RIGA TEHNICAL UNIVERSITY

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Construction of Intelligent rifleman performance monitoring and evaluation system

Doctoral thesis abstract

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CONFIRMATION

Hereby I confirm that I have worked out the presented thesis, which is submitted for consideration to the Riga’s Technical University for the degree of Doctor of engineering sciences. Doctoral thesis has not been submitted in any other university for obtaining the Doctor’s degree.

Juris Kiploks …………………

Date: ………………………....

The doctoral thesis is written in Latvian language, contains: 136 pages, introduction, 4 chapters, conclusions, 83 figures, 33 formulas, 6 tables, 76 references and 5 appendixes.

THE IMPORTANCE OF THE RESEARCH

This research considers the necessity for various shooting simulator equipment in Latvia, which has considerably increased recently, both with transition to professional army, and developed interest in live shooting sports. [6].

The practical application of the use of shooting simulator equipment confirms that its employment during the shooting training may reduce the number of the live shooting exercises and considerably increases the efficiency. It is especially important in the Military field in order to comply with the interoperability the training process must be organized in compliance with NATO requirements; the training must me intensified and with improved quality.

THE AIMS AND OBJECIVES OF THE RESEARCH

The aim is to create during the research process advanced shooting simulator that enabled the assessment of every rifleman's performance and to identify mistakes that interfere to reach the best result.

The objectives:

- To determine shooting simulator optimal construction that enabled to imitate the simulation conditions to real life actions;
- To determine the set of factors influence the shooting score and evaluate their significance.
- To determine ballistic qualities of the weapon and their influence on the shooting score as well as the possibilities to perform their simulation.
- To determine the functionality of the equipment that could evaluate the performance of the rifleman (trainee) the most efficiently.

METHODS AND INSTRUMENTS OF THE RESEARCH

During the research the information was collected concerning rifleman performance monitoring and evaluation system; analytically determined optimal construction of the rifleman performance monitoring and evaluation system and the set of factors which influence the shooting score. The calculations have been done in order to determine the influence of the ballistic weapons to shooting score as well as assessed the possibilities to perform simulation. It has been practically developed and tested the equipment that can evaluate the most efficiently the performance of the trainee. The algorithm of such equipment has been developed.

SCIENTIFIC NOVELTY OF THE RESEARCH

1. During the research the classification of the shooting training workout equipment has been created, that enables clearly define such equipment. Up to now it was not clearly defined differences among shooting training workout equipment, which is simulation, exercise and technical aids equipment, as a result there was confusion in the usage of terminology.

2. Up to now in shooting simulator equipment determining the hit target it was disregarded to take in consideration neither the elevation angle of the weapon nor the angle of the lateral inclination. The system and the algorithm of the calculation of hit targets depending on elevation and inclination angles are provided.

3. The author of the research has received Latvian Invention Patient Nr. 14311 "Development of Shooting simulator, Inclination Information System".

PRACTICAL APPLICATION OF THE RESEARCH

The outcomes of the research are applicable for the development of the new Shooting simulators, both for civilian and military and security services needs. The developed system of elevation angle of the weapon and the angle of the lateral inclination enables calculation of the hit targets correction depending on the weapon's position.

Introduction

The need for a variety of simulation equipment in Latvia and especially within the Latvian armed forces has grown significantly in recent years both in connection with the transition to a professional army, and the increased interest in shooting sports [6].To ensure full force compatibility the training process for soldiers must be organized in accordance with the requirements of the NATO alliance – to make them more intense and to improve their quality.

According to U.S. scientists during battle actually less than 90% of munitions are used [8], most of the ammunition is used in the shooting process simulation. Therefore it is important to use a shooting simulator not only while training professional soldiers at an early stage, but also to maintain and develop shooting skills.

Shooting simulators cannot fully replace real shooting lessons, because the factors that affect shooting accuracy are very diverse [9]. Simulator use during practice demonstrates that their use can significantly reduce the amount of actual shooting lessons (only in regard to maintaining shooting skills) and significantly increases their efficiency, reducing costs and amount of lesson time required to achieve the necessary level of training [10].

According to research conducted by the Swedish armed forces [11], more than 80% of the ammunition spent is fired at a distance of 50 meters. In this situation the leading shooting simulator manufacturers are mainly focused on the so-called situation simulators where the main focus is to use various weapon imitation situations leaving the ballistic properties of the weapon in second place. Such simulators are often used by law enforcement agencies and the key factor is the response rate. Such simulator action is visually effective and reminds one more of a video game where there is a first person shooter. Unfortunately the knack for proper shooting skills is overlooked and the high conformity needed to develop a rifleman's arms simulator. Mainly private companies work on the development of the simulator for the needs of the army, law enforcement agencies and athletes and for entertainment purposes. These companies are primarily profit oriented and therefore information about local studies doesn't get published or the general principles of the equipment are protected by patents.

