,2], Wei Liu[1], Qing He[1], Ning Wei[1], Chenxi Wang[1], Tingfang Yan[1], Chao Hu[1,3], Max Q.-H. Meng[4]
1.Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China
2.College of Communication Engineering, Chongqing University, Chongqing, China
3.Ningbo Institute of Technology, Zhejiang University, Ningbo, China
4. Department of Electronic Engineering, The Chinese University of Hong Kong, Hong Kong, China
{zheng.wei, wei.liu, qing.he, ning.wei, cx.wang, tf.yan, chao.hu }@siat.ac.cn, max@ee.cuhk.edu

***Abstract* - This paper introduces a touch screen technology based on infrared optical. This technology has apparent advantages in the large-size applications, which is simple, low cost, high feasibility. In the system, the detection of ambient light and the adaptive control of IR LED can effectively enhance the adaptability of the touch screen in complex light environment via the MCU. In image processing, the image of foreground and background are segmented by Otsu's method with a coefficient. Integral projection is adopted to recognize the contact area. The result shows that the performance of the system fully meets the requirements of real time and accuracy.**

Index Terms* - *HCI; optics-based; MCU; Integral projection.

I. INTRODUCTION

In the virtual reality environment, keyboard, mouse, joystick are the main input tools, which used to conduct human-computer interaction. With the growing development of touch technology, touch screen, as a new human-computer interaction device is widely used in industrial control, home appliances, military, medical electronics and other fields. In traditional infrared touch screen technology, IR emitter and IR are arranged around the screen, which form cross-horizontal and vertical infrared matrix. Using both horizontal and vertical infrared blocked by finger, the controller can calculate the corresponding coordinates and determine the location of touch point [1]. To achieve human-computer interaction in the large-size applications, this paper introduces an infrared touch technology based on optical principles. The technology is simple, low cost, high feasibility.

A. DI(Diffused Illumination)

During the operation, Infrared light is shining at the screen from below the touch surface(Fig.1). A diffuser is placed on top or on bottom of the touch surface. When an object touches the surface, it reflects more light than the diffuser or objects in the background; the extra light is captured by a camera. Depending on the diffuser, this method can also detect hover and objects placed on the surface [2].

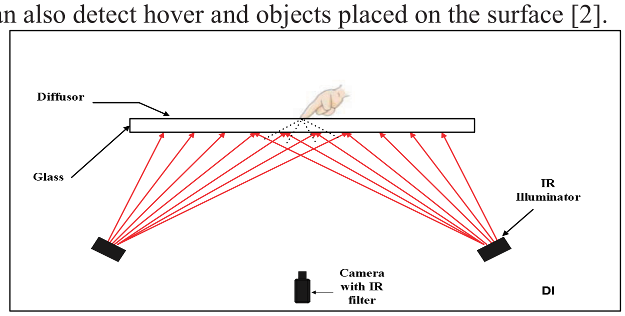

Fig.1 DI schematic.

B. FTIR (Frustrated Total Internal Reflection)

In 2005, Jeff Han presented FTIR, a simple technique for multi-touch(Fig.2). According to Snell's Law, no refraction occurs in the material, and the light beam is totally reflected. Han's method uses the principle of Total Internal Reflection, flooding the inside of a piece of acrylic with infrared light by trapping the light rays within the acrylic. When the user comes into contact with the surface, the light rays are said to be frustrated, since they can now pass through into the contact material (usually skin), and the reflection is no longer total at that point [3].

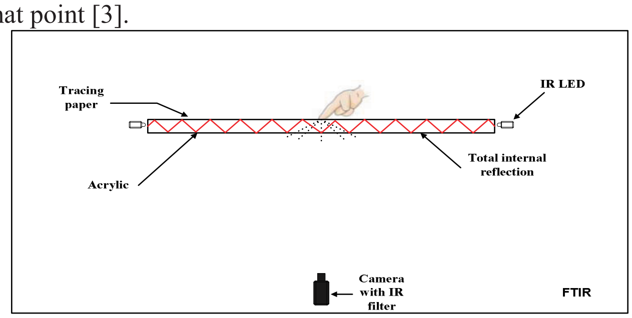

Fig.2 FTIR schematic.

The system can be packaged as a screen by using FTIR. In this paper, FTIR is adopted to achieve design of infrared touch screen.

