**“System for identifying the origin of the shot for the laser shooting range at the Brigada de Fuerzas Especiales N° 9 Patria”**

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# System for identifying the origin of the shot for the laser shooting range at the Brigada de Fuerzas Especiales N° 9 Patria

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***Abstract* — The shooting origin identification system is carried out with the aim of designing a tool that allows evaluating the conduct of military personnel from the Brigada de Fuerzas Especiales N° 9 Patria in the face of the progressive use of force. To evaluate this parameter, graphics have been generated that indicate the order of the shots. Another parameter that the project evaluates is the shooting origin, where data synchronization and image segmentation were used.**

**The system is made up of the following stages; the first where there is a transmitter that looks like the weapon, composed of a laser diode and push buttons. The second is the registration stage, it is composed of a night vision camera accompanied by a computer, where the processing of the video of the military training is carried out. The third stage consists of the channel, which is the means of communication between the laser weapon, the recording camera and the administration computer, for the project wireless communication was used through a Wi-Fi microcontroller. Finally, the last stage is the sending of data to the Rumiñahui Supercomputer.**

***Index Terms—Synchronism, Segmentation, Laser, Processing.***

## I. INTRODUCCTION

Currently, the territory of Ecuador is facing a surge of threats, including delinquency, organized crime, irregular armed groups, and drug trafficking, among others. At the end of 2021, a mortality rate of 13.7 deaths per 100,000 inhabitants was reported. However, by the end of 2022, this figure had risen to 25 deaths per 100,000 inhabitants, representing a growth of 82.5 \% [1]. In order to counteract these threats, it is crucial that the Armed Forces act swiftly and demonstrate a high level of professionalism and effectiveness when responding to potential threats or armed conflicts[13].

Therefore, there is a pressing need to enhance the skills of the institution's personnel to ensure they are adequately prepared to carry out missions against criminal groups[14].

necessary to progressively use force, while always seeking to minimize damages and harm. The use of force is permitted in the following cases: for self-defense, when there is a threat of death, to prevent the escape of individuals who pose a danger to society, and only if less extreme measures are insufficient to achieve the aforementioned objectives[7].

The Armed Forces provide training at the shooting range to improve weapon handling, refine shooting techniques, and develop psychological factors. However, the limited budget significantly reduces practice time and makes it difficult to properly develop shooting techniques and strategies.

A virtual shooting range offers significant benefits, such as reducing safety risks for military personnel by eliminating the use of real weapons, decreasing maintenance costs and ammunition expenses, increasing practice hours to improve their ability to react to hostile attacks, and enabling them to develop the same skills as in a real shooting range [10].

Several projects related to automating shooting ranges exist in the country. For example, the "Automation of serialization processes, scoring and shooting registration of small arms in a shooting range", project processes data on a target by applying a Gaussian filter and digital filters to attenuate disturbances or variations in light intensity around a pixel. The project provides results such as participant identification, score, position of the shot, and efficiency [6]. The project "Design and construction of a military training system focused on shooting ranges through virtual reality to improve the skill of the personnel of the Armed Forces of Ecuador" uses augmented reality and a gun equipped with sensors and a vibratory motor to simulate the shooting sensation. A virtual reality software was used to create the virtual environment, adapting it to the technical specifications required for the shooting range available in the Armed Forces. The records of the participants are kept to validate the effectiveness of the system. [2].The "Augmented Reality Precision Shooting Training System for Specialized Sports Club 'Polygono'" project uses a mixed reality system designed to improve accuracy when shooting at close ranges by providing a wider field of view. The system is implemented through a game