The purpose of dissertation is to create a complete intelligent shooter activity monitoring system, which enables the evaluation of each shooter's level of training and as soon as possible to identify those gaps that hinder achieving the best results: incorrect breathing, sudden disruption in shooting, "the weapon's angular displacement from the target axis, in other words to provide a higher training efficiency. Usually to determine what is lacking an experienced instructor must be constantly present, which is not always possible, when practicing individually or in large groups.

To achieve this goal the following tasks must be performed:

1. Determine the optimal design of the simulator which would allow for a maximum closer simulation of real conditions of operations;

2. Determine the combination of factors that affect shooting performance and assess the impact of materiality.

3. Determine the ballistic properties of the weapon and its impact on the results of the shooting, as well as for ballistic properties simulation.

4. Set up a facility operating principle, which is optimum to assess the learner's (the shooter's) performance.

This Doctoral thesis first part is devoted to the shooting simulator operational framework for the assessment and global experience in maintenance in order to determine the optimal design of the shooting simulator for training performance.

2nd. part deals with the shooting performance measurement principles in order to establish objective criteria, as well as the potential of various factors on the shooting results to determine the proportion of proper shooting skills development.

3rd part deals with the alleged arms simulator equipment to determine necessary enhancement type and number of successful shooter performance monitoring.

4th part describes the shooting of automated performance measurement system operating principles and its practical application possibilities.

1. Types of Shooting Simulators and Their Operating Principles

After the study performed by the company Haskett Consulting Inc. [4] from the results people remember only 20% of what they had seen, 40% of what they saw and heard and 70% of what they saw, heard and did in practice. According to the results of this study it is quite clear that continuous training is an integral part of quality training. One of the priorities in implementing training simulation equipment is linked to the learning process cost reduction.

The simulation equipment management system works in three specific levels (Fig. 1), namely, electronic, mechanical, and biological [19]. This division of tasks is related to the time required for the system's response to a certain parameter change.

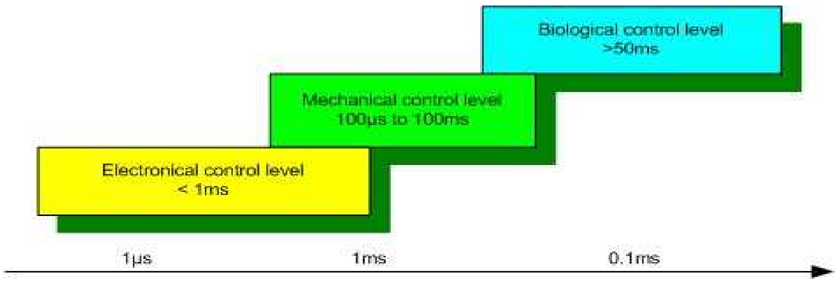

Fig.1 Simulator control levels of breakdown

The first of the control levels is biological control which has to ensure the simulator's strategic management decisions. Management programs at this level are the most complex however at this level you do not need high performance. Results of retention programs at this outlet may exceed 1/20s or 50 ms. This response time is comparable to the speed of human reaction to processes that are controlled by the central nervous system. In shooting simulators such processes, for instance are for determining the results of the shooting.

At the motor control level normal mechanical work is ensured such as electro-mechanical valves, motors, electromagnets, etc. This is the simplest programming level, because here the process uses electrical signal breaks. Reaction time here can range from 100µs to 100ms. In this level the best results can be obtained using microcontrollers.

The electronic control level simulator provides a variety of electronic assemblies for mutual communication and cooperation. Also this level interface input / output functions are implemented. At this level programs have to ensure maximum speed. Typically, these programs are not too complicated, but they are linked to processes that are underway in other levels of operation.

Shooting simulators have various restrictions and additional requirements for their application. First there are safety requirements that apply to the procedures used in the simulation of weapons and their operational products.

Secondly in reality there are high security requirements.

Thirdly you have to ensure the availability of simulation and economic efficiency. Shooting simulators have to ensure the availability of holding classes outside or in classrooms which are not specially meant for shooting sessions and at the same time maintaining a sense of reality, and personnel safety.

