RealShooting: Expanding the experience of point-and-click target shooting games

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***Abstract*—Shooting games underwent several transformations throughout their long history. However, the use of light guns in shooting games has not experienced significant development in the last decade. This article proposes a laser capture solution to achieve a new interaction with regular point and click shooting games. For that, we developed an intermediate solution that can adapt gameplay with no need to modify the original games. We used four different games to evaluate the proposed solution: two titles explicitly developed to test the model, and two commercially published third-party games. We tried different weapons (toys, airsoft, 3D printed etc.), and sowed that the obtained results were very satisfactory. No loss of performance was observed in the games – all the tested games ran stably at 60 FPS. Moreover, the players did not notice any lag between the gun shot and the corresponding mouse click performed by the system.**

***Index Terms*—Shooting games; Light guns; Point and click shooting games.**

I. Introduction

Target-shooting games have a long history since they appeared in tents in the famous carnivals of the 1890s [1]. Over time, electromechanical devices replaced the stands in the tents, and eliminated the need for a human operator to restore the targets every round. Later, with the evolution of technology, it was possible to substitute the physical projectiles by short emissions of light beams. So, light guns appeared as simulacra of real weapons. The 1936 Ray-O-Lite [1] already used vacuum tubes as receivers. The evolution continued with more and more added sophistication of the shooting systems and capture sensors, to the point of allowing human/machine competition as in Jungle Charlie, from 1971 [1].

Later, the evolution of electronics allowed the replacement of electromechanical devices, and led to the use of virtual targets presented on screens. Thus, this type of entertainment, previously restricted to bars and similar establishments, became a household entertainment. In 1972, for example, the Magnavox Odyssey became the first domestic game console to have a light gun. That simulation revolutionized the entire market by having the receiver in the simulated weapon itself [1].

In the 1990s, adopting CCD sensors [2] made it possible to use video cameras with smaller dimensions and lower costs to capture the light beams fired by the simulacra. Thus, arcades began to have light gun shooter games. And with that, new specific genres of games have emerged, such as target shooters, which feature moving targets on static screens, and rail shooters, where the player moves through the stage in predefined paths. Later, with the increase in visual realism, some companies adapted those game technologies to simulators in order to train military and police forces [3]. Thus, it allowed safer training models with lower environmental costs due to the substitution of gun ammunition by virtual shots.

Despite the technological advances, the participation of shooting games in the market suffered a significant decrease mainly because of the launch of titles with questionable quality [4] and the consequent public's lack of interest. However, in recent years the arcade industry as a whole is undergoing renovation [4].

There are still some arcade titles, but games available for other platforms are unlikely to repeat the expected natural interaction. Thus, computers, videogame consoles, or mobile devices ended up replacing the use of simulacra by, respectively, mouse clicks, joystick movements, and touch screens. This is because, in general, replicating the technologies used in the most advanced games, which employ light guns or similar devices, demands high costs, incompatible with domestic environments.

In this article, we propose a low-cost solution that makes it possible to use weapon simulacra of different kinds (toys, airsoft, 3D printed guns etc.), or real weapons, in standard shooting games, with no need to adapt those games. The games are executed on common personal computers, and, originally, they do not use light guns or any similar devices. For this purpose, intermediate hardware and software elements are proposed, presenting new interaction possibilities to the players.

We divided this paper into five sections. In Section II, we present previous related works. In Section III, we present our solution and its relevant elements. We define the reference model and explain how each module interacts with each other. Also, we discuss how the software and the hardware interact. In Section IV, we present implementation issues. We show how to implement the reference model. We show software and hardware details, and how we perform tests with the proposed solution. In Section V, we make our final considerations, summarize our results, and present some suggestions for future works and the expected contributions of this article.