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engine that simulates the silhouette of the participant. The advantage of this system is that it streamlines the training process, while using a real firearm to maintain a realistic recoil reaction [11]. The project "Multiple Object Detection using HSV" uses a camera and a microcomputer board to detect and differentiate multiple objects in real-time. An algorithm processes the images captured in RGB format and converts them to HSV to detect objects of different colors. The resulting image is filtered using a binary mask to eliminate data outside the predefined range and a process of erosion and dilation is applied to remove noise. The contours of the remaining shapes are detected, and the set of contours containing the largest area is used to determine the size and orientation of a bounding rectangle that is then applied to the original image in RGB format. [4]. The project "Ship Detection from Coastal Surveillance Videos via a Canny-Gaussian Morphology Framework" proposes an algorithm to detect ships in coastal surveillance images. It uses the Canny detector to find possible edges of the ship in each frame, followed by an adaptive Gaussian filter to accurately discard noisy edges. Experimental results show that the proposed ship detector has good performance compared to other algorithms. This approach could provide real-time traffic information to maritime regulators for the development of intelligent maritime transportation.[5].The project "Optical system for the evaluation of virtual firearms training simulators based on artificial vision" develops a system that combines virtual reality and artificial vision to create shooting technique training spaces. Virtualized images of typical targets are used, and the location of the infrared laser beam is evaluated to improve shooter accuracy. The system processes the image using color recognition, edge detection, center of mass, and point detection techniques to discriminate the laser's contour and center, assigning a numerical value to the shot fired. [12].

In the aforementioned projects, none make reference to registering the progressive use of force in the results, nor the synchronization of data as a method of detecting the origin of the shot.

Reason why the following work presents a system for identifying the origin of the shot.

The process begins with three laser light waves emitting pulse trains to the computer through a WiFi microcontroller while impacting the surface of the silhouette that simulates the person to be neutralized.

The impact on the silhouette is captured through a night vision camera that generates a video, which is sent to the computer where an algorithm compares the generated pulses with the silhouette's luminosity difference through data synchronization to obtain the origin of the shot. Subsequently, the silhouette's parts are sectioned for the identification of the impact location. Finally, the identification and origin of the shot results are visualized on the Rumiñahui supercomputer.

By implementing the system, control over the progressive use of force is obtained, as recording the shots allows identifying the participant who fired each shot and their progress. Additionally, the implemented algorithm enables counting the shots fired and identifying the failures of military personnel,helping to reduce the costs associated with the loss of ammunition during field exercises. [3][8].

## II. METHODOLOGY

The methodology describes the proposed architecture, which is divided into hardware and software components. These components will be illustrated through a block diagram for hardware and a flowchart for software.

### *A. Architecture Solution*

The progressive use of force involves immobilizing a person who poses a threat to the lives of others, thereby minimizing harm and damage. The first step is to immobilize the person's upper limbs if they are carrying a firearm, followed by targeting their lower limbs, and finally aiming at their body or vital organs.

The hardware used in the experiment consisted of a night vision camera as the receiver, which was aimed at the silhouette where various tests were performed. The resulting video was saved to a computer for processing with the algorithm. The emitter included several differently colored lasers and a microcontroller, specifically the ESP-8266, which recorded data from the lasers.

After obtaining the video and laser data, they will be sent to the Rumiñahui Supercomputer for processing the video and synchronizing the pulses. This will result in determining the origin of the shot and the impact location on the silhouette, as shown in Fig. 1.

The implemented algorithm is described below. First, there are two inputs to consider: the pulse trains generated by the red, green, and purple lasers, which are transmitted to the computer via a WiFi module (ESP8266). Second is the training video captured by the night vision camera.

Previously, the video is processed by the implemented algorithm and decomposed into frames, where 30 frames per second are generated. Once obtained, all the images created must be rotated and adjusted.

For the detection of each impact, the HSV filter is used, which detects color through luminosity, saturation and color. This filter is important because when the laser hits the silhouette, it generates a dispersion of color, which causes a fake ID of 2 places at once. Another filter used is the Canny that allows detecting the edges of the color that is impacted on the silhouette. Finally, the Gaussian filter is used to smooth and remove noise from the image.

Each image is sectioned in a loop, for each part of the body, if it does not enter any loop it means that it is out of range.