The modern shooting simulator has to ensure not only individual rifleman shooting training, but also the rifle group co-training and training co-operation skills. Questions that are related to rifle shooting group training using shooting simulators, has not yet been fully resolved.

Requirements for firing simulators can be summarized as follows: it is shooting at high-availability and high assurance of reality, while maintaining complete safety during the shooting simulation for the students, the public and the environment.

Currently, neither in Latvia nor anywhere in the world, is there shooting training equipment, classification this is why each manufacturer or developer named their products according to their ideas - a simulator, stimulant, trainer, interactive installation, virtual shooting range, etc. In spite of this name diversity often, different sources at the same plant call their products in different ways. Part of this mess is due to the fact that the Latvian explanations of these terms are ambiguous and their use of vague criteria. For this reason, there is a single classification for shooting training equipment illustrated by practical examples.

We can put shooting training equipment into four main groups:

Shooting Trainer - mechanical, electrical or electro-mechanical equipment to get the necessary skills and acquire basic skills.

Shooting Simulators - computerized equipment that mimics the reality of proxy shooting conditions.

Interactive Shooting Range - machines that use real guns with real ammunition, or reduced power, but hits the target projection and the coordinate reading is computerized.

Technical aids - mechanical or optical equipment, as well as computer programs, which use a separate shooting skills or training of error identification.

Shooting trainers in more detail could be divided as follows [25]:

1. Motor fitness;
2. Pattern recognition machines;
3. Algorithmic trainers;
4. Emergency trainers;
5. Decision-making machines.

Nowadays, the training may be composed of a computer, but unlike the simulators here computer performs ancillary functions -error tracking, time control, collating results and records, etc.

Shooting simulators are added based on virtual simulators. Such an approach corresponds with the definition of simulator -simulation environment and conditions.

The shooting simulator group may be divided into several sub-groups:

1. Optical simulators, which in turn further divided into:

a. Laser simulators, which hit the determination use both direct and reflected laser beams;

b. Electronic optic shooting simulators - the hit here is used to determine optical sensors.

2. Indirect fire simulators - devices where the hit is used in determining the weapon's barrel change in registration status.

3. Hit simulators - simulators, where a hit is used for determining the location of the physical body.

4. Virtual shooting simulators. In these simulators aiming is done without a weapon or mechanical or optical sighting devices.

5. Field tactical shooting simulators, these simulators are for tactical training and the organization of both indoor and field conditions. Field based tactical simulators are equipped with laser transmitters, but the U.S. investigations are underway to replace the laser transmitters with pulse radio transmitters [26]. Based on the above, we can create a shooting training device classification which is shown in Figure 2. In addition, the breakdown of all the shooting training equipment can be divided depending on their use for in the environment - indoor, outdoor or general purpose.

Also, depending on the type of shooting training workout equipment can be divided into individual and collective training facilities (maintenance, unit). Shooting Simulator evaluation is complex and not straightforward. Mainly which specific simulation equipment you choose, determines the purpose for which it serves. It is also necessary to know all the limitations that are associated with the equipment operating conditions. These are no less important to plant operation and service provision. In this situation, the main equipment of benchmarking can serve their economic performance assessment and comparison. Such a methodology was developed in military simulation equipment of economic efficiency (Cost effectiveness) evaluation of the NATO Scientific and Research Organization (RTO) Modeling and Simulation Group (MSG) study [46].
Overall, the use of the simulator training process should bring many benefits - to make the learning process more intensive, relatively cheaper and safer.

May have slightly different criteria to be chosen for those simulators, which are used for entertainment purposes, but also here the importance is of purely financial consideration.

Evaluating the above simulators in accordance with this methodology, we can determine the most appropriate simulator's certain tasks.

