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Computer controlled Intrusion-detector and automatic firing-unit for border security

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***Abstract*—This paper describes a novel computer-controlled intrusion-detector and automatic firing unit, which may be used for the surveillance of borders, either of a country, or of areas requiring high security, especially in regions of extreme climatic conditions, where it is difficult to deploy personnel. This system not only detects intrusion but also provides a video-coverage of the suspicious area, for remote vigilance, via a satellite based communication system. It is also provided with automatic firing mechanisms which can be used to automatically locate and fire at the target. Thus, several kilometres of the borders, which would have otherwise required several hundred personnel, can be effortlessly monitored with this system, with only a few personnel. Since, the actual firing occurs only after an authoritative personnel has doubly confirmed the presence of an intruder, chances of firing at innocent people are completely ruled out. As thermal cameras are used for imaging, this system is immune to changes in ambient conditions, and therefore, is equally suited for operation during the night. This paper also throws light on the prototype of this system, which has been successfully developed.**

***Keywords*-Automatic firing unit; Intrusion detection; MATLAB; ATmega; Border security;**

I. Introduction

Reckoning the increasing security threats, it becomes very necessary to cautiously defend the borders of a country, or of any other areas demanding extreme security. However, owing to the vastness and the extreme climatic conditions which may be prevalent in these regions, it becomes practically impossible to deploy personnel throughout the borders. Hence, the need for an automated device is felt, which can render the efficient guarding of the frontiers, without any compromise on safety. This paper attempts to throw light on the design of a "Computer Controlled Intrusion Detector and Automatic Firing Unit for Border Security" and its features. This system, equipped with Thermal cameras and a Digital Signal Processing unit, can not only detect intrusion attempts, but also provide a video coverage of the suspicious area, for remote vigilance. Moreover, it is equipped with mechanisms for automatically firing at the target. This paper also discusses its prototype, which has been successfully developed, not with all the above-said features though, due to practical difficulties.

The paper is organised as follows: §II discusses the system configuration and §III describes the prototype developed in the laboratory. The algorithm used in the programs is concisely explained in §IV and the details specific to the Automatic Firing Unit (AFU) are mentioned in §V. A sample run of the program has been illustrated in §VI and the possible enhancements have been listed in §VII.

II. System Configuration

A block diagram of this system is depicted in Figure 1. This system uses Thermal cameras (TC) for imaging, as they can be used regardless of the amount of ambient light, rendering its usage in the night as well. These cameras are lined up along the borders, at a certain distance apart from each other, depending on the range of the cameras. These cameras which continuously scan the corresponding areas of the border, are in turn connected to a Digital Signal Processing (DSP) [1] unit, which accomplishes the task of intrusion detection by continuously comparing the images obtained, with a reference image and also with the images captured previously. Any signs of change in the succesive images indicates dubious movements in that area, which would result from intrusion. This is immediately reported, by means of a wireless communication system comprising a satellite, to a centralised control room, which may be located far away from the borders, in a convenient location. The authority at the control room is then facilitated a Real-Time video-coverage of the area under consideration, in order to provide scope for human-judging. Upon ensuring that the cause of alarm is indeed an intruder, a 'fire' command is sent to the Automatic Firing Unit (AFU), which, based on the target locations determined by the DSP, automatically fires at the target. The AFU is built out of a gun-turret equipped with stepper/servo-motors to facilitate accurate three-dimensional motion. Since, the actual firing takes place only at the discretion of the concerned authority, and not by

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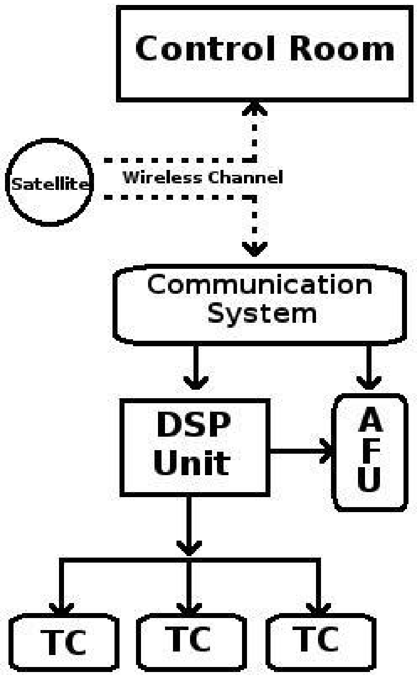

Figure 1. The Block Diagram

this device itself, possibilities of stake to innocent lives, due to false alarm, are ruled out. Thus, several kilometres of the borders, which would have otherwise required several hundred personnel, can be effortlessly monitored with this system, with only a few personnel.