Ⅱ. SYSTEM DESIGN

As the image acquisition source, a camera with infrared filter is often used to capture real-time information for touch in both FTIR and DI. Infrared touch technology realizes the detection of contact area with a simple phenomenon of optical reflection. Under a serious infrared interference environment, for example, direct sunlight in outdoor, indirect light enough or relatively strong infrared emission source in indoor, FTIR will result in error detection or complete failure. In order to enhance system adaptability in a complex light environment and ensure the effect of the touch screen, the system is detected ambient light with infrared sensors and operated adaptive control of IR LED by MCU.

978-1-61284-4577-0270-9/11/$26.00 ©2011 IEEE

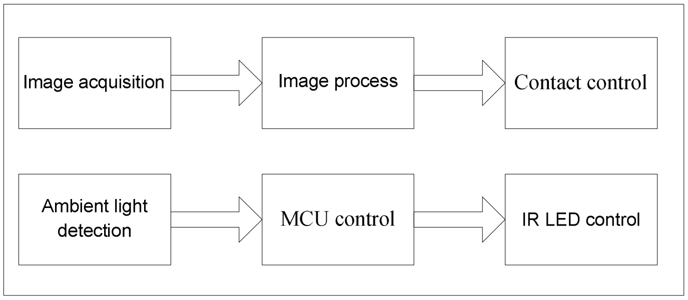

Fig.3 The system of Infrared Touch Screen.

The touch screen is made by the acrylic with tracing paper whose size is 80cm×55cm. Both left and right sides of the screen install IR LED array. Touch input is captured through a CCD camera, whose resolution is 768×576 pixels and frames/second is 25, with IR filter under the bottom of the screen. These materials are very cheap, easily obtained. The cost of the system is no more than 100 dollars.

The system of ambient light detection and adaptive control of IR LED take Freescale's MC9S12DG128 microcontroller as the core. This system assembles the infrared sensor module, signal amplifier module, switch control module and IR LED control module.

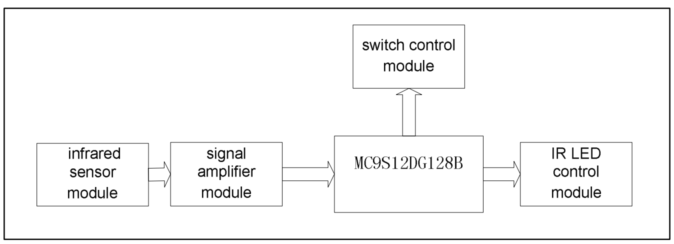

Fig.4 The system of MCU.

Ⅲ. IMAGE PROCESSING

VC has faster, real time and powerful features for image processing. To make the system highly integrated and easily to develop, image processing functions of OPENCV library are called in the VC. Image processing includes image acquisition, image preprocessing, image segmentation and contact area detection.

A. Image Preprocessing

Firstly, the original image captured by camera should be converted into gray image. The infrared images are different from the visible images. There is a certain degree of difficulty to segment the foreground and background, because they are big noise, low contrast and edge blur, which need filter processing to lower the noise. Through analysis, the noise of the infrared image is mainly from the 1/f noise, generation-recombination noise, thermal noise [4]. There are three typical filter methods, mean filter, median filter, high pass filter. Median filter is easily to implement. It not only provides a good denoising capability for certain types of random noise, but also makes image low fuzzy [5]. Through the practice tests, the use of median filtering method is the best(Fig.5). Noise in the image is filtered through smoothing processing.

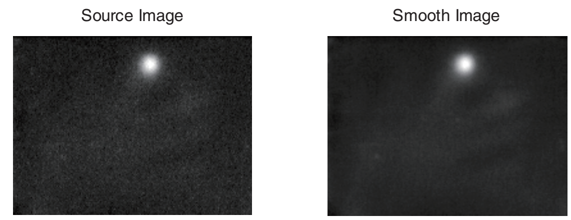

Fig.5 Left image is the source image .The right one shows the result after median filtering.