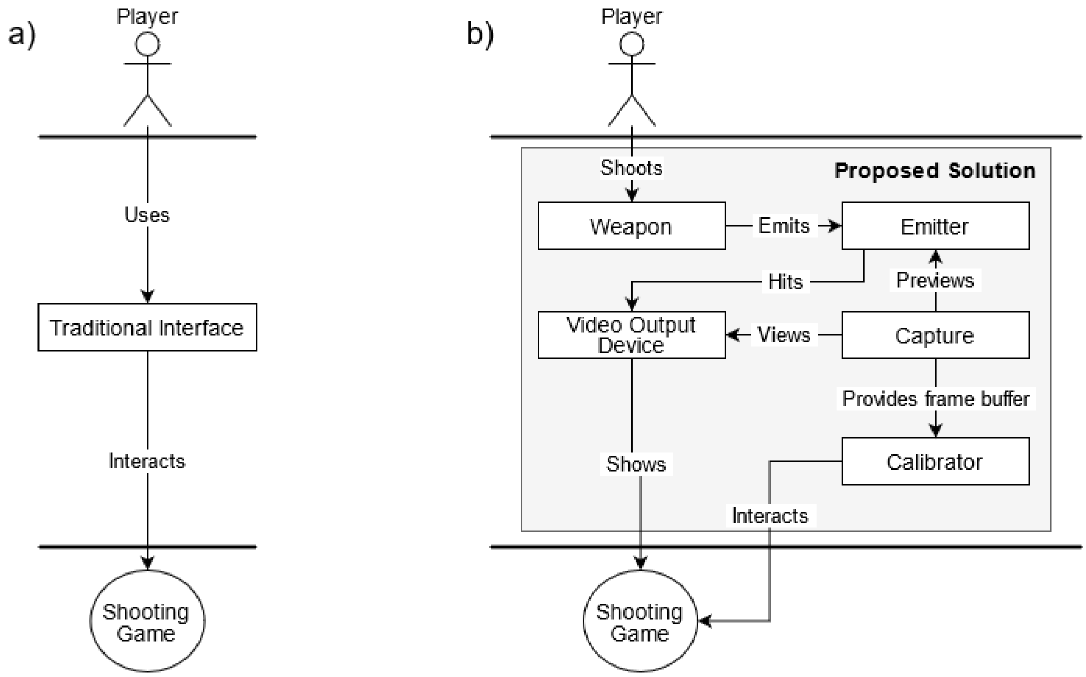

Fig. 1: Interaction modes (Traditional and Proposed Interface).

II. Related Work

A low-cost solution that makes it possible to use weapons in standard shooting games executed on common personal computers and using no light guns or similar devices needs intermediate hardware and software elements to propose new interaction possibilities to the players.

Although this idea is not found in the literature, some works explored somewhat similar ideas that make the proposed solution in this work possible.

Soetedjo et al. [5] and Soetedjo et al. [6] proposed systems that use laser pointers for low-cost target-focused shooting simulation. The first of their solutions uses a round target containing photodiode sensors, which identify where the laser hits. The second solution uses a camera sitting behind a screen to capture the screen position where the laser hits.

However, target-focused systems limit the system to shooting training and the number of targets that physically exist. Nevertheless, it is possible not only to extend those solutions so they become more general, but also to use them in games.

Zakaria et al. [7] established a pipeline for using spot laser detection. The solution follows the general technique of most laser spot detection algorithms: thresholding, background subtraction, and extraction of the region of interest [7]. Unfortunately, it has low robustness, especially in environments with constantly changing lighting.

Soetedjo et al. [8] proposed an optimized algorithm for laser detection adopting Raspberry Pi. However, their solution is limited to using a red laser. Pinheiro et al. [9] also proposed a low-cost shooting simulation system using laser shots, but this simulator is restricted to the training application they developed.

Considering a correlated area, Virtual Reality, Molina et al. [10], Torchelsen et al. [11] and Amir et al. [12] proposed solutions adapting 3D games to consider human aim, vision, and body movement. Also using VR, Wei et al. [13] and de Armas et al. [14] developed systems for shooting training. The first one added haptic simulation, and the second included an evaluation system. Nahavandi et al. [15] developed a solution for firefighter training, also adding haptic simulation.

In general, assessing those works, it is clear that the differential of our work is the use of simple devices and games without any adaptation.

III. Solution

This section of the work explains our proposed solution, describing its elements and their interrelationships.

A. *Overview*

The proposed solution specifies an architecture and its respective implementation/use pipeline to establish a new perspective for interacting with target shooting games.

