Design of An Augmented Reality Teaching System for FPGA Experimental Instruction

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***Abstract*—AR technology has shown great application potential in education field. A new FPGA experimental teaching system was developed with AR smart glasses (EPSON BT-200) and OpenCV computer vision library. It accomplished the position recognition of the FPGA development board without relying on the two-dimensional code tag, displaying experimental instructions nearby. It will effectively complete the instruction process of unsupervised teaching, and plays a good supporting role in professional learning.**

Keywords—AR glasses, teaching experiments, feature recognition, OpenCV, image processing

I. INTRODUCTION

Augmented Reality (AR) is a new technology that integrates the objects of real world with information in virtual world. It tracks the objects in the real world, and uses space registration technology to calculate the three-dimensional coordinates of virtual objects in the real world, so as to realize the real-time fusion of the virtual information and the real world. One area which might significantly benefit in the future from AR technology is the education process [1,2,3]. AR tools could guide students through learning process in enhanced way, as AR can upgrade traditional books with a digital layer and bring interactive dimension into the whole learning process. For example, we can find some AR musical app for children's musical education and using AR to teach kindergarten students English vocabulary. Bring AR into education will probably change the way we perceive information and our reality.

Learning FPGA is complex and hand-on experiments is significant. The majority of teaching systems are based on paper. As a result, students need to read or watching without synchronization in operation. In addition, many of the current AR systems rely on the identification of two-dimensional code tags in order to complete the overlay of relevant information or to complete the positioning of objects[4,5], which will have a great impact on the scope of users' use.

The algorithm proposed in this paper is assisted with OpenCV computer vision library, and related algorithms are developed in terms of feature recognition. According to the outward appearance of FPGA development board, the algorithm is expanded to accomplish the identification and location of each module on it. It effectively gets rid of the dependence on the tag, and makes this teaching system more convenient and practical[6].

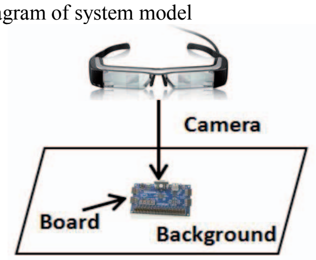
II. CONSTRUCTION OF AUGMENTED REALITY TEACHING SYSTEM

A. System Construction

In this system, contour extraction and location identification of the FPGA development board are completed by acquiring real-time images from camera and utilizing related image processing algorithm. Followed by processing the edge of the development board, its angle relative to the screen is finished. After that, according to the size of the development board in the area of image, predict the height between AR smart glass and development board, make further amendments to the development board position, and complete each module identification and instruction on the basis of the above content.

The specific system implementation scheme is shown in Figure 1:

Fig. 1 Schematic diagram of system model



B. Hardware system selection

This system is based on AR smart glasses(EPSON BT-200). These AR glasses are equipped with 0.42 inch display screens, which are 960x540 resolution and 300 thousand pixels camera. The operation platform is Android4.0.4, meeting the hardware requirements of the system.

Fig. 2 BT-200AV glasses and the camera

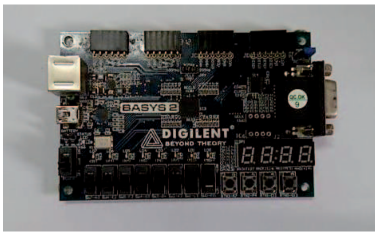
C. Software system selection

The software system is based on Android Studio as well as Android SDK， using API provided by Google to make UI design and function realization. For image processing, OpenCV computer vision library is configured by OpenCV4 Android in Android system.

III. KEY TECHNOLOGIES

This system needs to recognize the FPGA development board whose model is Basys2, as shown in Figure 3.

Fig. 3 Basys2: the FPGA development board for starters

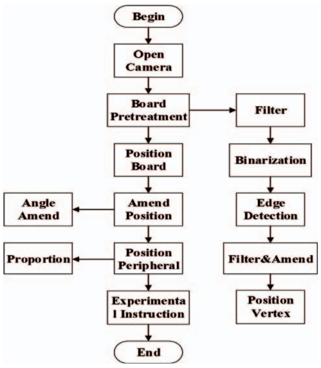


The main difficulty of the project is how to accurately locate the development board without introducing the two-dimensional code tag.