B. Image Segmentation

Image segmentation is binary processing. To get mono image, Otsu's method is adopted in image binarization processing and used to automatically perform histogram shape-based image thresholding [6]. The selection of threshold is based on the law that the foreground and background class variance is maximum. Otsu's method is a commonly used automatically thresholding method due to its good performance, simplicity and fast speed. The basic idea is as follows: image's gray level is L, and in this image, the number of the i th pixel is n_i, the total number of all pixels is $N=\sum_{i=0}^{L-1} n_i$, the appearance probability of the i th pixel is $p_i=\frac{n_i}{N}$. Obviously, $\sum_{i=0}^{L-1} p_i=1$. A threshold value T is set to separate the image to be two classes C_0 (the gray level is from 0 to T) and C_1 (the gray level is from $T+1$ to $L-1$). Where w_0, w_1 represent the proportion of two classes' area and can be calculated as (1), (2).

$$w_0=P_r(C_0)=\sum_{i=0}^{T} p_i=w(T). \tag{1}$$

$$w_1=P_r(C_1)=\sum_{i=T+1}^{L-1} p_i=1-w(T). \tag{2}$$

Obviously, $w_0+w_1=1$. The mean gray value of the image, mean gray value of class C_0 and C_1 are presented as u, u_0, u_1, which can be calculated as follow (3)-(6)

$$u=u(L-1)=\sum_{i=0}^{L-1} ip_i. \tag{3}$$

$$u_0=\sum_{i=0}^{T}\frac{ip_i}{w_0}=\frac{u(T)}{w(T)}. \tag{4}$$

$$u_1=\sum_{i=T+1}^{L-1}\frac{ip_i}{w_1}=\frac{u-u(T)}{1-w(T)}. \tag{5}$$

$$u(T)=\sum_{i=0}^{T} ip_i. \tag{6}$$

The variance of two classes is defined as follow,

$$\sigma_B{}^2=w_0(u_0-u)^2+w_1(u_1-u)^2=w_0w_1(u_1-u_0)^2. \tag{7}$$

Where T is increasing from 1to L until $\sigma_B{}^2$ achieves the maximal value and T is the optimal threshold value [7]. When the image object and the background are more evenly distributed and the variance of the object and background is not significant, Otsu's method is effective [8]. However, in this system, the distribution of the object and background of infrared images are extremely uneven with Otsu's method for image segmentation, the threshold will produce drift and wrong object into the background. For small object, it will get satisfactory result if the threshold determined by Otsu's method is multiplied by an experience factor. According to the experiments, the experience factor is 1.5 in this system(Fig.6 and Fig.7).

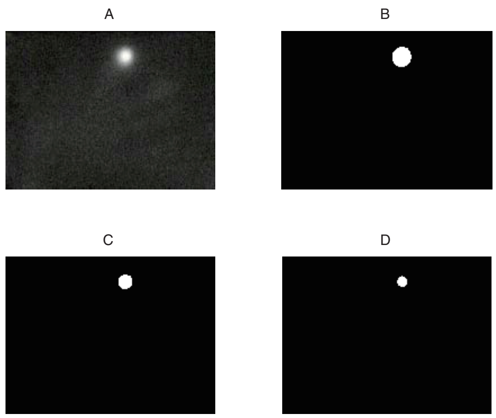

Fig.6 Image segmentation. A: source image. B: threshold=105, experience factor=1. C: threshold=158, experience factor=1.5. D: threshold=210, experience factor=2.

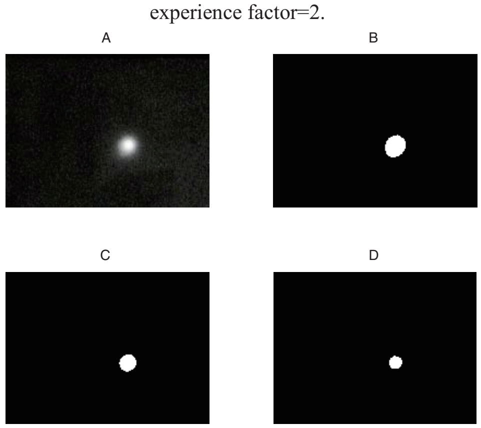

Fig.7 Image segmentation. A: source image. B: threshold=93, experience factor=1. C: threshold=140, experience factor=1.5. D: threshold=186, experience factor=2.