III. The Prototype

Figure 2 depicts a photograph of the prototype of this system developed in the laboratory. For the purpose of demonstration, a 350K pixel web-camera has been used to mimic the thermal camera. However, as the web-camera is prone to variations in ambient light, the overall performance of the system is abated. Furthermore, the web-camera can not be used for intrusion detection in the absence of light, making it totally unfit for this purpose. Nevertheless, the performance of this system was satisfactory under the conditions prevalent in the laboratory. The gun has been simulated using a toy-LASER and the AFU is built using two Stepper-motors rated at 12V DC, with step angles 1.8° each. One stepper is used for rotation about the horizontal axis and the other for rotation about the vertical axis. The camera has to be mounted such that its optical centre coincides with the centre of the LASER. As it is impossible to achieve it, care is taken to see that the camera-centre lies as close to the centre of the LASER as possible. MATLAB 7 [2] running on a Personal Computer (PC) serves the purpose of the DSP. A set of codes have been written to carry out the task of acquiring the images and processing them to detect

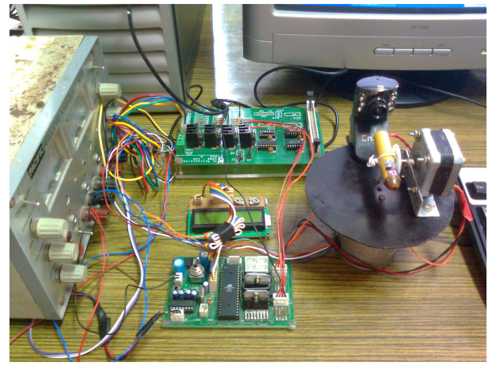

Figure 2. An image of the developed prototype.

intrusion.

The steppers are controlled using an ATmega32 [3] microcontroller, aided by two L298N [4] motor-drivers and other peripheral components. The steppers are hooked to an 8-bit parallel port of the ATmega32 and a Liquid Crystal Display (LCD) is used for debugging. The communication system is emulated on the ATmega32 itself, and it is connected to the PC through the serial port (RS-232 protocol). The same PC is used for the video-coverage. ATmega32 is clocked at 12Mhz using an external crystal. A MAX-232 [5] IC has been used to translate the RS-232 levels of the serial port to CMOS levels. The microcontroller is programmed with the aid of the Usbtiny [6] programmer incorporating an ATtiny2313 [7] microcontroller, via the USB port. Avrdude [8], an open-source utility has been used for flashing the programs into the microcontroller.

IV. The Algorithm

This unit makes use of a very simple algorithm coded in MATLAB to process the images and monitor changes. The camera is interfaced to the computer via the USB port, using the image acquisition toolbox. The frame grabbed by the camera is acquired into the MATLAB workspace, and is stored in a three dimensional matrix, each dimension of the matrix corresponding to the colours Red, Green, Blue, and having values ranging from 0-255. For ease of computation, the image is first converted into a two-dimensional grayscale image. A gray scale image has values from 0-255. The image is then decomposed using a simple procedure, taking the aid of another standard function 'bwlabel' and the number of objects in it determined. This is done so as to compare the number of objects in the successive images. Any mismatch in the n^{th} and the $(n+1)^{th}$ image (n is a positive integer) would infer a change in the image, resulting from intrusion. As a further check, the image is converted into a digital image, i.e. an image consisting of only ones and zeroes, by choosing a threshold value which depends on the ambient conditions and the characteristics of the camera. This threshold value can be calibrated to filter