The next step in the process is to compare the processed pulses with the laser pulses, which were obtained through the serial port with the ESP-8266 module, which are sent to

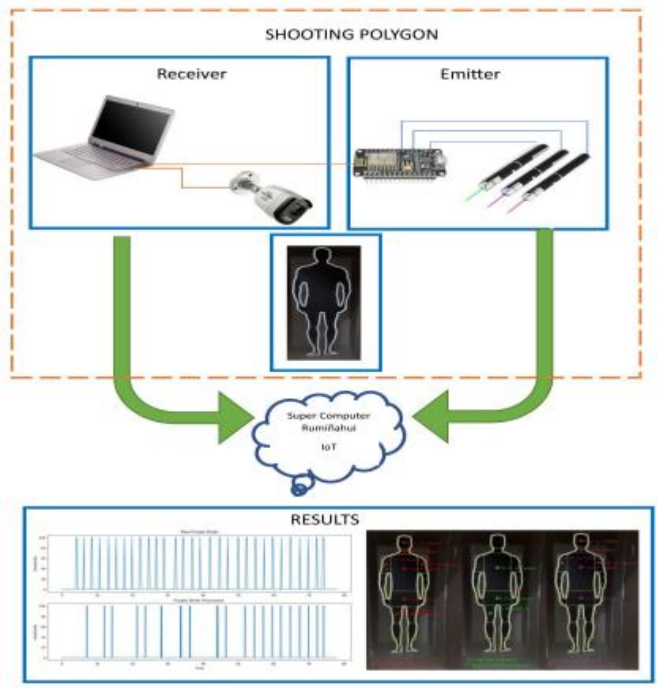



Fig. 1. Main architecture diagram.

Python. If the synchronization is correct, the algorithm detects the origin of the shot and the place of impact.

Finally, the data is sent to the "Rumiñahui Super Computer" of the Universidad de las Fuerzas Armadas-ESPE, where the video processing is carried out. The entire process can be viewed in the flowchart of Fig. 2.

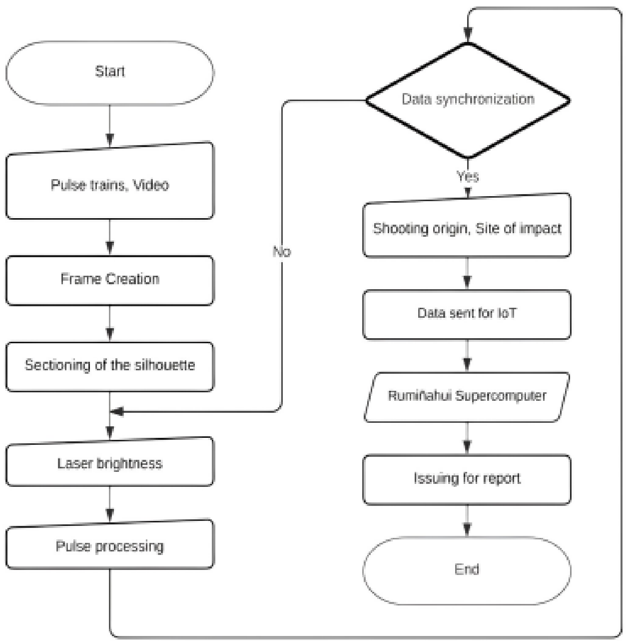



Fig. 2. Flowchart of the implemented algorithm.

The following results were obtained after performing several experiments and will be detailed in different sections, which are shown below.
For image processing there are different applications that can help to recognize patterns, brightness, image quality, etc.[9].

The silhouette has been divided into six different parts, each section covering subsections which are: Section 1 covers the following subsections: left shoulder, left arm, left wrist, and left hand. Section 2 covers the following subsections: right shoulder, right arm, right wrist, and right hand. Section 3 covers the following subsections: right thigh, right leg, and right foot. Section 4 covers the following subsections: left thigh, left leg, and left foot. Section 5 covers the following subsections: body and waist. Section 6 covers the following subsections: head and neck, as shown in Fig. 3.

The purpose of dividing the silhouette into sections and subsections is to identify which part of the body was impacted by the laser. Using the algorithm, the system searches for the pixel where the brightness has changed and stores the data for later comparison with the emitter's data.

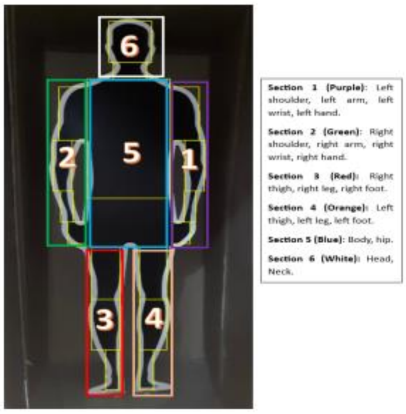



Fig. 3. Sections and subsections of the silhouette.