C. *Contact Area Detection*

A centroid calculation algorithm is used in the study to calculate the coordinate value of center point of blob [9]. However, when image segmentation is not complete or there is more background noise, the centroid calculation algorithm can not achieve the desired results. In single-touch system, the contact area is a bright and the gray value of contact area is significantly higher than the background, In addition, the accuracy is not highly required in the application of large-size touch screen. Therefore, integral projection can be used to detect contact area. $I(x,y)$ represents gray value of an pixel point (x,y). $H(x)$, $V(y)$ represent the horizontal integral projection value and vertical integral projection value, which can be calculated as (8),(9).

$$H(x)=\left[\frac{1}{(x_2-x_1)}\right]\sum_{x_1}^{x_2} I(x,y). \tag{8}$$

$$V(y)=\left[\frac{1}{(y_2-y_1)}\right]\sum_{y_1}^{y_2} I(x,y). \tag{9}$$

Where x_1, x_2 represent the range of coordinates in the horizontal integral y_1, y_2 projection and the range of coordinates in the vertical integral projection [10].

In this paper, the corresponding coordinates of the peak are found out by utilizing grayscale integral projection along row and column direction (Fig.8). Integral projection can effectively reduce the effect of the noise, which is simple, with low computational complexity and easy implementation.

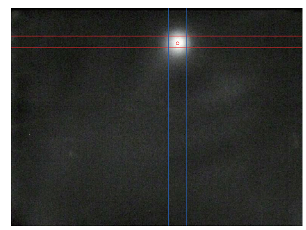

Fig.8 Using integral projection to detect contact area

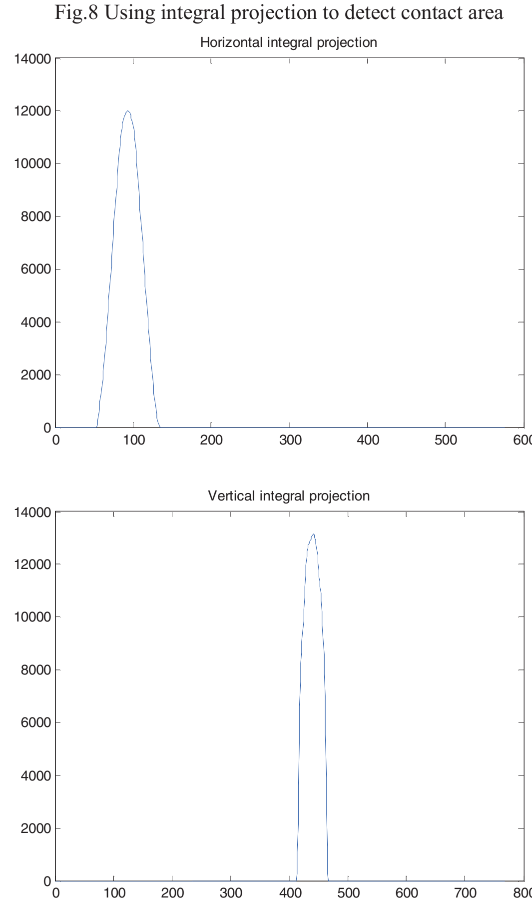

Fig.9 Integral projection

IV. MCU CONTROL

Application software of IR LED control was developed by Metrowerks IDE Code warrior for HCS12. Development of language use HSC12 C language of whose grammar is the same as the basic standard C language [11]. The system software combines the initialization module, infrared sensor module, signal amplification module, MCU control module, IR LED control module and switch control module. The algorithm flow chart is as follows.

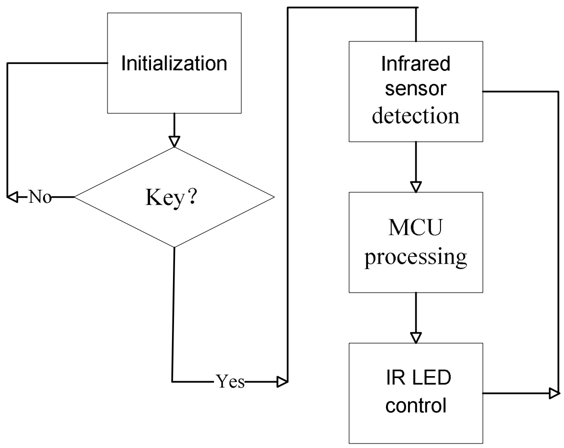

Fig.10 MCU control flow chart.

