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Development of a Cost-Effective Shooting Simulator Using Laser Pointer

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Abstract— **In this paper, the development of a cost-effective shooting simulator is presented. The proposed system employs the photodiode sensors for detecting the laser pointer. To reduce the cost, the photodiode sensors are arranged into rows and columns, and the scanning technique is adopted to detect the presence of the laser beam on the sensor arrays. A cheap microcontroller system AT89S52 is used to perform the task. The experiment results show that the developed shooting simulator achieves a high reliability in the laser pointer detection, especially for indoor application. Additionally, the developed application software running on a PC is very useful and effective tool to monitor the shooting process, and the shooting reports could be generated for analysing the shooter's performance.**

Keywords— **shooting simulator, laser pointer, photodiode.**

I. Introduction

In military, shooting is a fundamental skill of a soldier. A shooting practice should be done regularly and continuously. In military training, the conventional shooting range which uses a target from plastic or paper and firearm with the bullet, is commonly used. This system requires high cost for installation and providing the bullets, and need a specific area for avoiding injuries. Further, the environmental issue caused by the toxic waste of the weapon should be considered [1]. To overcome the drawbacks, a shooting simulator is used for replacing the conventional shooting range.

The shooting simulator usually uses a laser pointer attached on the gun (gun simulator) and a laser sensor on the target. There are several types of the sensors used on the target, such as [2]: a) CCD sensor; b) Laser beam deviation sensor; c) Sound sensor. The CCD sensor (camera) is the most popular sensor used to detect the laser beam, from the simple camera system to the complex multimedia system. The laser deviation sensor is the complicated devices with the same order of accuracy, mostly used in the field with the limited shooting distance until 200 meter. The sound sensor is used to detect the sound of the real gun, which is used indoor or outdoor. The accuracy depends on the sound sensor's configuration.

The commercial shooting simulators usually consist of a camera projector system and the gun equipped with laser pointer. In this system, the shooter aims the laser pointer into the target screen which is projected by a projector, then a camera system captures the position of the laser pointer on the target and further analyses by a computer system [1], [3].

The main challenging task in the camera-based shooting simulator is the technique to detect the laser beam under different lighting conditions. In [4], a simple thresholding is employed to detect the laser beam. After detected, the position of the laser beam is determined by calculating the centroid of the cluster of the brightest pixels. The technique allows the low computation cost. They noted that the usage of the very shiny object as a target causes the problems, as they reflect laser in arbitrary different directions. To work under varying lighting conditions, the technique by adjusting the camera parameters is proposed in [5]. However it could not ensure that the laser spot could be detected by a fixed threshold.

The camera-based shooting simulator as described above is an effective way to replace the conventional shooting range, however the cost is relative expensive. In this paper, we overcome the drawbacks of the camera-based systems by employing the photodiode sensor as the laser sensor on the target. The proposed system deals with the cost-effective shooting simulator. Since the large numbers of photodiodes are required on the target, the scanning technique is employed to minimize the numbers of electronic components used in the input-output interface with the microcontroller system. Further, the application software running on a PC is developed as the man machine interface for monitoring and recording the shooting positions and scores.

The organization of the paper is as follows. Section 2 describes the proposed system. Section 3 presents the experimental results and discussions. Conclusion is covered in section 4.

II. Proposed System

The configuration of proposed system is shown in Fig. 1. It consists of a laser pointer attached on the gun, a shooting target, and a personal computer. The target is composed of the photodiode sensors form ten concentric circular pattern. This circular pattern is similar to the conventional shooting target,

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where the outermost circle has the lowest score, i.e. 1, and the innermost circle has the highest score, i.e. 10. When a laser beam hits the photodiode sensor, the microcontroller-based system in the shooting target finds the position of the detected laser beam, and calculates the score, which is displayed on the scoring display. The position of detected laser beam is also sent to the computer for further process, such as monitoring and recording, and for generating the sound effect of the gun shooting.

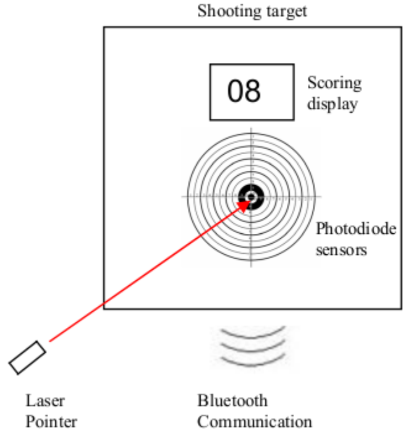

Fig. 1 Configuration of the proposed system.

