An Eye Controlled System Based on Nios II

Wen-Jie Ye, Ke Huang, and Qiu-Xiang Chen

College of Communication Engineering, CHONGQING University

174 Shazhengjie, Shapingba, Chongqing, 400030, China

yewenjiecqu@sina.com

ailsacqx@163.com

15023101840@139.com

Abstract— **In the background of current hot sight-tracking technology , this topic aims at designing an eye controlled system based on Nios II and solving the HMI problems of the disabled so that it can provide a way for them to communicate with the outside world, improve their ability of living and help them regain confidence. We have also designed some Interactive functions such as an eye controlled calculator, an eye controlled Whac-A-Mole game and an eye controlled voice-help. It can provide convenience and help them communicate with others, seek help, have fun and study.**

***Keywords*— SOPC; VGA display; Image Processing; Relative Offset Calculation; View positioning; Edge detection**

I. INTRODUCTION

The ultimate goal of scientific visualization, virtual reality for people and multimedia technology is to find a best way for people to communicate with computer system [1]. In the design of Human Machine Interface, the research of the features of eye movements provides another dimensional information for Constructing Virtual Human, and have greatly deepened the study of Human Machine Interface. By now, while the manual input technology has become very common and mature, the voice recognition technology has been practical, and the tracking technology of heads or bodies has been widely used in the virtual reality technology, the tracking technology of sights is still in its infancy. But we are very interested in the application of the sight-tracking technology in Human Machine Interface because of its directness, naturalness and bidirection. Obviously, for visual object selection and operation, any other accesses(such as heads and bodies) are under the visual conducts .As a result, eye-fixation is a very excellent and potential input channel, as it makes Human Machine Interface more convenient ,natural and bidirectional. Eyes, as an input channel, can control the peripheral equipment by sight-tracking and achieve multitasking operation, and it has a broad development prospects in industrial control, robotics and clinical medicine. It also has a great application prospects in the Human Machine Interface, for example, the disabled assistant tools, clinical medicine, intelligent computers and robots that can understand human's intentions, household appliances that have mutual functions, virtual reality and games.

In the background of current hot sight-tracking technology , this topic aims at designing an eye controlled system based on Nios II and solving the HMI problems of the disabled so that it can provide a way for them to communicate with the outside world, improve their ability of living and help them regain confidence. The method proposed in this paper is non-intrusive and is based on the reflection of light [2]. Firstly, the system captures images by using a low illumination and analogic CCD camera. The first task is to compensate for natural head movements to ensure that the user's eye is always in the field of view of the camera tracking the eye [3]. Secondly, the images are digitalized into digital images by the video decoding module on DE2 board. The inner ring of LEDs (LED I) is mounted in front of the camera lens to acquire the bright pupil image [4]. Thirdly, through using a designed algorithm, digital images are processed in FPGA and the position of eye-glazing point can be worked out, and the position will be displayed on VGA screen. The developed gaze tracking system, FreeGaze, detects gaze position by the two processes. First, the pupil and the Purkinje image are detected from the captured image. Then, the gaze position is computed from these two images by using the eyeball model. Finally, due to the personal calibration, accurate gaze direction is estimated [5]. Finally, we can use the calculated result to control the movements of a cursor with a wink, which can be used to make a choice on a visual object .In this way, we can realize the function of HMI by eye movements. Accuracy is measured as the distance between the estimated point of gaze and the actual location of the calibration marks in the scene image averaged over all nine calibration points [6]. In this system, we have also designed some Interactive functions， such as an eye controlled calculator ,an eye controlled Whac-A-Mole game and an eye controlled voice-help. It can provide convenience and help the quadriplegia, high level paraplegia, cerebral palsy, Parkinson and ALS patients communicate with others, seek help, have fun and study.

II. FUNCTION DESCRIPTION

This system is based on FPGA Platform, using SOPC technology, Programmable logic design technology, infrared imaging technology, VGA display technology, and network transmission technology. The system works in the office

environment, the di-stance is 50 to100 cm from the human eye to computer screen, which has a 17-inch 1440*900pixels re-solution. Place an infrared light and infrared camera in the front of computer screen, which can be used to capture the face image. When the system works, the face image captured by the simulating camera can be converted to a digital video signal with an 8-bit ITU-R BT.656 format via a video decoder. After a series of digital image processing, the system can superimpose the gaze position calculated on a computer screen, and used it to select the operation control object. The proposed method is successful in detecting eyes of varying scale, within a certain allowable image plane orientation [7].Users can easily control the object selections and the system through eye gaze. We also have designed an eye controlled calculator, an eye controlled voice help, and an eye controlled Whac-a-mole game in this system. The user can use the eye gazes and blinks to achieve human-computer interaction without hands. However, it is usually not possible to isolate the eye blob only by picking the right threshold value, since pupils are ofien small and not bright enough compared with other noise blobs [8].The system implements the above functions through the following steps:

A. Video capture

This system based on the image processing technology, has chosen to use the simulation CCD camera as image sensor for acquiring image, a 10 bit and 4 times over-sampling video decoder chip ADV7180 made by ADI company for the conversion from an analog image to an digital image. After being configured, the ADV7180 video decoder chip can automatically detect the input analog video signal format, and convert it to an eight Y Cb Cr 4:2:2 component video image data, which is compatible with the standard ITU-R.656 interface.