The project can be divided into three main parts. One is to accurately locate the development board, that is to identify the location of the four vertexes without two-dimensional code tag. Another part is to determine the position of the peripherals on the board. Considering that changes of the distance between the camera and the board will directly affect the captured board size, it is difficult to locate the development board peripherals according to the vertex position. The last part is experiment instructions, which shows experiment instructions based on location results

In order to facilitate the image processing, white is used as the recognition background in the system. The overall flow chart of the project is as follows(Figure 4)：

Fig. 4 Overall flow chart of this project



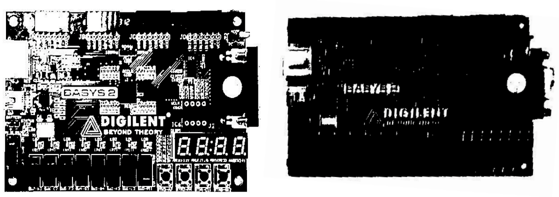
IV. EXPERIMENTAL APPLICATION DESIGN

A. *Image pretreatment algorithm*

Capture the overall image of development board through the BT-200 camera and then, with Gauss filter, eliminate the brighter reflection point existing on the development board surface.

Subsequently, image binarization processing is necessary as is shown in Figure 5.a. And then, after corrosion and expansion, the existing white holes from binarization processing in the board are eliminated, which means removing white small connected domains in the development board(Figure 5.b).

Fig. 5 Image processing effect diagram

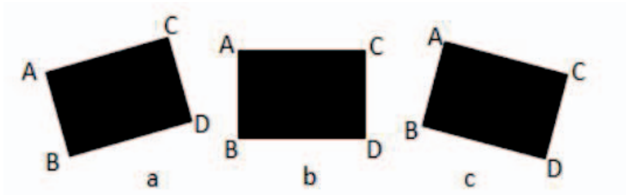


a. binaryzation diagram b. corrosion and expansion diagram

B. *Development board vertex positioning algorithm*

It is found by experiment that the position of the development board in the white background has only three cases, as shown in the Figure 6:

Fig. 6 Diagram of development board position



So, the main task of the system is to accurately recognize the specific coordinates of the four vertex angles of the development board in the above three cases. After analysis, the three conditions are satisfied with the following conditions:

$$\begin{cases} A.y - c.y > 10\,pixel & \text{Fig.6.a} \\ |A.y - c.y| \le 10\,pixel & \text{Fig.6.b} \\ A.y - c.y < -10\,pixel & \text{Fig.6.}c \end{cases} \quad (1)$$

Therefore, different recognition algorithms are designed for three different situations.

First of all, binaryzation images are scanned 4 times line by line to find the feature points.

(1) The first scan is from left to right. When point (x， y)is black, point (x-1,y) is white and point (x-2,y) is also white, that is, a black spot appears after successive white spots. So a point on the left border of the development board is identified. Scan from top to bottom, recording the coordinate of left boundary of the development board and storing it in the array left.

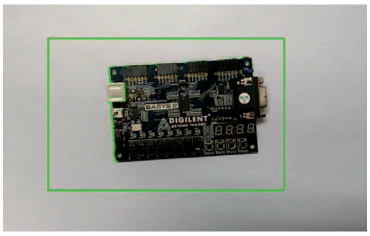
(2) The second scan is from right to left. When point (x， y)is black, point (x-1,y) is white and point (x-2,y) is also white, that is, a black spot appears after successive white spots. So a point on the right border of the development board is identified. Scan from top to bottom, recording the coordinate of right boundary of the development board and storing it in the array right.

(3) The third scan is form top to bottom. Record the first row coordinates that are not all white points, that is, record the line that contains black dots for the first time, stored in the variable up.

(4) The forth scan is form bottom to top. Record the first row coordinates that are not all white points, that is, record the line that contains black dots for the first time, stored in the variable down.

Using the median filter to amend the array right and left, eliminate the interference may exist. Storing the filtered data in the array left and right. The acquisition of the right and left bounds is completed, as shown in the following figure (Figure 7).