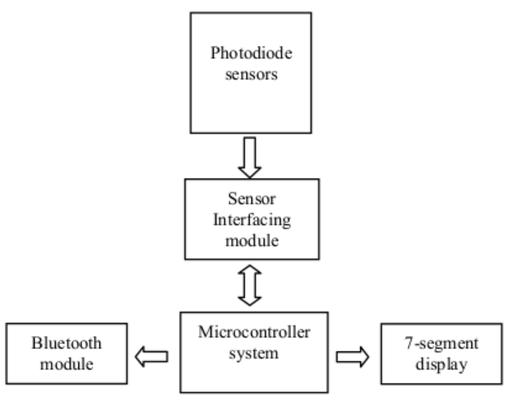

Fig. 2 Block diagram of the shooting target.

A. Shooting Target

The main components of the shooting target are: a) Photodiode sensors; b) Sensor interfacing module; c) Microcontroller system; d) 7-segment display; and e) Bluetooth module as shown in Fig. 2. The most critical issue here is the determining of the diameter of the circular pattern, yields in the numbers of the photodiodes required. In this experiment, we consider the diameter of the outermost circular pattern is 10cm as the reliable one. The dimension of the target box is 40cm x 40cm. The nominal shooting distance is 10m.

The circular patterns of the target requires the total of 360 photodiodes, consists of 70, 62, 56, 48, 38, 30, 22 18, 11, 5 photodiodes on first, second, third, fourth, fifth, sixth, seventh, eight, ninth, tenth circles respectively, where the first circle is the outermost one. By this arrangement and after several efforts in drawing the PCB (Printed Circuit Board) for implementation, it is impossible to use two layers PCB, it needs the multi layers (more than two layers) PCB. Since our aim is to develop the low cost system, we should use two layers PCB by paralleling every two photodiodes on every circle, except the innermost one. It reduces almost half of the total photodiodes. Thus the numbers of sensors should be processed are 183 only. The arrangement of the photodiode sensors is shown in Fig. 3.

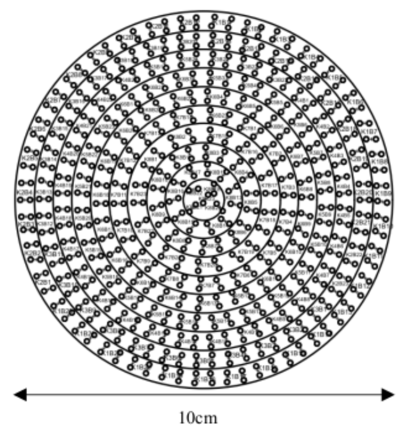

Fig. 3 Photodiode sensors.

The common photodiode circuit is shown in Fig. 4, where an op-amp is used as the comparator. In this circuit, photodiode is operated in reversed bias. When light falls on the photodiode, the current flows into photodiode, thus drops the voltage across it. The reference voltage on the inverting input of the comparator is determined by the values of R_2 and R_3. Here, the reference voltage is determined so that when laser beam falls on the photodiode, the comparator's output is in the Low state.

The simple method to access 183 photodiode sensors is by connecting all anode pins to the ground and connecting each cathode pin to the comparator. However, it requires 183 comparators circuits, and 183 input ports should be provided by the microcontroller system. To reduce the numbers of comparator circuits and input ports, we employ the scanning strategy by arranging the photodiode sensors into arrays of 23 rows and 8 columns as shown in Fig. 5. The rows are connected to the comparator circuits, while the columns are connected to output driver of the microcontroller which is used for scanning the sensor arrays. Using this strategy, only 23 comparator circuits and input ports are needed, and 8 additional output ports are needed. Thus, the numbers of components are reduced significantly.

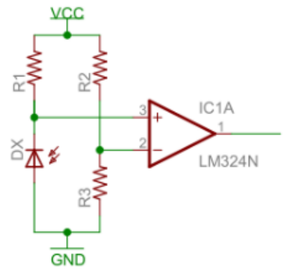

Fig. 4 Photodiode circuit with a comparator.

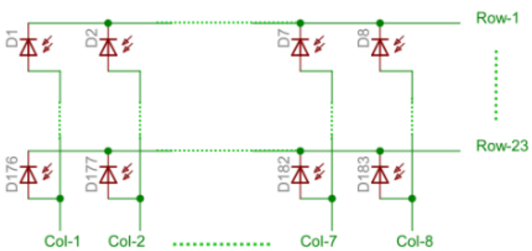

Fig. 5 Photodiode sensor arrays.