This system has implemented the specific configuration of the video decoder chip, completed the conversion of the effective image data, and extracted the brightness signal from the 8 bits video image data to get a gray image with a 704*576 resolution for the subsequent processing. In addition, to meet the image quality and the design's requirements, the original image is down sampled, and the image size can be cropped to 288*288. Digital image is stored in the SDRAM for later processing. For observing the image effect and processing results, the system has designed a VGA scanning display control module added into SOPC system as a custom peripheral to implement the function of image acquisition and display, and the VGA module takes SRAM as the display data cache.

B. Point positioning

The eye tracking based on active IR illumination utilizes the special bright pupil effect [9]. This system is based on the principle of the corneal reflex, and makes the relative position of the pupil centre and the spot on the eye constructed by reflecting the infrared light as the human eye gaze point. With this micro-feature approach, not only the position of the features can be found, but also the shape of the features [10]. Therefore, the design of the positioning algorithms and the computing of the viewpoints are the keys to fulfil the system. In the process, the captured image pre-processed and denoised will reduce some interferences to the following processing. For the locating the pupil center, we need do the following works: user detection, eye pupil coarse positioning, spot and figure two adaptive threshold segmentation, extraction of the value of the two images and pupil, the spot center coarse positioning, pupil edge location, the pupil center circle fitting and accurate positioning. According to the relative position of the pupil and the spot center, we can calculate the actual view through a coordinate transformation. Finally, the actual view can be displayed on the LCD screen for us to judgment its Correctness.

C. Eye movement control

The control function of eye movement is to achieve a computer control by the information of the eye movements and the eye gaze positions. Firstly, calculate the relative offset between the pupil and faculae .Secondly, work out the eyes' gazing points according to the coordinate transformation function. Finally, fulfil the eye controlling function combined the blink detection for visual target selection. This system can implement the eye controlled calculator, eye controlled voice help, and some eye controlled games and so on.

III. The Structure of System Design

The control system of eye movement based on Nios II abstract the face image by a simulated CCD camera. The infrared LED light, as a part of the system, provides stable and uniform illumination environment for the system, at the same time, the highlighting spot that is formed when the light to the human eye also gives reference to the viewpoint of positioning. ALTERA DE2, the core of the system, aims to complete analog video signal acquisition, display control, the transmission and processing of network, and control the system by point information obtained from processing, which makes it possible for eye control calculator, eye voice control, eye whack-a-mole game, and other functions. Analog video signal acquisition mainly completed by ADV7180, the chip can automatically detect the input analog video signal format, and transform it into YCbCr 4:2:2 eight components of pixel data in video image data that is compliant with the ITU - r. 656 interface standards, for the FPGA effectively extract and cutting processing, etc. According to the requirements of the display interface and the resources belongs to the DE2 board, we choose VGA LCD as human-computer interaction devices to complete the display of control interface and user action operation and feedback of the results. In the realization of the eye control voice for help, we choose MP3 audio module to complete speech. According to the user at operating, driving the stereo after decoding MP3 audio file that pre-stored in the

SD card. For the convenience of collecting images by MATLAB algorithm analysis, the network controller is added in the system, the send the image obtained by FPGA to PC for display storage. Figure 1 is the diagram of system structure.

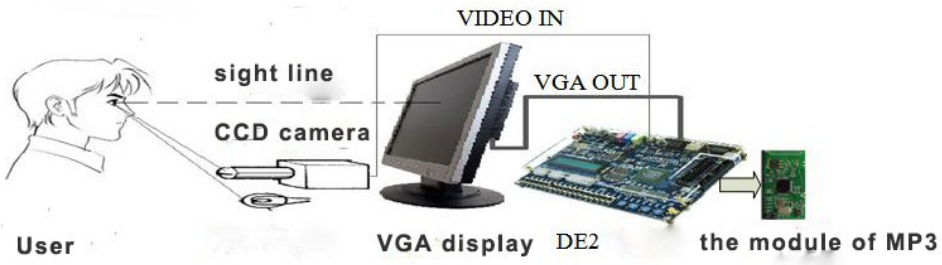

Figure 1. Schematic diagram of the system

A. Hardware design

The control system of eye movement based on Nios II collected face image via the CCD camera, after Image preprocessing、Object segmentation、the realization of the pupil and spot center location by the least square fitting. This system according to the relative position of the pupil and the spot，and superimposing with the actual fixation point by the coordinate transformation displayed on the LCD screen, achieved the human-computer interaction function such as a calculator of eye control, voice help of eye control and hamster game of eye control. The system makes full use of the resources of DE2 development board, and designs the infrared LED light driving circuit board.