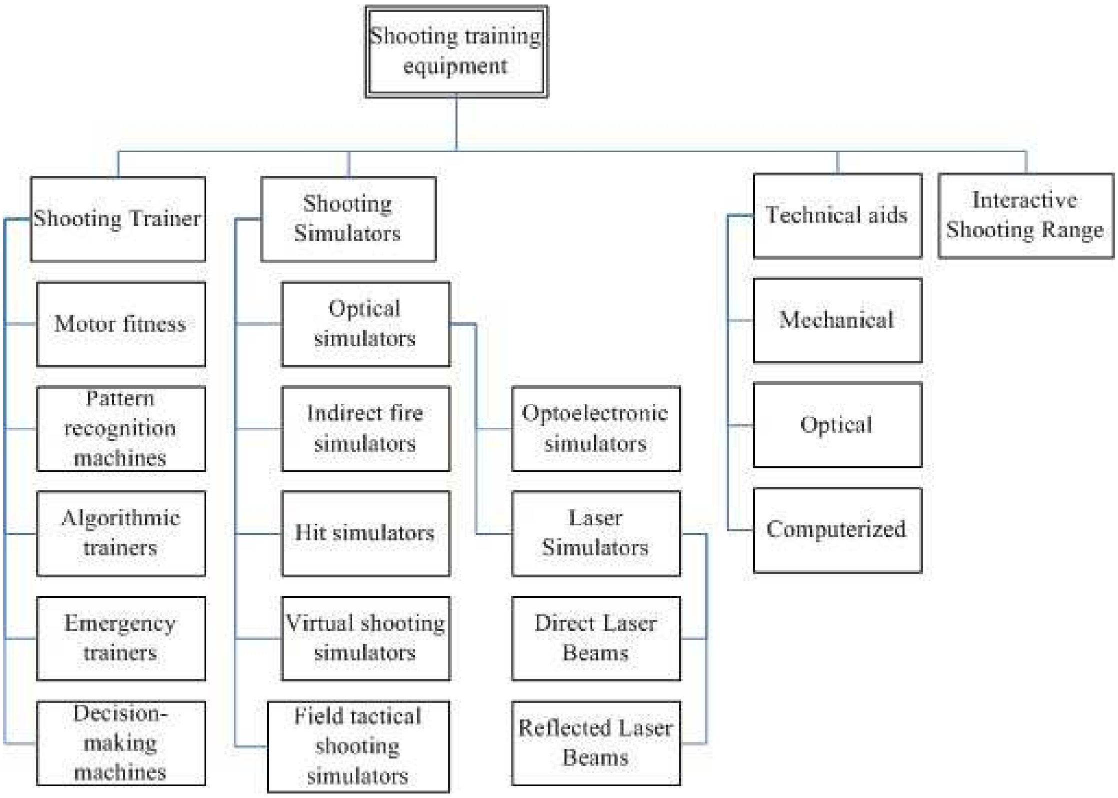

Fig.2. Shooting training workout equipment classification

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Simulators intended for athletes (the classic shooting disciplines), training is important for athletes' skills in the maintenance and tracking of specific training methodologies, not so important here is to provide authentic weapon activities, namely the recoil imitation, is important to obtain a report on the athlete's condition and actions before the shot (pulse, respiration, movement of the weapon, the tongues pressing force). Such needs are best suited to Finnish companies like Notpel and the Russian company's SKATT simulators. Despite the Noptel Simulator ST-2000 Sport II and SKATT simulator-similar performance [15, 16], preference should be given to the latter, because:

1. There is a wireless link between the sensor and the computer.
2. There are additional sensors which enable to control the trigger action when pressed and control the shooter's pulse.
3. The SKATT WS1 with wireless sensors according to the manufacturer's price is around 850 EUR, which is cheaper than the Noptel simulator.

This simulator's main disadvantage is that it is not possible to dynamically change the target size. For practical shooting advocates much more appropriate are the company's "Laser Shot" simulators, which use a laser emitter and the image is projected on the screen.

For hunting simulators it is important to keep momentum at a wide target area, but taking into account the fact that the rifleman's position is fixed, you can also use the weapons associated with the simulator, using a data cable.

For those shooting simulators used for law enforcement bodies need a wide range of simulated situations, and also they require a high degree of real visibility. More emphasis is placed on the simulation's speed of reaction and not the nuances of ballistic weapons. From the above it can be concluded that nearly ideal in this case is the branded "Laser Shot" TWS-DT simulator.

The highest requirements for simulators are in military structures, and are determined by both combat operations and training specificity: firstly it is a relatively large group of training shooting skills in a limited time (a soldier's basic service conscripts learning for young people), second infantry military units have a wide range of firearms from pistols and finally ending with automatic anti-tank grenade launchers and thirdly, these weapons are used while the unit (group) exercises, which requires the identification of each weapon hits, fourth is the use of arms length range, which makes it necessary to examine each individual weapon ballistics, and weapons are used both in the individual shooting mode and shooting overall, fifth there is a very broad range of military operations, which include protection from the operations of fixed positions to offensive terrain. Military shooting simulators can be integrated into the top-level virtual simulators as an element that represents the unit combat capability, where a high-level simulator generates a picture of the situation with the goals. Closest to the ideal of this group is the company Meggitt Training Systems simulator CST-300D which is able to operate with the virtual simulator JCATT. Partly the high cost of the simulator, and partly the differences in shooting training specification requires each country to create its own military shooting simulators.