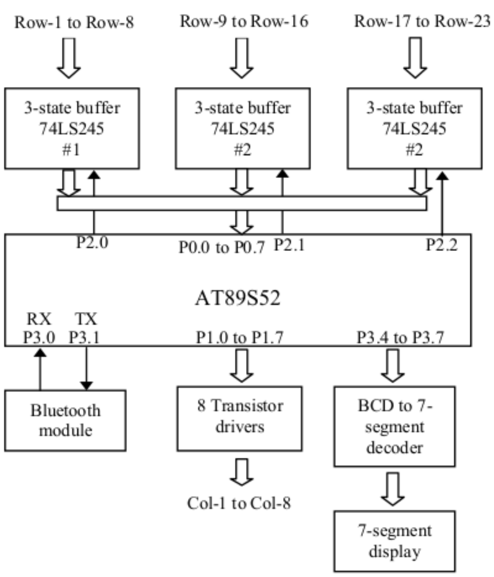

Fig. 6 Microcontroller's ports allocation.

A low cost microcontroller AT89S52 is employed in our system. Fig. 6 shows the port allocation to access all peripherals used in the system. In the figure, the labels of Row-1 to Row-23, Col-1 to Col-8 are the ones in Fig. 5.Three 3-state buffer IC's are used to read all 23 columns, where each buffer is selected by P2.0, P2.1, and P2.2 respectively. Eight transistor drivers are used to switch the Col-1 to Col-8 either to the ground or VCC. When P1.x is high, the transistor is ON and the column line will be connected to the ground. When P1.x is LOW the transistor is OFF and the column line will be connected to VCC. Fig.7 shows the flowchart of overall process done.

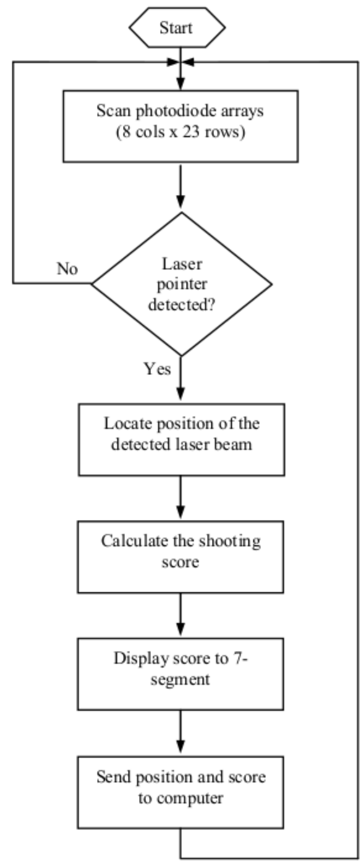

Fig. 7 Flowchart of the shooting target operation.

B. Application Software

The application software is designed to support the monitoring process, recording, and reporting. In the monitoring process, the computer receives the data contains the position of laser spot on the target from the shooting target via a serial communication using a Bluetooth. The circular pattern target and the position of the shooting laser beam are drawn on the screen. While in the shooting target, only the score is displayed on the 7-segment display, the application software displays both the score and position of the laser beam. In addition, the application will generate the shooting sound once the laser hits the target. In the system, one computer is able to monitor up to six shooting targets simultaneously.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

The proposed system is implemented in real hardware as shown in Fig. 8. The shooting simulator box is made from a plastic material. To increase the sensitivity of the laser pointer detection, a clear lens is put in front of the photodiode sensors. The total cost of this shooting target is about US$250.

Fig. 8 The shooting target.

To verify the reliability of the proposed system, we do some experiments as described in the followings. By arranging the photodiode sensors as explained in Section 2, we found that the distance between the successive photodiodes along the perimeter of the circular pattern is 1mm, while the distance of the successive photodiodes along the radial direction is 2mm. In the experiment, we use two types of laser pointers: the regular laser pointer for presentation and the Sharp Ace Laser Point which is usually used the airgun. In the first experiment, the shooter shots the target from the distance of 10m and the score displayed on the target is observed. From the experiments, it is obtained that the shooting target responses or detects the laser point for all shooting trials when the laser beam falls on the circular target area. Both types of the laser pointers have the same responses. It means that the photodiode sensors always sense the laser beam that falls on the target area. In the other word, there are no blank spots found on the target area. From the observations, the results are affected by the clean lens which is installed in front of the photodiode sensors. When there is no lens installed, several shooting trials are mis-detected. The reason is that the lens diverges the laser beam.