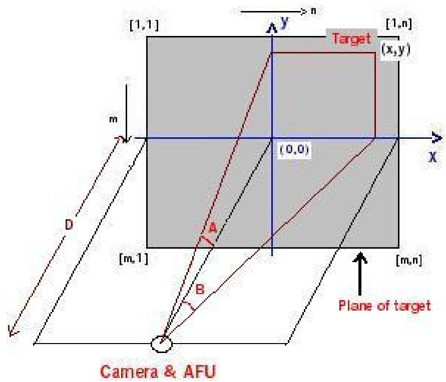

Figure 3. Co-ordinate transformations

out small changes occurring due to variations in light. The successive digital images are now compared with each other and their difference is found out. The resulting matrix would correspond to the difference in the two images. The median of the changed pixels is calculated, which is the centre of the change. This is precisely the point where the AFU has to fire. However, if the intrusion is occurring gradually, the subsequent images may not differ significantly. Hence, to take care of this case, every n^{th} image is checked with the $(n+k)^{th}$ image, where k is an integer greater than 1. If there are two different centres of change, then medians are found out separately for each of the changes. For indicative reasons, a red boundary is drawn in the immediate vicinity of the change.

V. The AFU

The AFU comprises of a circular disc mounted on the shaft of a stepper-motor (SM-1) which facilitates rotation in the horizontal direction. Another stepper-motor (SM-2) mounted on the disc enables motion in the vertical direction. The LASER is mounted with its centre pivoted on the shaft of SM-2. The camera is mounted on the disc, and is free to rotate in the horizontal plane. The camera-centre and the LASER lie in the same vertical plane for all orientations of the LASER. The stepper motors are driven by an 8-bit port of ATmega32, via two L298N motor-drivers, as the microcontroller can not supply/sink currents over 20ma. The location of the target communicated to the microcontroller, is of the form (x,y), where x and y are the ordinates of a co-ordinate system with the centre of the image as the origin. If the image grabbed by the camera is such that the size of the associated matrix is 'm x n', then the co-ordinate system with respect to the image is depicted in Figure 3. Here [m/2,n/2] forms the origin of the transformed co-ordinate system.

Strictly speaking, the distance of the target from the camera is required for accurate firing. Determination of distance is impossible with the usage of a single camera. In our case, as a LASER is used, it does not matter what the radial location of the target is, as the beam travels along a straight path. For simplifying our calculations, we need to define two angles namely, 'A_c' and 'B_c' which are numerically equal to half the angles swept by the camera in the vertical and the horizontal directions respectively. To calculate the same, keep a rectangle of length 'L' and breadth 'B' at a suitable distance 'K' from the camera such that the whole of the image grabbed, is occupied by the entire rectangle. Then,

$$A_c = \arctan \frac{B/2}{K} \tag{1}$$

$$B_c = \arctan \frac{L/2}{K} \tag{2}$$

These values are constant for a given camera.

For instance, suppose that the target is located at the point (x,y) as shown in Figure 3, at a distance 'D' from the camera (and the LASER), 'A' (vertical angle) and 'B' (horizontal angle) are the angles by which the vertical and the horizontal steppers need to rotate, to fire at the target. The value of (x,y) will be known as a result of the execution of the MATLAB based programs. A and B can be found out as follows:

$$\tan A_c = \frac{m/2}{D} \tag{3}$$

$$\therefore D = \frac{m/2}{\tan A_c} \tag{4}$$

$$\tan B_c = \frac{n/2}{D} \tag{5}$$

$$\therefore D = \frac{n/2}{\tan B_c} \tag{6}$$

$$A = \arctan \frac{y}{D} \tag{7}$$

From (4) and (7),

$$A = \arctan \frac{y}{\frac{m/2}{\tan A_c}} \tag{8}$$

$$B = \arctan \frac{x}{D} \tag{9}$$

From (6) and (9),

$$B = \arctan \frac{x}{\frac{n/2}{\tan B_c}} \tag{10}$$

Having obtained the values of A and B, the number of steps can be found out by dividing them by the step angle, which happens to be $1.8°$.