In addition, the system configures the infrared LED light source, the CCD camera, the VGA display screen, and the MP3 playback module besides the DE2 development board, system of object and hardware block diagram in Figure 2, in figure 3.

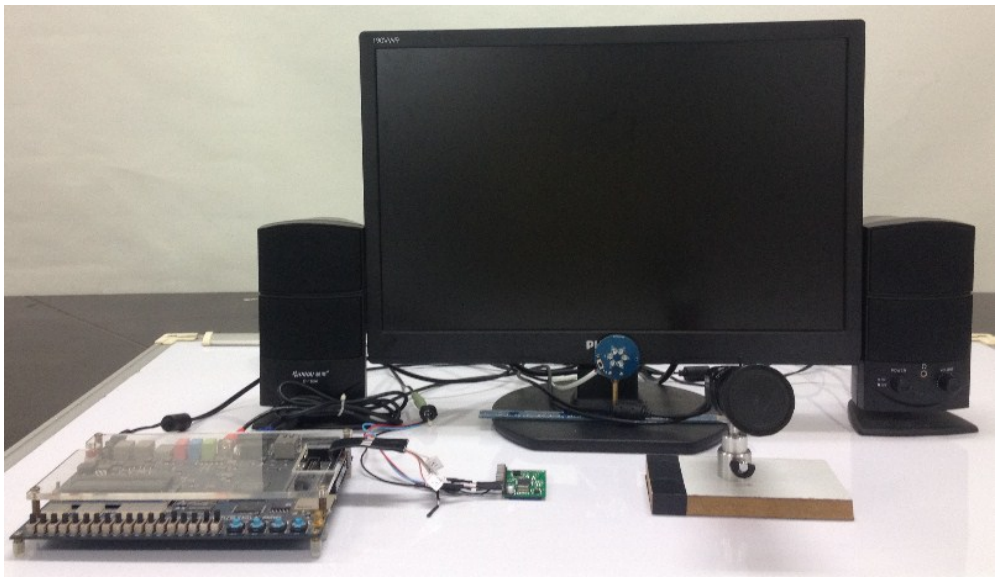

Figure 2. The system physic

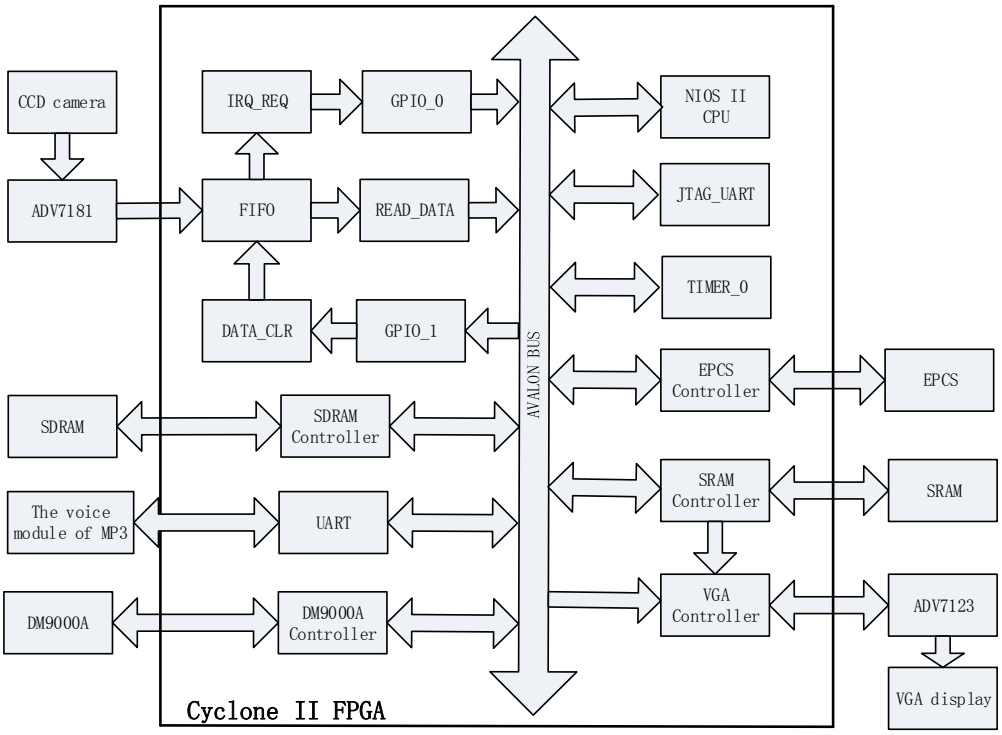

Figure 3. The hardware structure of the eye controlled system based on Nios II

B. Software design

The process of software processing system includes: systeminitialization, image acquisition, calibration, viewpoint positioning and human-computer interaction, etc. When the system is powered on, first step is to initialize including initialize ADV7181 video decoder, VGA display, NCU and so on. After that, the system collect pictures from analog CCD camera and save them into corresponding image buffer. Through the process of user detection, eyes location, pupil and light spot segmentation, coarse position, pupil edge detection, circle fitting and centre localization, we get relative offset between pupil and spot, which is gist of calculating actual calibration parameters and human eyes gaze. After the calibration, we locate the human eye sight and make system control and target selection. There are calculator, voice help and Hit Hamster interface controlled by eye. The users can control function interface by eyes' movement and then realize result of controlling computer without hand.