When including stimulants in the shooting tactical simulation composition, it is important to ensure that the fixed information such as information on shooting performance, storage, processing and transfer is included. Simulators which are used for mastering shooting skills, have to be able to collect and analyze information that is related to the shooting conditions, namely the shooter's physiological state (heart rate, breathing), and the weapon's condition (the force pressing the trigger, barrel movement, weapon side deflection and elevation angle). This is necessary to be able to identify the shooter's errors, or to perform specific exercises so the simulator must be integrated with the appropriate sensors.

2. The Evaluation of the Principles of Shooting Results

Shooting with a gun under unchanged conditions due to various random reasons makes the bullet hit points different from one another. This phenomenon is called dispersion [48]. The area of dispersion is usually circle or ellipse-shaped and the greater the number of shots, the more this regularity is fulfilled. Usually in the dispersion area bullet hits are asymmetric, with a tendency to cluster closer to the center area of dispersion [41]. In the dispersal area one can determine the average hit point against which all other hits are arranged symmetrically (Fig. 3).

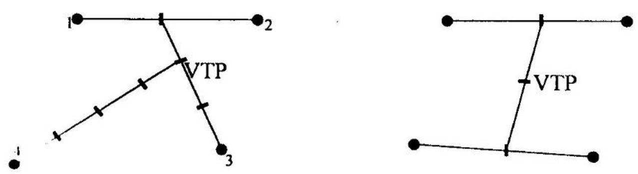


Fig. 3. Figurative average hit point detection using the straight-sharing method

In practice, a small number of hits (up to 5 hits), the average hit is determined graphically using the straight-sharing method, as shown in Fig. 3. This method is used with a greater number of hits which are grouped into four groups, separating them with sharp lines.

In the latter case usually a transparent stencil is used which outlines the mutually perpendicular axes. Usually they are supplemented by a circle 10 cm in diameter, which corresponds to the target center, to determine the number of hits outside the allowable spread.

The methods described above are quite convenient to use under field conditions, however, difficult to implement in a computerized performance. Mathematically, the average hit points are located in the arithmetic mean deviation of the coordinate axes

This method can be very well-used with computerized systems. Such a method is fully appropriate when a shooting simulator is defined by hit point, namely, receiving the camera target image in one corner, usually the top or the bottom left corner (in this case all the coordinates of the same sign) selects the coordinate axes starting point and all the hit co-ordinates are calculated exiting from this point, thus, each hit and target center already has its coordinates in a single coordinate system [41].

Thus determining the average hit coordinates on the x and y axis using formulas (1) and (2)

$$S_x = \frac{\Sigma_i^n =_1 x_i}{N} \quad (1)$$

$$S_y = \frac{\Sigma_i^n =_1 y_i}{N} \quad (2)$$

where S_x and S_y are the average hit point coordinates of the i-th hit with the coordinates xi and y_i. N - the number of hits. Each shot distance from the center of the group is known as d_s according to this formula

$$d_s = \sqrt{(x_i - S_x)^2 + (y_i - S_y)^2} \quad (3)$$

The total deviation from the group is in the center at Ds

$$D_S = \frac{\sum_i^N =_1 d_{s\,i}}{N} \quad (4)$$

In determining the average hit points, we can conditionally evaluate the quality of shooting. Such methodology is used in the U.S. Army [49].

In shooting simulators these values have to be recalculated after each hit. In the case of hits outside the target field they are perceived by the camera, the hits are not recorded and the result is not recalculated.

In order to electronically evaluate the results of the shooting, it is important not only to know what the average hit point is and how dense is the set of hits, but also how far from the center of the average hit point [45]. It is ideal when the average hit point coincides with the target center. To determine the cumulative error can be calculated for each shot deviation from the target center

Shot deviation from the target center dc is calculated using formula (5) where x_c and y_c are the center of the target coordinates on the x-and y-axis:

$$d_c = \sqrt{(x_i - x_c)^2 + (y_i - y_c)^2} \quad (5)$$

In this case not only the distance is important but also the direction to be able to adjust targeting. In this case it would also be useful to point out not only distance but also direction on the basis of the horizontal (x) axis. The angle σ is the angle between the horizontal axis and a straight line which is formed connecting the target center and the hit point which tangent is calculated using formula (6):

$$tg\sigma = \frac{y_i - y_c}{x_i - x_c} \quad (6)$$

Common hits deviation from the target center is calculated using the formula

$$D_c = \frac{\sum_i^N =_1 d_{c\,i}}{N} \quad (7)$$

With formula (1) - (7) the results can determine shooting results and objectively assess the performance of the shooter, but they do not give more information on fault causes.