## B. *Processed Pulses*

To identify the origin, pulses from the receiver are generated, which are obtained with image processing. For the analysis, it was decided to verify the impacts of the red laser in section 6, where it can be seen that there are four shots in said section as shown in Fig. 4. For the next participant, the impacts in section 5 were analyzed, where it can be seen that most of the shots were on the body and waist, as shown in Fig. 5. Similarly, for the next participant, the impacts in section 6 were analyzed, where three impacts were identified as shown in Fig. 6.

# III. RESULTS

The following results were obtained after performing several experiments and will be detailed in different sections, which are shown below.

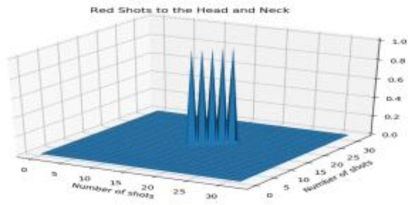



Fig. 4. Red impacted pulses on the head and neck.

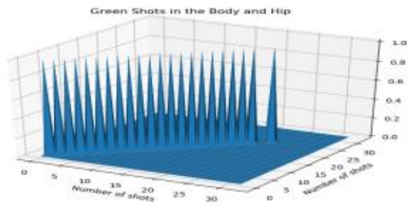



Fig. 5. Green impacted pulses on the body and hip.

## A. *Shot count at the virtualized laser shooting polygon.*

The implemented code allows the visualization of successes in the different sections and subsections mentioned above, as well as the number of successes in each of them, and a total count of successes and failures.

The visualization of impacts was carried out for the three participants: red, green and purple laser, where the impacts are shown in the silhouette as seen in Fig. 7, literals a, b and c, respectively.

## B. *Progressive use of force.*

The graphs analyzed below will start from the second shot as the first shot was for testing purposes for all three participants.

The Y-axis represents the aforementioned sections in Section A of the methodology, while the X-axis shows the number of shots.

To verify the progressive use of force by the first participant, we observed that they began shooting at section 5 of the silhouette, followed by section 4: left thigh, left leg, and left foot. By the 15th shot, they hit section 6, which belongs to vital body parts, as shown in Fig. 8.

The shot sequence of the second participant, represented by the green laser, consisting of most of the shots directed at section 5 of the silhouette, was also analysed, as shown in Fig. 9.

In the case of participant number three, whose graphic is in blue, the first shot was in section 1, the fourth shot was

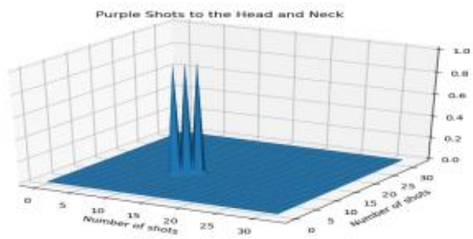
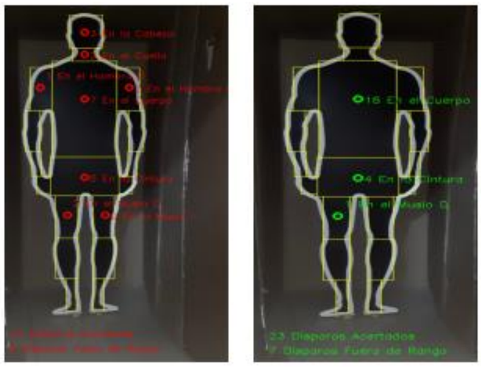
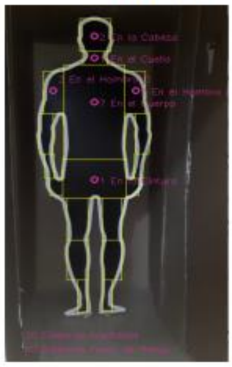



Fig. 6. Purple impacted pulses on the head and neck.



(a) Impacts from red laser shots. (b) [Impacts from green laser shots



(c) Impacts from purple laser shots.