It is worthy of note that we should make calibrat-ing operation in order to find the relationship of relative offset between pupil and spot and the real fixation when calculating the actual fixation of eyes. The calibrating operation includes two steps: staring at a few point on screen and calculate relative offset between pupil and spot in corresponding image, and then make sure the mapping relationship between fixation point changes caused by eyes movement and offset.

The calibrating operation is especially important in the process of software processing system, which involves accuracy of viewpoint positioning in application, and the accuracy of viewpoint positioning depends on the merit of calibrating operation and calculation accuracy of relative offset between pupil and spot. System overall software process is shown in figure 4.

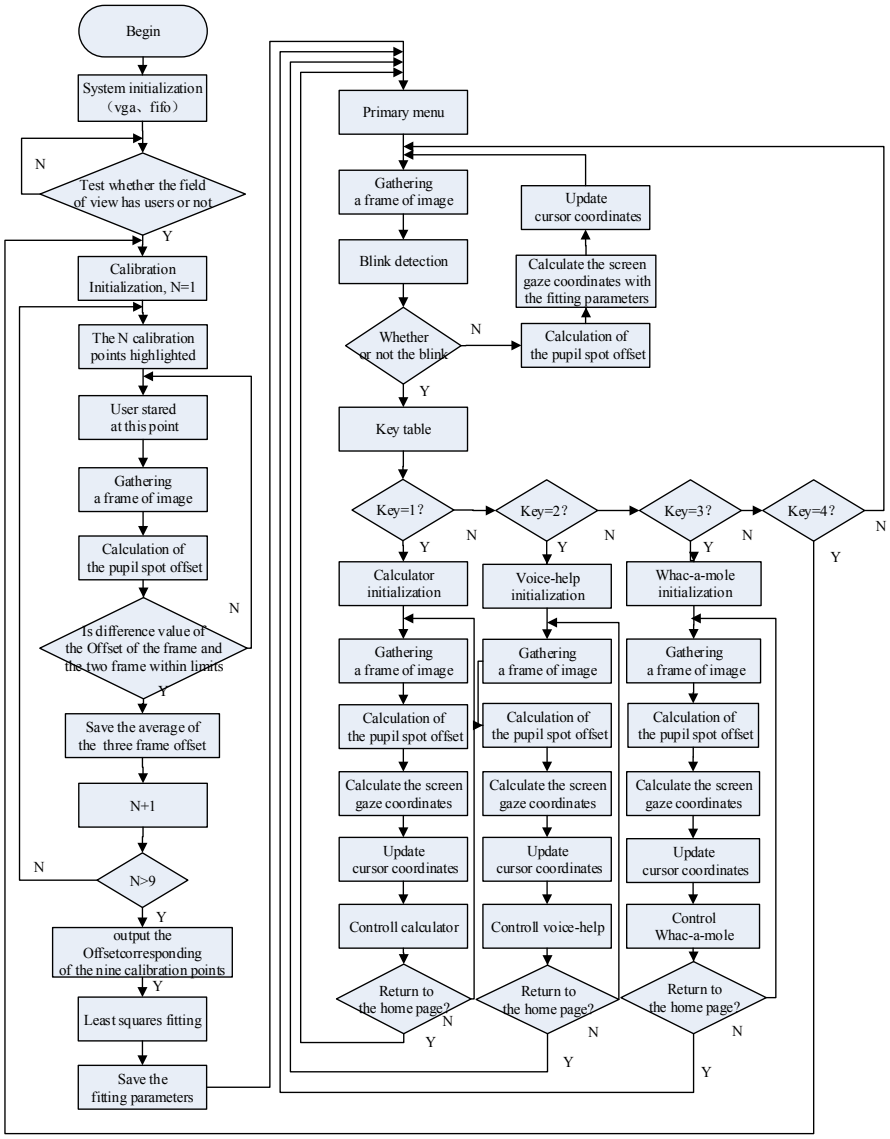

Figure 4. The software flow diagram of the eye controlled system

IV. DESIGN METHOD

A. Design survey

First of all, it's based on requirement analysis and performance index that we have determined the system's hardware structure and completed the selection of hardware device in the process of designing. Then, combining with the SOPC technology, VGA display technology, Ethernet technology, infrared imaging technology, image processing technology, we structured the hardware platform of the system. In the early stages of design, For fast realizing algorithm design of the system, the completion of the feasibility of system design verification, FPGA will be collected effectively image data through Ethernet interface is sent to the PC machine is saved as JPG format, for MATLAB software analysis. In the PC terminal, image display, storage is realized through the software design of host computer, the host computer software can receive image data real-time display in the interface, and can be stored in a variety of formats.