In the second experiment, the illumination conditions around the shooting target are changed. The results are given in Table 1. In the table, "Success" means that the shooting target could detect the laser pointer properly, while "Fail" means that the shooting target fails to detect the laser pointer. In "Fail" condition, the shooting target displays the score of 1 permanently, i.e. this score does not change even the laser pointer hits the target. It means that the shooting target only detects the surrounding light, not the laser pointer.

TABLE I
RESULTS OF THE ILLUMINATION CHANGES

No	Illuminance (Lux)	Fail/Success	Remark
1	7	Success	Shooting target is put in the room without glasses windows, without lighting
2	30	Success	Shooting target is put in the room without glasses windows, with lighting comes from 80 Watt fluorescent lamp
3	350	Success	Shooting target is put in the room with glasses windows, lighting comes from the sunlight
4	2000	Success	
5	3000	Success	
6	4000	Success	
7	5000	Success	
8	6000	Fail	
9	7000	Fail	

The application software is developed using Delphi language programming running on a PC Windows. The shooting monitoring screen is shown in Fig. 9. There are 6 shooting targets available in the screen. Each target is used by one shooter, and 6 shooters could practice simultaneously. The shooting results are indicated on the target screen with the different sizes and colours for distinguishing between the shooting trials as shown in the shooting target number 1 (top-left target) in Fig. 9. The number on the top-left of each target indicates the current score, while the number on the top-right of each target indicates the total/cumulative score.

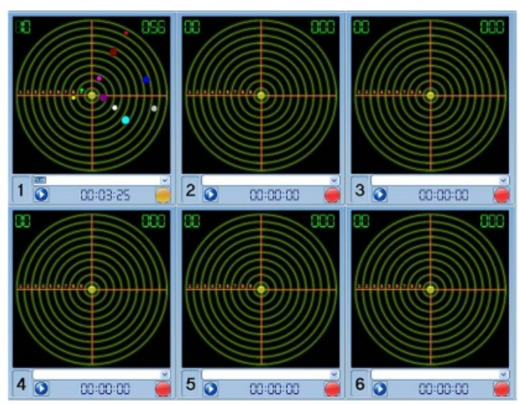

Fig. 9 Shooting monitoring screen.

The shooting report of the individual shooter is shown in Fig. 10. In each shooting turn, a shooter should shoot ten times. The application will record the ten shooting trials consist of the shooting scores which are tabulated in the table and the shooting positions which are drawn in the figure as shown in Fig. 10. In addition to this report, the report of the cumulative turns is also generated as shown in Fig. 11. Both reports are very useful for analysing the shooting performance of the shooter.

IV. Conclusions

The low-cost shooting simulator using laser pointer is developed. The photodiode sensor arrays are arranged to form the circular pattern of the target. Since 183 photodiodes are required, to minimize the numbers of interfacing components, the scanning technique is adopted, i.e. by scanning the rows and columns of the sensor arrays. The proposed system is implemented in real hardware and the additional application software is developed for monitoring and reporting purposes. The developed shooting simulator is tested indoor under the different lighting conditions, and shows the good performance.

In future, the system will be improved to work in outdoor condition. Further, the different shooting scenarios will be considered.

SKOR TEMBAKAN										
Tembakan	1	2	3	4	5	6	7	8	9	10
Skor	4	4	4	4	4	3	4	4	4	4

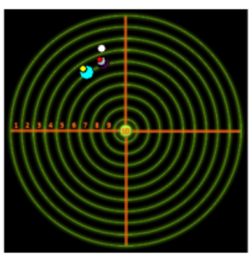

Fig. 10 Shooting report of the individual shooter.

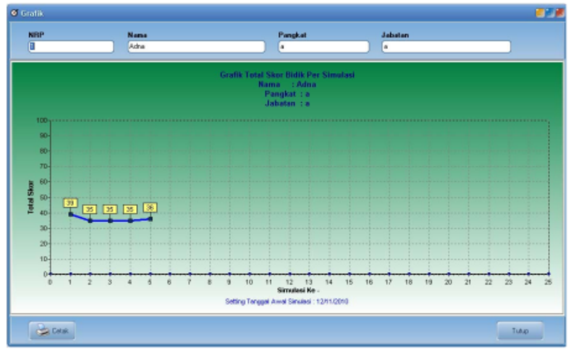

Fig. 11 Shooting report for the cumulative turns.

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