This solution defines a set of intermediate entities that allow the player to interact in a new way with common shooting games without requiring any changes to be made to those games. Thus, instead of using a computer mouse, the player uses a simulacrum with a laser emitter attached to its barrel. When the trigger of the simulacrum is activated, the emitter shoots a pulse of light to a screen. Then, specific hardware and software elements detect and identify the point where the laser pulse hits the screen and automatically perform the respective command in the game, simulating the mouse click in the appropriate game region reached by the "virtual shot".

In the following, we describe the hardware and software elements that establish this solution.

B. Reference Model

The solution's reference model includes specific hardware and software elements to enable the proposed interaction between the player and the target shooting game. Figure 1 shows the common relationship between a player and a computer game. Originally, the player interacts directly with the game through a standard computer interface composed of a keyboard, mouse, or controller.

Adopting the proposed solution, we change that traditional pipeline, so that the medium of interaction becomes a weapon (real or simulacrum). Therefore, to intermediate the player's interaction with the game, we include the following entities: an Emitter, a Video Output Device, a Capturer, and a Calibrator (Figure 1).

In the following, we describe all the elements involved in the proposed solution.

Player

The Player is an active entity, consisting of the actor responsible for carrying out the initial interactions with the game. The solution treats such interactions and passes them to the game, obeying all its original rules and limitations.

Solution

The solution is formed by the following elements:

- The Weapon, which is the tangible interface with which the Player interacts directly, is the hardware entity with a direct relationship with the Emitter. For the solution exposed in this work, any kind of weapon can interact with the game, as long as it has an opening in the barrel and it emits a sound when the player pulls the trigger. Therefore, the Weapon entity can have a diverse nature: firearm, toy, Airsoft, 3D printed etc.
- The Emitter, which is the intermediate hardware element between the Player's Weapon and the Game, detects the sound generated by firing the Weapon and instantly shoots a laser pulse.
- The Video Output Device, which is a hardware entity, such as a projector screen or a TV, is responsible for displaying the game's image.
- The Capturer, which is placed in front of the Video Output Device's screen, is a video camera that detects the reflection of a laser pulse fired by the Emitter on the screen. It identifies that the Player fired the Weapon and automatically makes available the respective camera frames for processing.
- The Calibrator, which is the software entity responsible for ensuring the interaction of the game, processes, in real time, the frames saved by the Capturer, using computer vision algorithms. Such processing aims to identify the exact location of the screen reached by the Emitter's laser pulse. So, the Calibrator maps the physical screen point to the individual game pixel. After that, the Calibrator executes the mouse click action on the respective pixel of the game's screen.

Game

The Game is the software entity responsible for establishing rules, obstacles, and challenges for the Player. As the proposed solution avoids any change in the Game, it will normally handle inputs (mouse clicks simulated through the solution) and outputs (respective changes in its graphical interface presented on the Video Output Device).

C. Architectures

In this section, the architectures of the entities of the proposed solution (Emitter, Video Output Device, Capturer, and Calibrator) are presented, including components and their interrelations.

Emitter

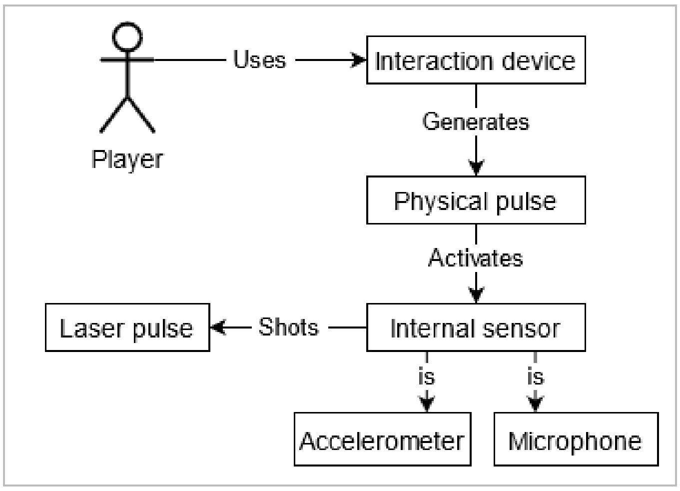

Fig. 2: Emitter's architecture.