Fig. 7. Visualization of impacts in the silhouette.

section 2, the seventh shot was in section 3, the ninth shot was in section 4 and the eleventh shot was in section 6, which is a vital part. It can be said that participant number three followed the progressive use of force procedure, as shown in Fig. 10, unlike participants one and two.

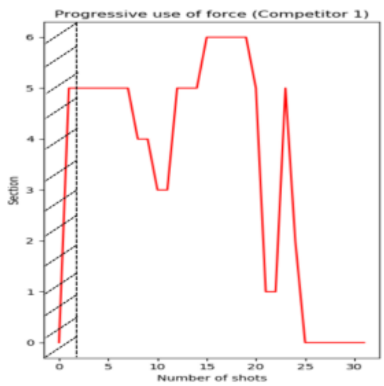



Fig. 8. Progressive use of force, participant 1.

A summary of the number of shots in each section of the silhouette is shown, both the actual and the one measured by

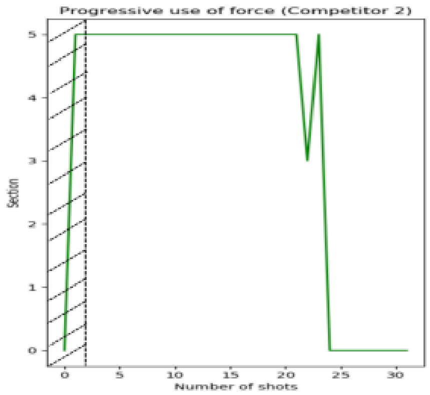



Fig. 9. Progressive use of force, participant 2.

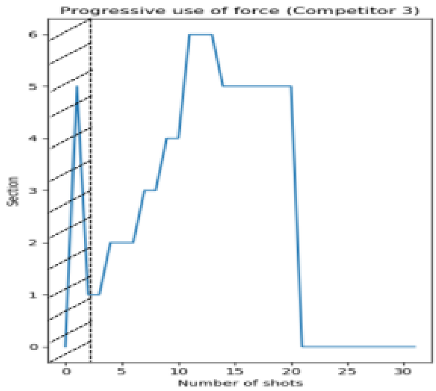



Fig. 10. Progressive use of force, participant 3.

the algorithm of each participant, as shown in Table 1.

TABLE I
TOTAL IMPACTS

| Sections | Red laser | | Green laser | | Purple laser | |
|---|---|---|---|---|---|---|
| | Real | Alg. | Real | Alg. | Real | Alg. |
| 1 | 2 | 2 | 0 | 0 | 2 | 2 |
| 2 | 1 | 1 | 0 | 0 | 2 | 2 |
| 3 | 2 | 2 | 1 | 1 | 3 | 3 |
| 4 | 2 | 2 | 0 | 0 | 2 | 2 |
| 5 | 14 | 13 | 21 | 22 | 9 | 8 |
| 6 | 4 | 4 | 0 | 0 | 3 | 3 |
| Failures | 5 | 6 | 8 | 7 | 9 | 10 |
| Total | 30 | 30 | 30 | 30 | 30 | 30 |

$$\%error = \frac{|Measured\ value - real\ value|}{real\ value} * 100 \quad (1)$$

Using the "(1)", the error percentage per section will be calculated, thus obtaining Table 2. With the results, the average error will be obtained to determine the efficiency of the algorithm.

$$\%average\ error = \frac{\sum partial\ error}{total\ numbers\ of\ errors} \quad (2)$$

TABLE II
PERCENTAGE ERRORS

| Sections | Red laser | Green Laser | Purple Laser |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 |
| 5 | 7.14 | 4.76 | 11.11 |
| 6 | 0 | 0 | 0 |
| Failures | 20 | 12.5 | 11.11 |

The average errors were obtained by "(2)", obtaining the results presented in Table 3.

TABLE III
AVERAGE PERCENTAGE ERRORS

| Red laser | Green Laser | Purple Laser | Average |
|---|---|---|---|
| 3.877 | 2.465 | 3.174 | 3.172 |

### C. Emitter pulses and Receiver pulses

The emitter pulses that were acquired at the beginning of the training were stored for comparison with the receiver pulses generated through changes in luminosity in the pixels of the video frames. A total of 30 emitter shots were generated, while only the successful receiver shots were generated, as the failed shots were outside the silhouette range. This was done for all three participants: red, green, and purple, as shown in Figs. 11, 12, and 13, respectively.