Figure 4. 1^{st} frame: Without intruder

Figure 5. 2^{nd} frame: With intruder

Figure 6. Program-Output: Indicating the change

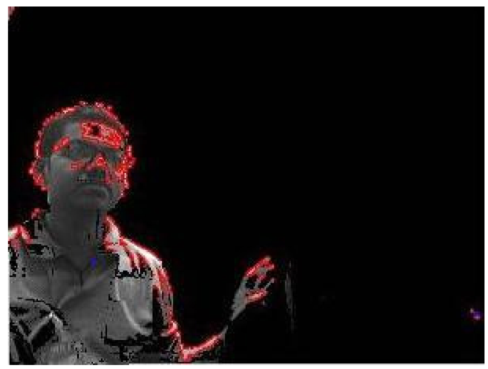

Figure 7. Program-Output: With red-outline

VI. Results

The program was successfully tested on various instances of intrusions, and for various ambient conditions, in the laboratory. In this section, one of the cases is illustrated.

An Intrusion was simulated by a person suddenly appearing in front of the camera, while the program was in action. Figure 4 illustrates the frame grabbed by the camera, in normal condition. Figure 5 depicts the frame grabbed in the presence of the intruder. The program successfully identified the change and displayed it as depicted in Figure 6. The same figure with a red-boundary around the change, as shown in Figure 7, is also displayed by the program for clarity. A careful inspection of Figure 7 also indicates the presence of a blue dot, which is the point where the AFU has to fire at.

VII. Scope for Enhancement

For brevity, a simple algorithm has been used in the prototype, for processing the images. The utility of this device can be further augmented by improvising the image-processing-algorithms. The prototype makes use of a PC, equipped with MATLAB to carry out the image processing tasks. Despite the rich features of MATLAB, the code generated by MATLAB is not efficient. Therefore, using a dedicated DSP Processor with real time code for this purpose, is more efficient and reliable. In the prototype, as the LASER beam is not affected by gravity, a recti-linear trajectory is assumed. However, in reality, the motion of a missile or a shell shall be complicated by the effects of gravity, wind turbulence etc. Furthermore, the AFU assumes that the centre of the camera and the LASER coincide, which is practically ludicrous. Hence the AFU is not accurate. This drawback can nevertheless be taken care of by modifying the equations suitably. Suitable position encoders can be incorporated to obtain feedback from the AFU, thereby enhancing its accuracy. A RADAR can be integrated into this device, by means of which the system can be made more versatile. It not only increases the range, but also provides scope for determining size, speed and direction of motion of the intruder and is absolutely fail-proof.

VIII. Conclusions

A working model of the proposed system has been devised. The performance of the system is found to be satisfactory in the laboratory. Its response is found to be dependent on ambient light, and therefore, it requires calibration for a given environment. It is clear that, this system, if deployed in the borders, can simplify the task of safeguarding them and also reduce the overall personnel-count.

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REFERENCES

[1] Alan V. Oppenheim and Ronald Schafer, *Digital Signal Processing*, 2nd ed., Prentice Hall.

[2] RudraPratap, *Getting started with Matlab 7*, Oxford University Press, 2005.

[3] Atmel Corporation, "8-bit AVR Microcontroller with 32K Bytes In-System Programmable Flash," ATmega32 datasheet, Oct. 2002 [Revised Apr. 2006]

[4] STMicroelectronics , "Dual Full-Bridge Driver," L298 datasheet, Jan. 2002.

[5] Maxim Integrated Products , "+5V-Powered, Multichannel RS-232 Drivers/Receivers," MAX232 datasheet, Jan. 2006.

[6] "USBtinyISP-AVR programmer & SPI interface," Oct, 2009. [Online]. Available: www.ladyada.net/make/usbtinyisp/ [Accessed Feb. 7, 2009].

[7] Atmel Corporation, "8-bit Microcontroller with 2K Bytes In-System Programmable Flash," ATtiny2313 datasheet, Sep. 2003 [Revised Sep. 2009]

[8] Joerg Wunsch, "AVRDUDE," Jan. 2010 [Online]. Available: http://www.nongnu.org/avrdude/user-manual/avrdude_1.html#Introduction [Accessed Feb. 7, 2009].