The architecture of the Emitter – the laser pulse triggering device attached to the barrel of the Weapon – is shown in Figure 2. In general, the Emitter works as follows:

1) the player fires the Weapon by pulling the trigger;
2) the Weapon's precursor or similar mechanism emits vibration or sound;
3) the physical stimulus (vibration or sound) activates an internal sensor on the Emitter (accelerometer or microphone, for example); and
4) the Emitter shoots a laser pulse.

Video Output Device

In general, the Video Output Device is the hardware that displays the images seen by the Player. It can be a screen projector, a television, or any other device with the same purpose.

But in architectural terms, the Video Output Device is a passive intermediary entity that allows the Emitter to interact with the Capturer indirectly.

Capturer

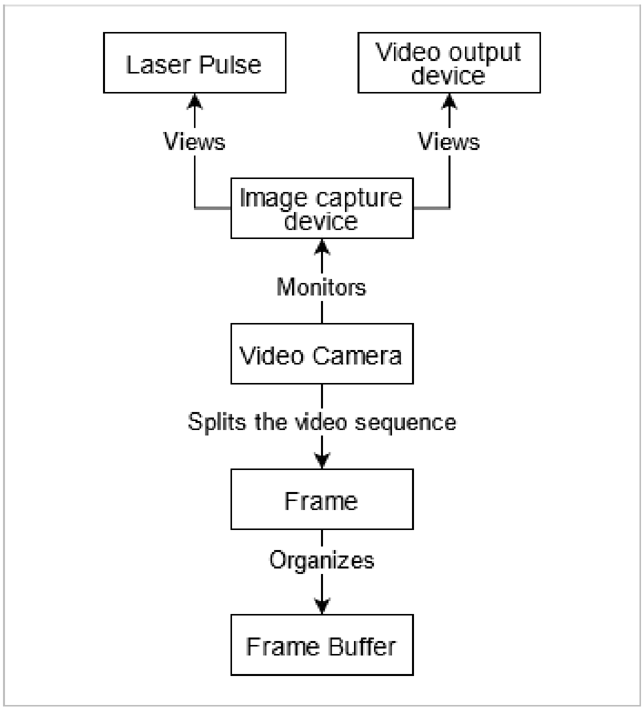

Fig. 3: Capturer's architecture.

The architecture of the Capturer – the video camera that monitors the image displayed on the Video Output Device – is shown in Figure 3. In general, the Capturer works as follows:

1) it monitors the image produced by the Video Output Device;
2) when it detects a laser pulse on the screen, it saves the respective video sequence;
3) the video sequence is divided into individual frames; and
4) the Capturer makes those individual frames available to the Calibrator.

Calibrator

The architecture of the Calibrator – the software that processes laser shots obtained from the video frames made available by the Capturer – is shown in Figure 4.

At the outset, the Player needs to execute the homography procedure [16], which is the processing that compensates for the deformation resulting from the misalignment between the video camera's plane and the Game's projection plane. For that, the Calibrator shows the camera view, obtained directly from the Capturer, in a preview area. So, using the mouse, the Player clicks on the four corners of the projection to generate a homographic matrix. After that, the Player can use the Weapon instead of the mouse.

While the Player executes the homography procedure, the Calibrator calculates a threshold that is based on the ambient light of the room and that aids in deciding whether a particular pixel is a laser shot or not.

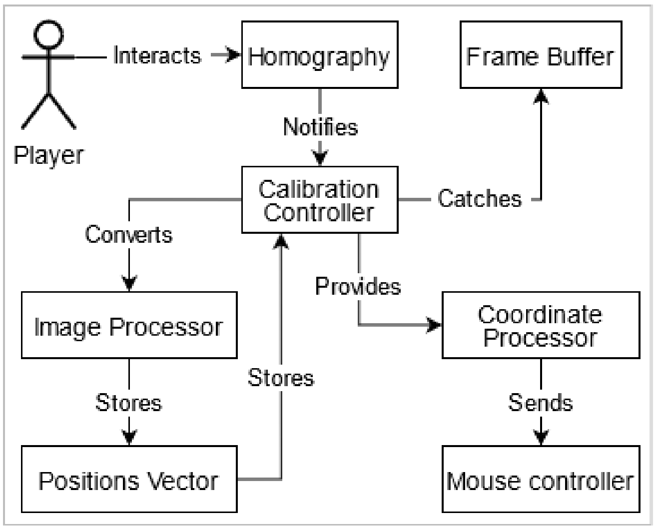

Fig. 4: Calibrator's architecture.