In the PC end of the MATLAB software to complete the design and feasibility of algorithm verification. In according to the characteristics of the hardware platform of DE2 to complete the algorithm transplantation. In the realization of the basic function to optimize the software algorithm, and improve the system precision and speed, the comprehensive effect of promotion.

B. Optical Imaging System Design

Based on principle of corneal reflection in eye tracking system, the images captured by CCD are transferred to the FPGA and after the image processing the pupil centre and spot

location information are extracted. And then we can estimate the eyes gaze direction. The quality of the captured eyes images is required higher. Image clarity directly affects the level of measurement accuracy. To reduce the visible light interference on the system, we uses near infrared light source. We uses near infrared sensitive CCD camera and an infrared illumination bandpass filter (to visible light, near-infrared light through) to obtain images, eliminate the impact on the measurement of visible light and increase the system's anti-jamming capability.The reflection of iris within 850nm infrared is 0.9, while the normal light is 0.5. And absorption and reflection of infrared ray in the eyes of the cornea, iris and pupil are different. Therefore, andthe infraredtime, in order to overcome the interference of visible light, and reduce dependence on ambient light and night lighting, system adopt 850nm near infrared light source.The circuit can realize the luminous intensity to be adjusted and continuous, and improve the system adaptability. Drive circuit principle diagram and object diagram as shown in Figure 5 and 6.

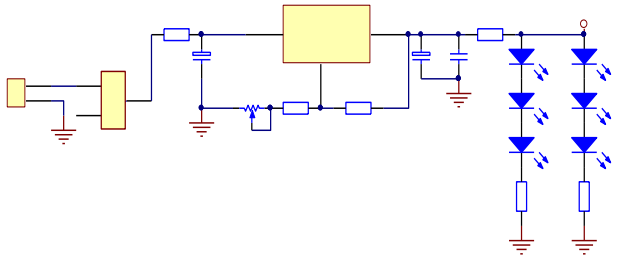

Figure 5. The drive circuit diagram of the infrared LED lamp

Figure 6. The infrared LED lamp board's physical map

C. *The design of image acquisition module*

According to the requirements of image quality system and the characteristics of the selected analog CCD camera image, we design the image acquisition module. The image acquisition module includes :ADV7181 video decoder, I2C video encoder configuration module, ITU-656 decoding module,and image data sampling and cutting module, image dataof FIFO buffers.Power on initialization, firstly according to the standard of CCD output analog video signal, we make configuration of the ADV7181 through the I2C video encoder configuration module. Then when ADV7181 initialization is successful, we put the inputting analog video signal into the AD conversion, finally output component video signal in ITU-656 format. According to the actual situation, we only need the gray image signals in this system, and design the ITU-656 decoding module for this. The module takes sample of digital video signal in ITU-656 format, extracting luminance signal in the way of the interlacing every points, and packaged the four pixel data as a group in the FIFO cache. When the number of data stored in FIFO is larger than the threshold value, custom interrupt module generates interrupt signals, and sends the interrupt signal into the Nios II processor. Finally, the Nios II processor executes interrupt processing functions and finish the reading of the image data effectively, and stored the data in the SDRAM for subsequent processing.

D. The design of SOPC system

According to the function and structure of the system, the SOPC system includes the Nios II soft core processor, Ethernet controller, SDRAM controller, SRAM controller, EPCS controller, VGA scanning display controller, serial port, the SOPC system structure is shown in figure 7. The Nios II soft core processor, SDRAM controller, EPCS controller, Ethernet controller, serial port are elements in SOPC Builder library, which is very convenient to use .SRAM controller and VGA controller as the self-defined module, which can be easily integrated into the SOPC system through the AVALON bus. The configuration can be completed with some simple operation. The SOPC system required in this design can easily be built using the SOPC technology .And the whole design process is with high flexibility and efficiency.

The core of SOPC design is the configuration of the self-defined VGA module. In the system VGA module can work as a master or as a slave.The main function of the VGA module (working as the slave of the AVALON bus): address 0 write data into the VGA, namely SRAM opens the first address of display buffer for the VGA. The bit 0 of address 1 controls whether VGA work or not, 1 work, 0 not, which is shown in Table II; VGA module works as master module of AVALON bus: the timing controller of VGA controls the reading of image data from the data buffer of the VGA (namely the SRAM module) through the AVALON bus, and also the data is converted to 10bits RGB values for display in the VGA interface. The sequence of VGA is shown in Figure 8(row timing) and Figure 9(field timing).