The laser-generated pulses are at the top, and the processed frames are at the bottom. As an observation, the pulses generated at the same time are enclosed in a red rectangle to visually verify the data synchronization, as shown in Fig. 11.

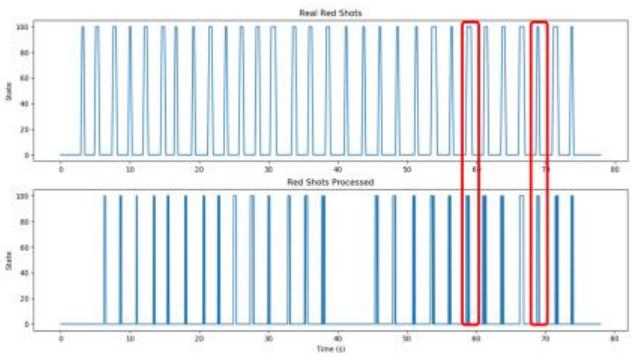



Fig. 11. Real pulses vs processed pulses (red).

## IV. CONCLUSIONS

The implementation of the system has allowed for modernization in the way that the shots taken by participants during training are recorded. Thanks to this system, there is an automatic record of hits and misses, as well as the location and total number of shots per participant. This allows for more precise monitoring of their performance, which results in better training in the progressive use of force.

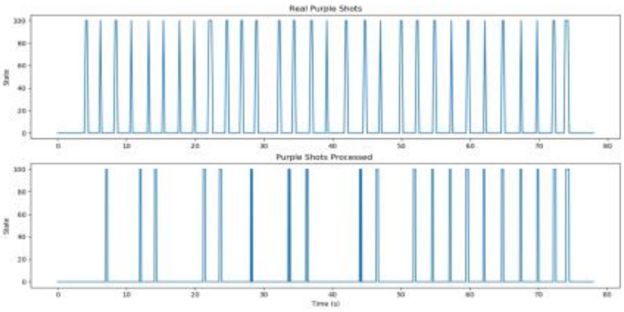



Fig. 12. Real pulses vs processed pulses (green).

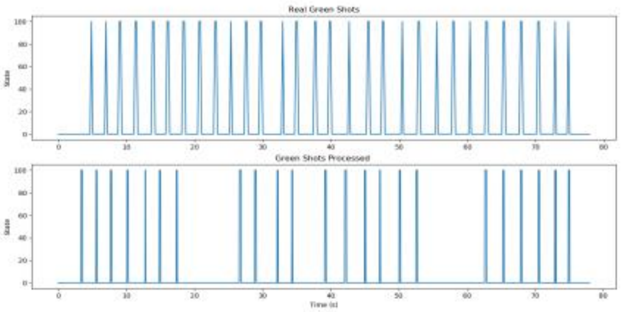



Fig. 13. Real pulses vs processed pulses (purple).

In addition, the system has proven to be cost-effective as it reduces the misuse of real ammunition, which is expensive for the institution responsible for training the participants, allowing for controlled and precise use of ammunition.

Although a medium error of 3.17% has been detected when comparing data obtained automatically with data obtained manually, this margin of error is considered acceptable and does not affect the system's efficiency. Determining the error is a way to guarantee the system's accuracy since the difference in results may be due to different factors such as lighting or viewing angle.

Regarding the color of the laser used, it has been determined that the violet laser has the best behavior in terms of silhouette absorption. Green and red colors have less absorption and more reflection, which can cause errors in shot recording as they reflect on more than one segment of the silhouette.

Likewise, it has been detected that when laser waves impact outside the silhouette, the data synchronization algorithm does not detect them because the laser pulses and processed waves are not related in time. This inconsistency in the data is recorded as failures in the final registration.

Finally, the algorithm is capable of involving more participants, as long as the laser pulses are synchronized with the pulses processed by the algorithm. That is, source detection can be performed simultaneously only if proper data synchronization is maintained.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