Considering the homography procedure and the threshold's calculation, the Calibrator works as follows:

1) after receiving frames from the Capturer, the Calibration Controller sends them to the Image Processor;
2) the Image Processor converts the image to grayscale.
3) the Calibrator divides the captured image into regions according to the threshold and based on comparisons of the gray levels of the pixels. This process separates the corresponding pixels from the laser pulse.
4) the Calibrator identifies all the pixels corresponding to the laser pulse, calculates the center of those pixels, and stores its Cartesian coordinates in the Position Vector;
5) the Position Vector sends the ordered Cartesian coordinates to the Calibration Controller;
6) considering the homographic matrix previously generated, the Calibration Controller converts the center of the laser pulse from projection coordinates to the corresponding Game coordinates; and
7) the Coordinate Controller sends the coordinates to the Mouse Controller in order to position the cursor on the respective game position, and to perform a mouse click – an interactivity action with the game.

The Capturer and the Calibrator are tightly interconnected, a hardware architecture (Capturer) complementing a software architecture (Calibrator).

IV. Implementation

To validate the proposed reference model, we implemented a version of each architectural entity described in the previous section. Thus, we can analyze, in practice, the solution's: viability, playability with the new form of interaction, and versatility.

A. *Implemented System*

The description of hardware and software implementation are presented in the following.

Hardware

Weapon, Capturer, Emitter, and Video Output Device are the hardware entities that define the new way of interacting with games and have the following connection and arrangement (Figure 5):

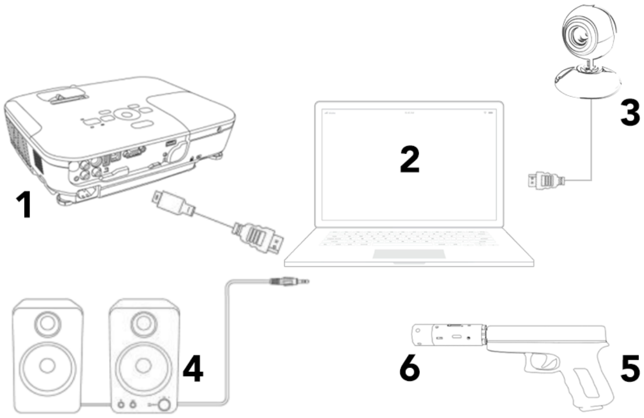

Fig. 5: Hardware devices.

1) Video Output Device: a multimedia projector responsible for projecting the video signal received by an HDMI cable connected to a computer on a suitable screen/wall.
2) Computer: a device responsible for performing all game processing, running the Calibrator, and leading with the user input. It acts as a centralizer and a manager of the other hardware entities.
3) Capturer: a webcam that responsible for monitoring the image displayed by the projector and for communicating with the Calibrator.
4) Speakers: devices responsible for transmitting all the sound signals emitted by the computer. It is an optional element, which, however, increases the sense of immersion during the game.
5) Weapon: a device for direct user interaction. It can be a real gun (firearm), a toy weapon, an Airsoft weapon, 3D-printed weapon etc.
6) Emitter: a device attached to the barrel of the gun, which emits a laser pulse when it perceives the firing of the weapon.

For the validation and to perform experiments in this work, we used the following hardware equipment (Figure 6):

- Epson Powerlite W10+ projector[1], native WXGA resolution, and HDMI output;

Fig. 6: Arrangement of hardware equipment.

- Lenovo Legion notebook computer[2] (core i5 8300H 2.30GHz, 8GB DDR4 RAM, 1TB hard drive, 500GB M.2 2280 SSD and Nvidia 1050TI graphics card);
- Logitech C270 webcam[3], 720p resolution, 30FPS frame rate, 55º diagonal view, USB cable connection and filter, adjusted to visualize red laser light;
- 6W USB speakers;
- Weapons with different characteristics (Figure 13);
- Laser emitter developed integrally creating a circuit based on an ESP32 microcontroller, accelerometer sensors, analog microphone, and battery charging subsystem with a voltage of 3.7V and capacity of 250mAh. The laser emitter case was designed using Autodesk Inventor[4] software and 3D printed with the BQ Witbox 2 printer using PETG filament (Figure 7).