Shooting results or bullet-scattering is dependent on a variety of incidental reasons, even when shooting with a gun under the same conditions. These reasons can be divided into three groups [41]:

1. the allowable tolerances of weapons and ammunition during production;
2. environmental conditions;
3. errors in targeting.

The first group which is associated with weapons and ammunition manufacturing tolerances cannot be influenced in any way. Their impact on hits usually is evaluated by making a test on the weapon namely by adjusting the sighting device. Simulations usually don’t take these reasons into account.

The second group is related to environmental conditions and is in no way influenced by the rifleman's hand. They objectively exist in the environment and determine the trajectory of the bullet’s flight. Factors such as air temperature, barometric pressure, wind speed and direction are evaluated by making calculations of the bullet’s flight and ballistics and they should be taken into account depending on the simulation task and the distance of the shot. The third group is dependent on the shooter and the following reasons can be divided into three groups, namely:

1. reasons related to the shooter's physiological state;
2. reasons related to the shooter's psychological preparedness;
3. reasons related to the shooter's motor abilities.

All these reasons are interrelated and not clearly separable from one another. With each of them are involved people working in such scientific fields as medicine, psychology, physiology, pedagogy, etc. Keep in mind that the simulator is firstly a training tool let’s look only at the reasons related to the shooter’s motor ability and for those that it is possible to train during a learning process.

The main task of any shooting stimulator is to train the shooter and his motor skills in order to minimize subjective factor influence on the shooting results. It is not enough to measure a shooter’s skill just by point fixation. The common trends in the performance of the shooter must be looked into and for this purpose is used the average hit point detection method. This method is well suited for military training, where the main evaluation parameter is the density of the shot.

Usually the tilt of the weapon to the side away from the vertical axis, is considered an error which should be eliminated because in this way is difficult to hit the target center. However, this method is used in practical shooting and is used in law enforcement, as well as military training team practice [58]. This is explained by the nature of the task, namely the limited response time, which does not always give the opportunity to take the classical stable shooting position, as in the task, where there is expected shooting contact with an armed enemy, the maximum natural cover, natural or artificial barriers which can protect one from the enemy’s bullets or lessen the possibility of direct target aim should be used.

Figure 4 shows the hit of the formation of a model gun tilting to the side. Given the structural performance of a weapon, resulting angle φ between the sighting line L_t and barrel center line Ls, but the gun tilt to the side is perpendicular to the axis of L_r which is located away from the sighting L_t. lines to each other by connecting the sights notch to the upper edge of the center - the top grain edge and the hit point on the target. The distance between the center of the barrel and grain upper edge of the *hst* (Fig. 5).