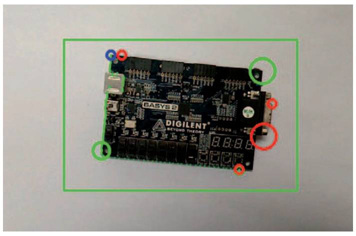
Fig. 7 Left border of development board identification



Find out the point with minimum(maximum) x coordinates in the left array as min_left(maximum). Find out the point with minimum(max_right) x coordinates in the right array as min_right(max_right).

After that, the acquisition of the boundary coordinates is completed, the following step is to determinate the four vertex positions. The coordinates of six points, min_left, max_right, up, down, min_right, and max_right, have been identified in the above. For the case shown in Fig6.a, the point A can be considered either up or min_right. After the experiment, the characteristic points obtained by different methods can be obtained as follows. So after some experiments, the corresponding relation can be obtained as follows (Figure 8).

Fig. 8 sketch map of characteristic points obtained by different methods



For the case shown in Fig. 6.a, the following conditions are met:

$$\begin{cases} A.x = \min\_left.x; A.y = \min\_left.y \\ B.x = down.x; B.y = down.y \\ C.x = up.x; C.y = up.y \\ D.x = A.x + C.x - B.x; D.y = \max\_right.y \end{cases} \quad (2)$$

For the case shown in Fig. 6.b, the following conditions are met:

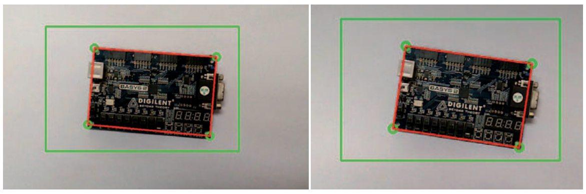
$$\begin{cases} A.x = \mathrm{up}.x; A.y = up.y \\ B.x = down.x; B.y = down.y \\ C.x = up.x; C.y = up.y \\ D.x = down.x; D.y = down.y \end{cases} \quad (3)$$

For the case shown in Fig. 6.c, the following conditions are met:

$$\begin{cases} A.x = \mathrm{up}.x; A.y = up.y \\ B.x = \min\_left.x; B.y = \min\_left.y \\ C.x = \max\_right.x; C.y = \max\_right.y \\ D.x = B.x + C.x - A.x; D.y = down.y \end{cases} \quad (4)$$

At this point, the initial recognition of the four vertices can be completed. For the development board, it is a standard rectangle, so the right edge must satisfy the parallel condition, that is, the slope of the edge is equal. As shown in the following figure (Figure 9.a): the red line around the area is not a standard rectangle, so it is modified according to the left and upper bounds, as shown in figure 9.b.

Fig. 9 boundary acquisition and correction



a. original boundary b. correction boundary

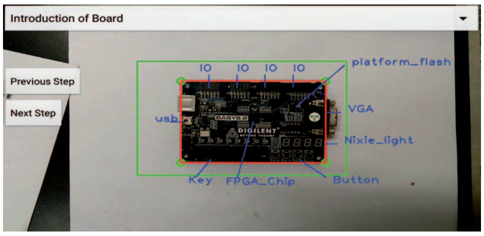
C. *Device positioning and experimental guidance*

After determining the vertex coordinates of the development board, the next step will be to determine the coordinates of the peripherals and chips on the development board. Due to the above mentioned, the peripherals relative to the development board is relatively fixed, therefore, by measuring the distance between the peripherals and the vertex, after zoom ratio and we can get the location of each peripheral on the board.

After that, the experimental guidance can be started.

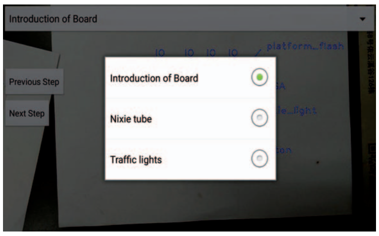
First, when the app-demo is started, the location of the peripherals relative to the development board can be positioned. Shown in the picture below (Figure 10).