Fig. 7: Laser emitter attached to gun barrel.

Software

For the context of this work and for validation purposes, we implemented the Calibrator following the architecture's pipeline presented in the previous section. The implementation of the Calibrator used the Qt multiplatform framework[5] and codes in the C++ programming language.

The Game is our main object of study since the solution presented in this article revolves around changing the way the

[1]https://epson.com.br/Suporte/Projetores/Epson-PowerLite/

[2]https://www.lenovo.com/pt/pt/laptops/legion-laptops/legion-y-series/Lenovo-Legion-Y540-15/p/88GMY501214

[3]https://www.logitech.com/pt-br/products/webcams/c270-hd-webcam.960-000694.html

[4]https://www.autodesk.pt/products/inventor/overview

[5]https://www.qt.io/

player performs inputs, but without having to change anything on the played game.

B. Experiments

We performed experiments with four different games to test the use of the implemented system. The analyzes of results focus on the technical elements of our solution.

B.1. The tested games

The games used and tested with the proposed solution followed two strands. The first being composed of two prototypes that we developed specifically to test the solution and two other existing and commercially published third-party games.

Prototypes

We designed the game prototypes to ensure the compatibility with the use of laser weapons. The inherent features of those games are static camera view while shooting and player action are restricted to shooting 3D objects.

They were developed with the Unity3D game development engine, using the Visual Studio programming environment and the C Sharp programming language. Adobe Photoshop (2D)[6] and Blender (3D)[7] software were used to create the needed graphic elements.

Fig. 8: Tactical Progression game.

In the first prototype, Tactical Progression (Figure 8), the player is in a 3D scene in which elements such as targets and victims appear, and the player must decide whether or not to shoot at them. After hitting all targets, the camera follows a predefined path to another location in the scene with more targets. That process is repeated a few times until the course is completed, and a report displays the player's results and scores, which are saved in a ranking table.

The second prototype, Duck Shooting (Figure 9), is a virtual version of the classic traditional amusement park game where metal duck-shaped plates appear in lateral movements, and the player must shoot to knock them down.

This prototype reproduces the same behavior as the traditional physical game, but it is more dynamic and playful, and adopts predefined scores.

[6]https://www.adobe.com/pt/products/photoshop.html
[7]https://www.blender.org/

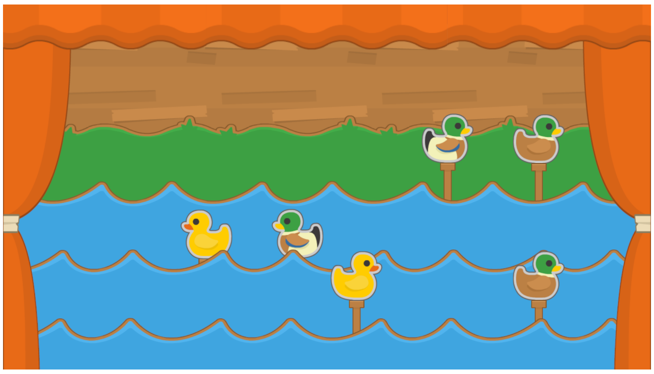

Fig. 9: Duck Shooting game.

Using the weapon to interact with the prototype makes the immersion and interaction level more enticing than playing in a real amusement park.

Third-Party Games

Testing our solution in Third-Party Games without making any changes to them is the actual validation test to observe whether the player interact satisfactorily with the game using the weapon simulacrum.

Two different games were tested. In the first test, we experimented with a rail shooter game based on mouse click interaction to evaluate the compatibility of the proposed solution. In the second test, we used a mobile-based game to validate the solution's versatility.

Fig. 10: Mad Bullets game.