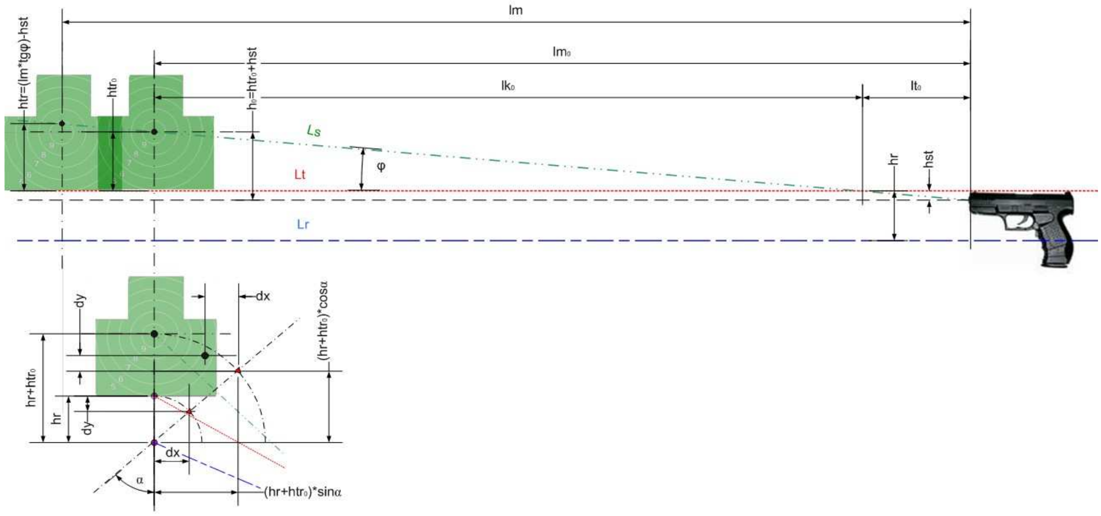


Fig.4. Guns hit the adjustment depending on the side of the tilt angle α

The lm0 distance is the distance which the weapon shoots. Sporting guns are shot"below target", that is to hit the center of the target you have to aim at the lower edge of the center, so the difference is formed between the sighting point and hit point at a of height hm0 (usually this distance is 10 cm). Tilting the gun to the side of the angle α with the axis perpendicular to the L_r the aim and hit point moves down to the distance dy and the tilts in the direction at distance dx, which is also the hit deflection of the vertical and horizontal axis, since we can assume that the sighting point is adjusted for the same distance.

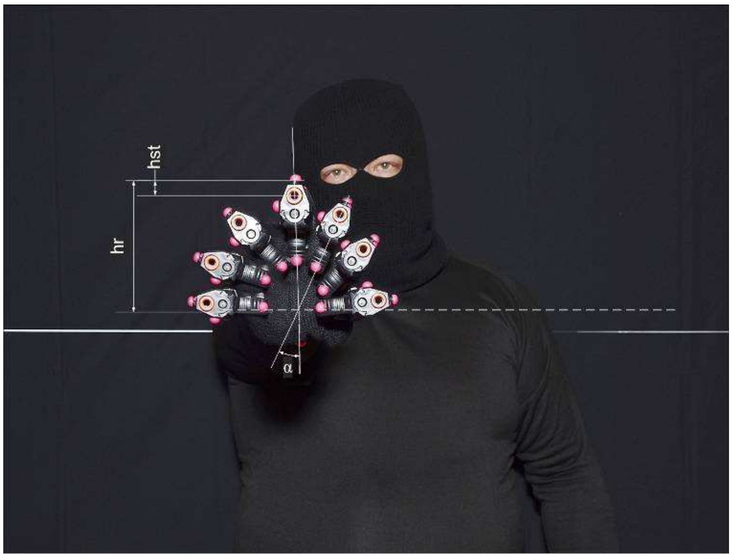


Fig.5. The guns side-tilt angle and axis of rotation of the weapon

Figure 6 shows how to determine the distance between the gun barrel and the center of the grain upper edge *hst* which is different for each weapon, such as the Walther P99 pistol is 15 mm, but small-caliber gun MCM is 20 mm. The distance from the vertex to the axis of the grain, which is rotated around the weapon *hr* is determined individually for each weapon and the shooter but on average it ranges around 10 cm. Performing trigonometric transfers [63], we obtain hit points per axis deviations dx and dy, depending on the weapon's side-tilt angle α is:

$$dx = hr \times \sin\alpha \quad , \qquad (8)$$

$$dy = hr - htr \times \cos\alpha \quad . \qquad (9)$$

Shooting simulator typically use laser transmitters where the hit is determined by a laser beam target foot on the horizontal and vertical x_0 and y_1 axis. Knowing these coordinates, we can determine the real hit coordinates x_1 and y_1 in accordance with the tilt angle α:

$$x_1 = x_0 + ((hr + htr) \times \sin\alpha - dx) \quad , \qquad (10)$$

$$y_1 = y_0 + ((htr - htr_0) - dy) \quad . \qquad (11)$$

The bullet's flight trajectories are used to describe a variety of ballistic models that could be described as follows.

In determining the exact distance to the target *lm* we use trigonometric relationships:

$$lm = lmt \times \cos\theta \quad . \qquad (12)$$

Knowing the true distance to target, we can determine the hit point height *htmt* on the target perpendicular to the sighting line *Lt*:

$$htrt = lm \times \sin\varphi \quad . \qquad (13)$$

Next we define the height of a hit against a target which is perpendicular to the horizon line, that is, normal. When using this formula you should take into account the lateral tilt angle α which reduces the height of the hit-to-target:

$$htr = \frac{htrt}{\cos\theta} + \left(tg(\theta+\varphi)\times\left(htrt\times\sin\theta\times\cos\alpha\right)\right) \quad . \qquad (14)$$

It should be noted that the angle θ can also be of negative value and in this case the absolute value of the angle should be used. Taking into account the new formula and changes in the calculation, it is possible to prepare a model of the software, which is evaluated by the elevation angle.