Fig. 10 development board identification results



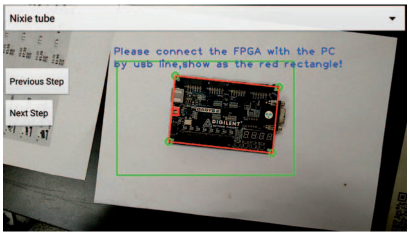
Second, through the Spinner control to select the teaching operations need to be carried out. Show in the picture below (Figure 11).

Fig. 11 Function selection through Spinner control



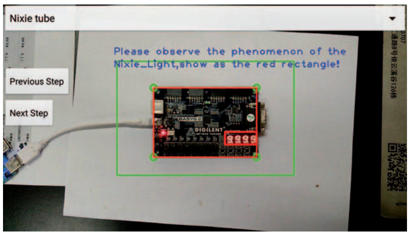
Third, the system will use text and icons to indicate how to connect the development board to the computer. Show in the picture below (Figure 12).

Fig. 12 Connect the development board to the computer



Finally, the experimental results will be shown in Figure 13.

Fig. 13 experimental guidance process display



V. Experimental Instruction Design

With the hardware conditions, with a white background, put Basys2 development board on the white paper, keep the camera remains 30cm height above the desktop. Changing the angle between the camera and the board to check the accuracy rate of this algorithm which is used to obtain the location of 4 vertexes.

The following are stipulated in the test experiment:

When the target point is (0, 0), the experimental measurement point is inside the area which is regard point (0, 0) as the center of the circle, and the radius is within 10 pixels. We define the positioning is accuracy otherwise fail. On the basis of this standard, 50 sets of experiments were carried out. The result just like shown in the following table.

TABLE I. Development board recognition accuracy at different angles

Angle	Left Vertex		Left Corner		Right Vertex		Right Corner	
	Right	Error	Right	Error	Right	Error	Right	Error
0°	48	2	47	3	48	2	49	1
Left 10°	45	5	46	4	45	5	44	6
Left 20°	44	6	45	5	46	4	44	6
Left 30°	42	8	45	5	43	7	46	4
Right 10°	48	2	46	4	47	3	45	5
Right 20°	47	3	45	5	46	4	45	5
Right 30°	46	4	48	2	47	3	44	6

The experimental results show that the accuracy rate of the recognition can be guaranteed more than 90% when the angle of the developing board and the camera is less than 30 degree. Therefore, the algorithm can position the development board to a certain extent.

VI. Conclusion

Using the feature recognition algorithm and without relying on the two-dimensional code tag as traditional AR application, a new FPGA experimental teaching system has been developed with AR smart glasses (EPSON BT-200). With this algorithm, the position recognition of the FPGA development board can be realized and the experimental instructions can be shown nearby. After verification, the positioning effect meets actual application requirements. And in the future, when the algorithms can be optimized to improve the recognition speed and accuracy, there could be more AR applications for experimental instructions and other education affairs.

References

[1] B. Thompson et al., "Participatory Design of STEM Education AR Experiences for Heterogeneous Student Groups: Exploring Dimensions of Tangibility, Simulation, and Interaction," 2016 IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct), Merida, 2016, pp. 53-58.
[2] A. G. D. Correa, B. H. V. Lemos, M. Nascimento and R. D. Lopes, "AR Musical App for Children's Musical Education," 2016 IEEE International Symposium on Consumer Electronics (ISCE), Sao Paulo, 2016, pp. 125-126.
[3] B. Kraut and J. Jeknić, "Improving education experience with augmented reality (AR)," 2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, 2015, pp. 755-760.
doi: 10.1109/MIPRO.2015.7160372
[4] B. Kraut and J. Jeknić, "Improving education experience with augmented reality (AR)," 2015 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, 2015, pp. 755-760.
[5] L. Farias, R. Dantas and A. Burlamaqui, "Educ-AR: A tool for assist the creation of augmented reality content for education," 2011 IEEE International Conference on Virtual Environments, Human-Computer Interfaces and Measurement Systems Proceedings, Ottawa, ON, 2011, pp. 1-5.
[6] T. Haramaki and H. Nishino, "An Engineering Education Support System Using Projection-Based AR," 2016 19th International Conference on Network-Based Information Systems (NBiS), Ostrava, 2016, pp. 267-272.