The first game, Mad Bullets[8] (Figure 10), is a cross-platform game developed in 2016 by the Hungarian company isTom Games. It is a rail shooter that adopts a western environment where the player automatically moves along predefined paths and have to shoot enemies, to rescue victims, to collect items, and to accomplish missions. The player must manage and reload the weapon after using up the shots in the gun's barrel. To allow competition among players, the game stores scores on global rankings.

In the experiment, we used the computer version from the

[8]https://www.istomgames.com/products/madbullets

Steam[9] digital gaming platform.

Fig. 11: Smash Hit game.

The second game, Smash Hit [10] (Figure 11), is a title for Android and iOS mobile devices developed in 2014 by the Swedish company Mediocre Studios. It is an infinite runner where the player constantly moves forward and faces various obstacles on the way. The player must shoot metallic spheres to destroy obstacles and crystals in order to get more ammunition (spheres) and keep progressing. If the number of spheres drops to zero, the game is over.

The Smash Hit's interaction consists of tapping the smartphone's screen to launch the spheres. For progression and scoring, the game stores the maximum distance traveled by the player.

In the experiment, we used the Android BlueStacks[11] emulator to use our laser weapons, and demonstrate the versatility of the proposed solution using a mobile game, originally with no mouse-based interaction.

B.2. The solution's elements

The technical part of our solution considers the reference model exposed in Section III-B and implements it using the following elements: the environment, the laser emitter, and the weapons.

Environment

The environment used for the experiments is a room located in the basement of a business incubator in the city of Évora, Portugal. The room has the dimensions shown in Figure 12.

The environment has tables to hold the pieces of equipment, chairs to accommodate the test participants, a white wall receiving the game projection, and light control to allow for better immersion of the players.

The environment adopted during the experiment is ideal, but, in a general manner, there are no limitations in terms of room dimensions or distances between the equipment used. The solution will work correctly as long as the camera can view the entire projection.

Regarding the possible influence of light sources, the threshold adjustment function present in the Calibrator entity (described in section III-C) automatically adjusts the camera parameters. So the solution does not require a room with controlled ambient light. The only limitation is that the ambient light sources cannot be more intense than the light shots from the laser emitter.

Laser Emitter

We adopted a red laser emitter since a red laser is more suitable for carrying out the tests precisely because it is visible to the human eye. Thus, it helps the capturer to identify the laser spot, and the player to analyze the shot's accuracy.

Weapons

To carry out the experiments, we used a wide variety of weapons in different categories (Figure 13): (a) a toy fuze gun, (b) a 3D printed gun with trigger and precursor working with springs, (c) a Glock 19 gas Airsoft pistol, and (d) a G3 and AK47 electric Airsoft rifles.

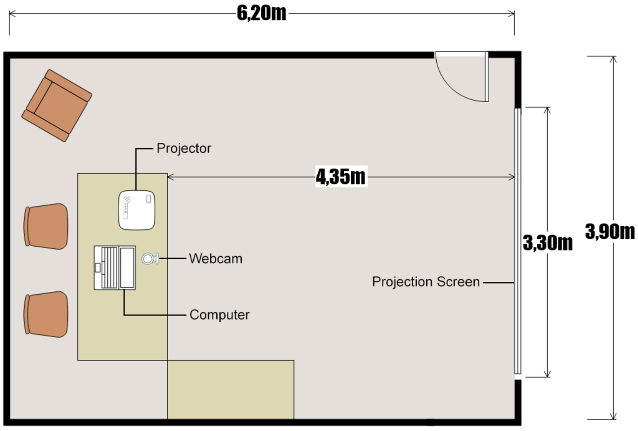

Fig. 12: Experiment's environment.

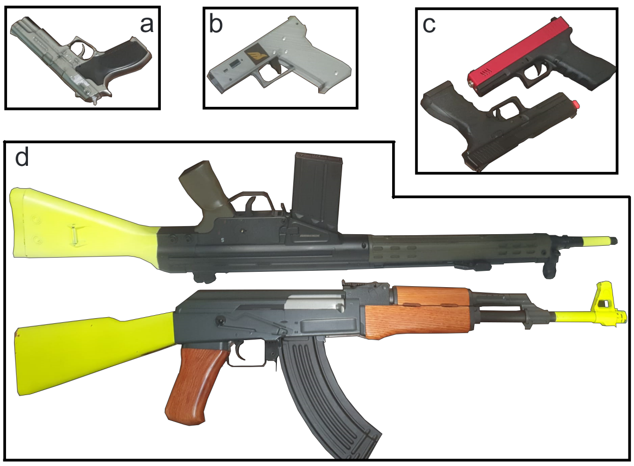

Fig. 13: Weapons compatible with the solution (a. Eletric Airsoft, b. Gas Airsoft, c. 3D printed weapon, d. toy gun).