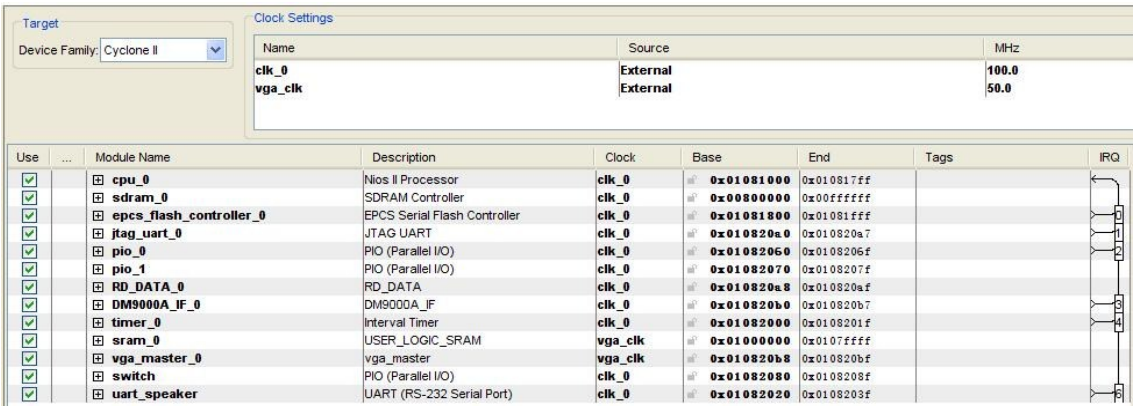

Figure 7. The SOPC system structure

Table II. Whether VGA work or not

Address 0	VGA Data buffer address
Address 1	32'b00000000_00000000_00000000_00000000

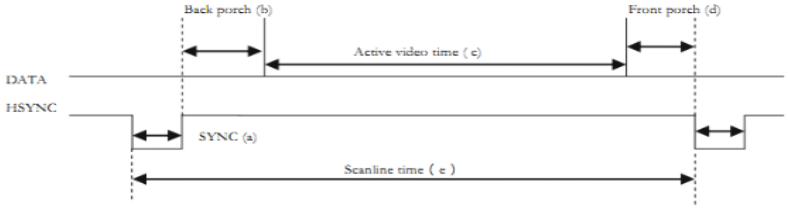

Figure 8. VGA row timing

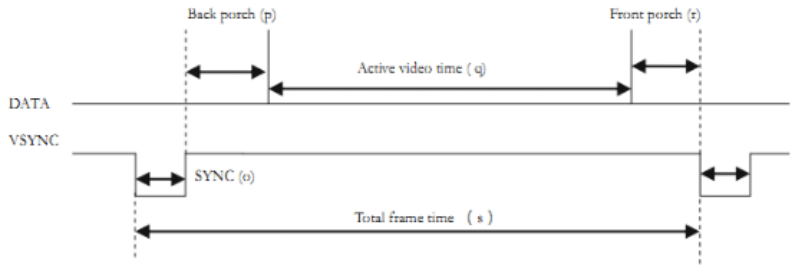

Figure 9. VGA field timing

E. The design of image processing algorithm

In order to realize the precise location of the pupil spot centre, the system need to process the collected image. Concrete steps of the algorithm include: image smoothing pre-processing, user detection, eye location, eye spot two value segmentation and centre coarse positioning, pupil edge location, pupil circle fitting and precise centre location. Then the main algorithm design is described.

1) User detection: The system uses eye operation, only when the face image enters into the camera field of view, the system can be controlled. Therefore, the system need to detect whether there is a face of each frame image. Based on infrared LED light spot formation characteristics in the shape, the algorithm design achieves face detection, the main use of the image gradient, binocular light spot position relation. The method is simple and easy, and the detection accuracy is relatively high.

2) Eye location: Because a human face image is collected, in which eyes are the proportion of the smaller, and spot is the proportion of smaller. The first problem to be solved is achieving to locate the local image of the eyes position from the entire human face image. Through the analysis of MATLAB software on face images collected, we found in the eyes of the bright spots of image gray and gradient, that is bigger and more obvious characteristics. So it can be combined with the image gray and gradient information to determine the positions of the spot eyes. Further the system can determine human local image. In the eyes of local image, the treatment can reduce the amount of data processing.

3) Pupil faculae two value segmentation and centre location: Position of pupil faculae is the key to implement the control system of eye movement. The first step to achieve localization is the segmentation of the pupil and spot from local image in the eye. The commonly used methods are segmentation method based on the shape feature and segmentation method based on gray of image. Because of simple algorithm, small

amount of computation, and high accuracy, the latter has been widely applied. When the environment changes in light intensity, the general method of image segmentation based on gray of image will fail. According to the characteristics of the problem and the small ratio of the pupil and spot in the image, we have designed the improved extraction algorithm of adaptive threshold based on otsu. The algorithm through the analysis of the statistical characteristics of image, and establish a criterion to realize adaptive image segmentation threshold extraction. The results show that the algorithm is stable and reliable, and the extraction of the threshold can achieve success that pupil is separated from the eye image. The pupil and the spot based on the Binary Image, location centre, through the centroid method can be calculated to get the spot.

4) Pupil circle fitting: Due to the influence of the light spot，the detected pupil centre based on The coarse positioning may be largely different from the actual one. In order to accurately locate the centre of the pupil, you should radial scan a circle which set the positioning centre as its circle centre, and a certain value that is slightly larger than the actual pupil radius as its radius, then gradient use [-1 0 1] one-dimensional gradient operator to calculate the area of each scan line pixel value. After the edge point, the factors of gradient, gray, distance to the rough location of centre and other factors of each scanning line search need to be integrated.