V. EXPERIMENTAL RESULT AND ANALYSIS

The whole system is implemented by using VC. Experiment is made in different ambient light conditions. Fig.11 shows the results of experiment in dark room. Integral projection can effectively overcome the impact of low-contrast for the detection of contact area. The system accurately recognizes the contact area and meets the requirement of real time. From Fig.12, we can see the performance of IR LED control via MCU. In outdoor with sunlight, the sunlight contains large amounts of infrared light which will impact on the detection. IR illumination intensity is increased by IR LED control module. Fig.12 illustrates that this system can be good fit under a complex light environment.

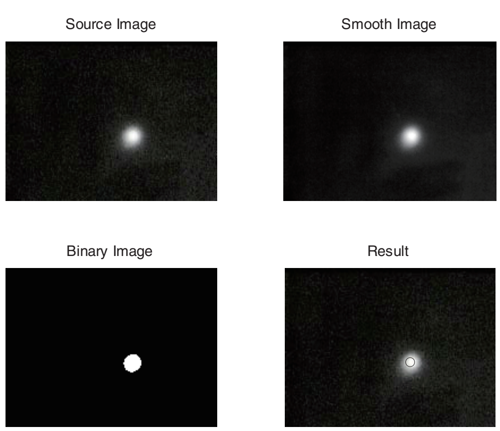

Fig.11 Experiment in dark room.

Fig.12 Experiment in outdoor with sunlight.

VI. CONCLUSION

In this paper, a simple system was builted, which was made by the acrylic with tracing paper, IR LED array, a CCD camera with IR filter and MCU. The Otsu's method with a coefficient was adopted to get Anti-noise binary image. In this paper, the detection of contact area based on integral projection could recognize touch point robustly and quickly. The control of IR LED could effectively enhance the adaptability of the system in complex light environment. The performance of the system experiment was satisfactory. In the future, the application of multi-touch technology will become the mainstream in the touch field. Regardless FTIR or DI device, High-performance multi-touch detection algorithm should be further study. We can trend to develop more applications of multi-touch for better user experience.

ACKNOWLEDGMENT

This work was supported by the grants from Key Lab of Robotics & Intelligent System, Guangdong Province (2009A060800016), the Guangdong/CAS Cooperation Project (2009B091300160), the Knowledge Innovation Eng. Funds of CAS, National Natural Sc. Foundation of China (60904031), Shenzhen Sc. & Tech. Research Funds (JC200903170436A).

REFERENCES

[1] Touchscreen, http://en.wikipedia.org/wiki/Touch_screen#Infrared.

[2] Rear DI, http://wiki.nuigroup.com/Diffused_Illumination.

[3] Han, Jerfferson Y, "Low Cost Multi-Touch Sensing through Frustrated Total Internal Reflection," In Proc.UIST2005,ACM press, 2005, pp.115-118.

[4] Qianjin Zou, Liang Feng, Ya Wang, "Analysis and improved preprocessing method of space noise in infrared image," Journal of Applied Optics, 2007, pp.426-430.

[5] Guohong Liu,Wenming Guo, "Application of improved arithmetic of median filtering denoising," Computer Engineering and Applications, 2010, pp.187-189.

[6] M. Sezgin, B. Sankur, "Survey over image thresholding techniques and quantitative performance evaluation," Journal of Electronic Imaging , 2003, pp.46–165.

[7] Bin Hu, Ningsheng Gong, "An Improved Otsu's Thresholding Segmentation Method," MICRO ELECTRONICS & COMPUTER, 2009, pp.153-155.

[8] Bin Hu, Ningsheng Gong, “An Improved Otsu's Thresholding Segmentation Method,” MICRO ELECTRONICS & COMPUTER, 2009, pp.153-155.
[9] Feng Wang, Xiangshi Ren and Zhen Liu, “A Robust Blob Recognition and Tracking Method in Vision-based Multi-touch Technique,” International Symposium on Parallel and Distributed Processing with Applications, 2008, pp.971-974.
[10] Dan Tao, Xiaoyu Feng, “Fast eye and mouth location algorithm based on integral projection and color matching,” Application Research of Computers, 2009, pp.1578-1580, 1587 .
[11] Liqin Liang,Yan Wang,Jianbao Zhang, “The Design of Intelligent Vehicle Model Based on Freescale MCU,” Development&Innovation&Machinery&Electrical Products,2010, pp.114-115,127.