B.3. Participants

To complement the experiments (Figure 14) we invited

[9]https://store.steampowered.com/
[10]http://www.smashhitgame.com/
[11]https://www.bluestacks.com/

guests and members from our development team to test the solution. Each participant chose a weapon and played all the four games described before for approximately one hour. Afterward, they reported their experiences.

Fig. 14: Participant using the proposed solution.

We selected five people with different profiles regarding nationality, experiences, occupations, and previous experiences with digital games, shooting games, and the use of real weapons.

We describe the five selected profiles below.

Profile 1

The first participant is British, 27 years old. He works as a game developer. He is an experienced player in many digital game styles, but he has little experience in shooting games. He has had contact with real firearms and trained with pressure weapons.

Profile 2

The second participant is Brazilian, 23 years old, master's student in tourism. He hasn´t experience with any kind of digital game, and never had contact with any kind of weapon.

Profile 3

The third participant is Portuguese, 27 years old, mechatronics engineer. He is a casual player in different types of games but is an advanced player in shooting games. He already had some contact with hunting weapons.

Profile 4

The fourth participant is Brazilian, 26 years old, digital marketing entrepreneur. He is a casual player with little experience in shooting games and never had contact with any kind of weapon.

Profile 5

The fifth participant is Portuguese, 32 years old, an administrator/accountant. He is a casual player in different types of games but is an advanced player in shooting games. He used firearms in the Portuguese air force.

The general results are specified below, taking into account the participants' reports and some technical factors.

C. Results

Considering the use of the proposed solution, we obtained the following results:

- The level of laser recognition by the Calibrator approached 100%, i.e., all shots were correctly identified and converted into mouse clicks.
- The processing time to perform the input interaction varied between 13 and 21 milliseconds. This is the total time spent from the instant the player shoots the laser beam to the instant the computer performs the respective mouse click on the game.
- All games ran steadily at 60 FPS on the computer settings described in Section IV-A.
- Some input lags between a mouse click performed in the game and its respective reproduction on the projection screen were observed. Those lags were probably due to the high latency projector and low frame rate webcam we used. Although input lag may impact the player experience and the game accuracy, in our case, the participants did not report that problem.
- The Emitter generated some false positives when using only its internal microphone. That was because of the sound emission caused by the release of the gun's trigger. However, when the internal microphone and the internal accelerometer were used simultaneously, the device emitted all the laser shots correctly once it detected the gun vibration.
- The participants' reported observations indicate that our solution was feasible and provided an exciting way of interacting with some games with no need to change them.
- Participants reported muscle fatigue due to the weight of the weapons but understood it as part of the experience and immersion.

V. Conclusion

This paper proposed a solution for capturing laser beams and allowing players to interact with shooting games without any adaptation of the games. We implemented the proposed solution and tested it using four different games: two designed and developed by the authors and two commercial titles with no adjustments. The obtained results indicate the solution and its implementation are efficient and represent a different approach that works for both legacy and new games.

We intend to apply tests with more participants of various profiles considering different assessments such as system usability and player engagement. We also want to collect more specific data, such as response times and shooting accuracy, by adopting specialized software and hardware.

We also want to adapt firearms, providing realistic recoil and improving the laser emitter. Although this is not the focus of this work, it can extend our solution for police, military forces, and sport shooting training.

In addition, we want to diversify the use of the proposed solution, testing other game genres (adventure games, educational games etc.), other than shooting games, but that also adopt the point and click interaction.

So, we hope our solution can bring new interaction alternatives for different purposes, from reviving old games, which were forgotten due to the fall in the arcade market, to new genres of games, such as point-and-click games.

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