Because of the influence of eyelash, eyelid may put in the false edge to edge in search. Hence, you should firstly sort all the edge points, and then remove the edge points of maximum and minimum. The left ones will be used for circle fitting to locate the pupil centre. By this method, the pupil centre with higher detection accuracy, can meet the precision need. The intermediate results with Algorithm, the detected pupil and spot centre as figure 10.

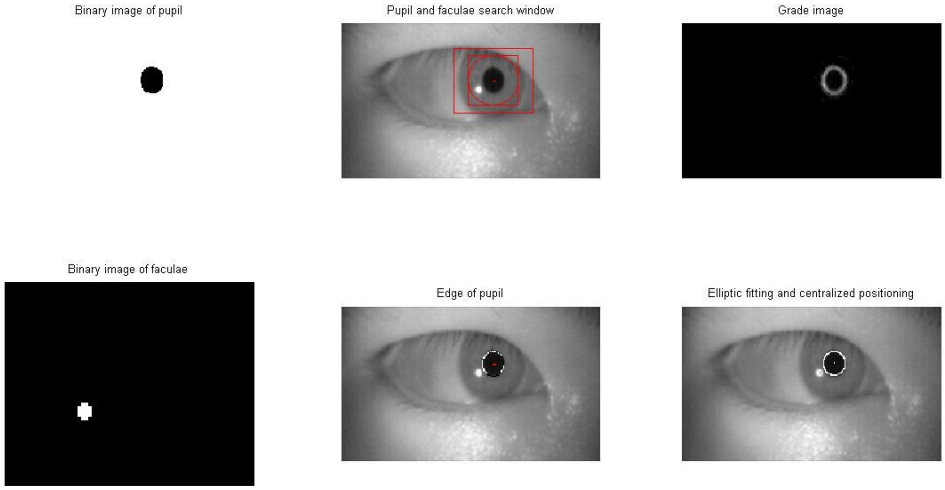

Figure10. The intermediate process and results of the pupil's and spot's centre location

F. The design of the Calculator of eye control

Based on location of view and blink detection, we have designed the calculator of eye control. User can control the computer by eye movement, and complete the operations such as add, subtract, multiply and divide. The work flow of the Calculator is as follows:

Through the main menu to select a calculator function, the system initialize at first. The calculator interface is shown in the VGA display screen. To process the collected image, the system will obtain fixation point by coordinate transformation on the screen after calculating the relative offset of pupil faculae. The fixation point coordinates and various screen button corresponding regions were compared to determine the key value, and change the corresponding button colour. When the detected active blink type key. Finally, according to the type of value, corresponding to add, subtract, multiply and divide operations and returns the result. To show the effect to realize the control of the SRAM and the VGA controller by Nios II processor calculator interface, the interface layout is reasonable, simple and beautiful.

G. The Design of voice help eye control

To meet the disabled limb basic communication needs and thoughts, the voice help of eye control is mainly geared to the needs of them. There contains the basic needs of daily life, the mood, the main parts of the body and common ailment in the control interface of voice help. The way of controlling the press is the same as the calculator of eye control. When the user selects a specific button, Nios II processor through the serial port send commands to control the MP3 voice module playing the corresponding voice stored in the SD card.

H. The design of the Whac-a-mole game of eye control

To enrich the system function and enhance its entertainment, we has designed the Whac-a-mole game of eye control. Through the eyes, user can achieve Whac-a-mole game, so as to give a person find everything fresh and new feeling. In the game, through the timer control the appearance of the hamster, and in which hole gopher appears to be random. When a

hamster appears, user should gaze the hamster. After detection of viewpoint and screen can be coordinate to determine whether hit hamster. When user hit a hamster, the goal of column is to add one point; otherwise, the loss of column is to deduct one point. In addition, screen time interval has two optional level, to meet the needs of different users.

I. PC software design

In the system design process, in order to facilitate the subsequent algorithm simulation by Matlab software, the system added the network module. The PC software is mainly used of sending and receiving video image data via the network module, and is displayed for you in real time. Besides, Video data may be saved as JPG images, BMP format according to the needs of users, and will provide materials for the simulation on Matlab platfom.

The PC interface application is a use of the MFC AppWizard wizard to generate application based on dialog box. The wizard can automatically generate the 3 class, the user can modify directly. The system interface of the PC to control in the main dialog interface, such as edit box, static text box, button, group box, Windows Socket thread is created in the dialog box initialization function, transmit and receive data through the socket, to achieve data transmission FPGA and PC machine. The overall PC interface diagram shown in figure 11:

Figure 11. The interface of the image acquisition on PC

V. CONCLUSIONS

A. High accuracy of sight line positioning

This control system of eye movement has higher accuracy in line of sight positioning. In experiment, the 19 inches VGA display are drawn 4 rows and 5 columns small square, the size of each small square is 40cm*60cm. if the human looks at the small square on the screen fixedly ,it will be highlighted to display as a selected target. The results showed that the accuracy of the target selection is higher than 90%, meeting the system requirements.

B. Simple system structure

This system has a advantage of simple structure, mainly including the DE2 development board, CCD camera, infrared LED light source, VGA display screen, MP3 playback module, and audio hardware. By increasing the viewpoint location accuracy, LCD display screen can be used in smaller size. In addition, the LED light source can also be integrated into the CCD camera, reducing the system's size and complexity. The hardware circuit of the system can also be a certain degree of cut according to needs, such as reducing the PCB size to make the system more integrated.

C. Wide application

The system is a fresh design and has a good prospects. The system has the advantages of simple structure, low cost and being easy to use. Further cutting and integrating can reduce the size of the system, improve the portability of the system. This kind of system is widely used, its applications include: industrial control, robotics, medical, advertising, psychology and so on. Especially in the clinical medicine, the system can provide an effective and convenient way for limb paralysis to express ideas and do the man-machine interaction, which can greatly increase the patient autonomy. If the system is integrated into the electric wheelchair, it can also improve the patient's freedom of action by using the eye movements to control a wheelchair.

D. Flexible SOPC Technology

The design of this system has adopted the SOPC technology, which has a very strong flexibility, and the scale of the system can be tailored according to the needs of users.The user can add SOPC Builder components from the library according to their own needs, or add your own customized modules into the SOPC system. That is to say, the use of SOPC technology can greatly shorten the development time in the development of embedded system, and it is helpful to push the product into the market quickly.

E. Low cost

Based on the DE2 development board with high cost performance, the system designing has made full use of the rich resources on board, such as memory, SRAM, SDRAM, Flash and CCD and so on, greatly reducing the development cycle, the system cost, complexity and power consumption.

F. Good expansibility

At present, there are lots of resources unused on the board. Except the functions of the eye controlled calculator, eye controlled voice help and eye controlled Whac-a-mole game, we can also make some further extension to rich the system's applications, such as with a large number of music files, text files stored on the SD card, we can design and implementation an eye controlled MP3, an eye controlled e-book, which can meet the needs of disabled people on learning and entertainment; and combining with the DDS technology, we can realize the eye controlled electronic organ ,with which people with disabilities can easily play.

ACKNOWLEDGMENT

For the competition, we would like to thank Altera Company, thank you for your company providing us with such a good platform. Through this competition we realized the power of the FPGA soft core combined with HDL code, in the competition we wrote some hardware modules, according to certain writing specification, and after a few integration and modifying, the content we have learned from the process is incomparable with other platforms!

Thank Altera provides university program IP (http://www.niosftp.com/pub/), the IP has greatly improved the progress of our development!

In the end, thank teacher He Wei and Zhang Ling for their guidance, thank the stuff in our lab for their active discussions!

REFERENCES

[1] J. Wang, "Integration of eye-gaze, voice and manual response in multimodal user interface", Proc. IEEE Int. Conf. Systems, Man, and Cybernetics, pp.3938 -3942 1995

[2] D.H. Yoo and M.J. Chung, A Novel Non-Intrusive Eye Gaze Estimation Using Cross-Ratio under Large Head Motion, Computer Vision and Image Understanding, vol. 98, no. 1, pp. 25-51, Apr. 2005.

[3] B. Noureddin, P.D. Lawrence and C.F. Man, A Non-Contact Device for Tracking Gaze in a Human Computer Interface, Computer Vision and Image Understanding, vol. 98, no. 1, pp. 52-82, 2005.

[4] Lim Choon Kiat, and Surendra Ranganath, "One-Time Calibration Eye Gaze Detection System", International Conference on Image Processing (ICIP), Singapore , 2004, pp.873-876.

[5] T. Ohno, N. Mukawa, and A. Yoshikawa, "Freegaze: A gaze tracking system for everyday gaze interaction", Eye Tracking Research Applications Symp., 2002 Tracking Research and Applications Symposium [C], 2002. 125 -132.

[6] D. Li, D. Winfield and D.J. Parkhurst, Starburst: A Hybrid Algorithm for Video-Based Eye Tracking Combining Feature-Based and Model-Based Approaches, Proc. Vision for Human-Computer Interaction Workshop, IEEE Computer Vision and Pattern Recognition Conf., 2005.

[7] R. T. Kumar, S. K. Raja and A. G. Ramakrishnan, "Eye detection using color cues and projection functions," In Proc. Int. Conf. Image Processing, vol.3, pp.111-337-340, 2002.

[8] X. Liu, F. Xu and K. Fujimura, Real-Time Eye Detection and Tracking for Driver Observation under Various Light Conditions, Proc. IEEE Intelligent Vehicle Symp. 2002.

[9] Z. Zhu, K. Fujimura, and Q. Ji, "Real-time eye detection and tracking under various light conditions", Symp. Eye Tracking Research Applications, 2002

[10] M. Reinders, R. Koch and J. Gerbrands, Locating Facial Features in Image Sequences Using Neural Networks, Proc. Second Int', l Conf. Automatic Face and Gesture Recognition, 1997.