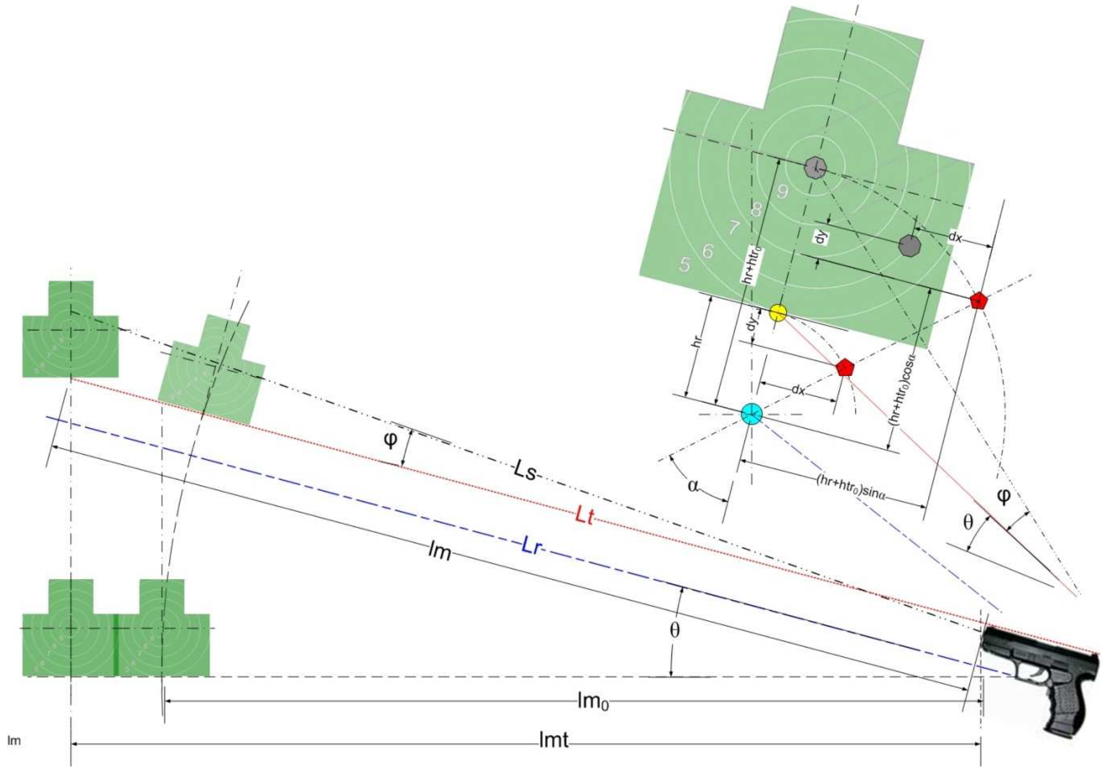


Fig.6. Adjustment of the hit of the gun depends on the elevation angle θ to lateral tilt angle α

Computerized compilation of results form the possibility of using additional characterizing parameters, such as, each shot deviation from the target center and total hit deviation from the target center. Angle sensors, showing a weapon deviation from the gravitational axis of lateral and vertical axis, may be evidence of improper targeting. The weapon's lateral tilt and barrel elevation directly affects the bullet ballistics, thus allowing for the necessary hit adjustments in the shooting simulator.

3. The Shooting Simulator's Equipment for Monitoring the Shooter

Pursuant to the requirements that are imposed on the shooting simulator and assessing the closest analog products (CST-300D, the company FATS - U.S. and SAIKAS 8 - Latvia), the design of the computerized shooting simulator is described in the following functional diagram (see Figure 7).

The staff weapon that was used for shooting training comes with an extra set of devices (1) an optical shot (2) and the rebound shot and ammunition exchange (3) simulators (the latter is not for grenade launchers). Shooting is carried out using the shooting simulator visualization system (4). In the shooting simulation mode the following happens.

The shot gun prepared for shooting (1) (pressing the gun trigger), triggers the gun firing mechanism which develops a team shooting (gun cock blow noise - audio impulse (5) – shooting team). Shooting optical simulator (2) Audio momentum (5) is transformed (with the audio signal receiver) for a shot of electrical command (6) (7th figure not shown) - impulse, which initiates:

• optical - shot (simulation) - a light impulse (7) (see fig. 8), radiated from the laser transmitter to the target (15)

• shot data (or command) signal transmission (8), passing data from the transmitter to the data receiver,

• weapon reload command (9), transmit (target shooter, machine gun) on a rebound shot and ammunition exchange simulator (3) a pneumatic actuator (12)

Weapon reload command (9), fed on a rebound shot and ammunition exchange simulator (3), initiates the pneumatic actuator (12) start of rebound shot by a firearm and ammunition in exchange simulation.

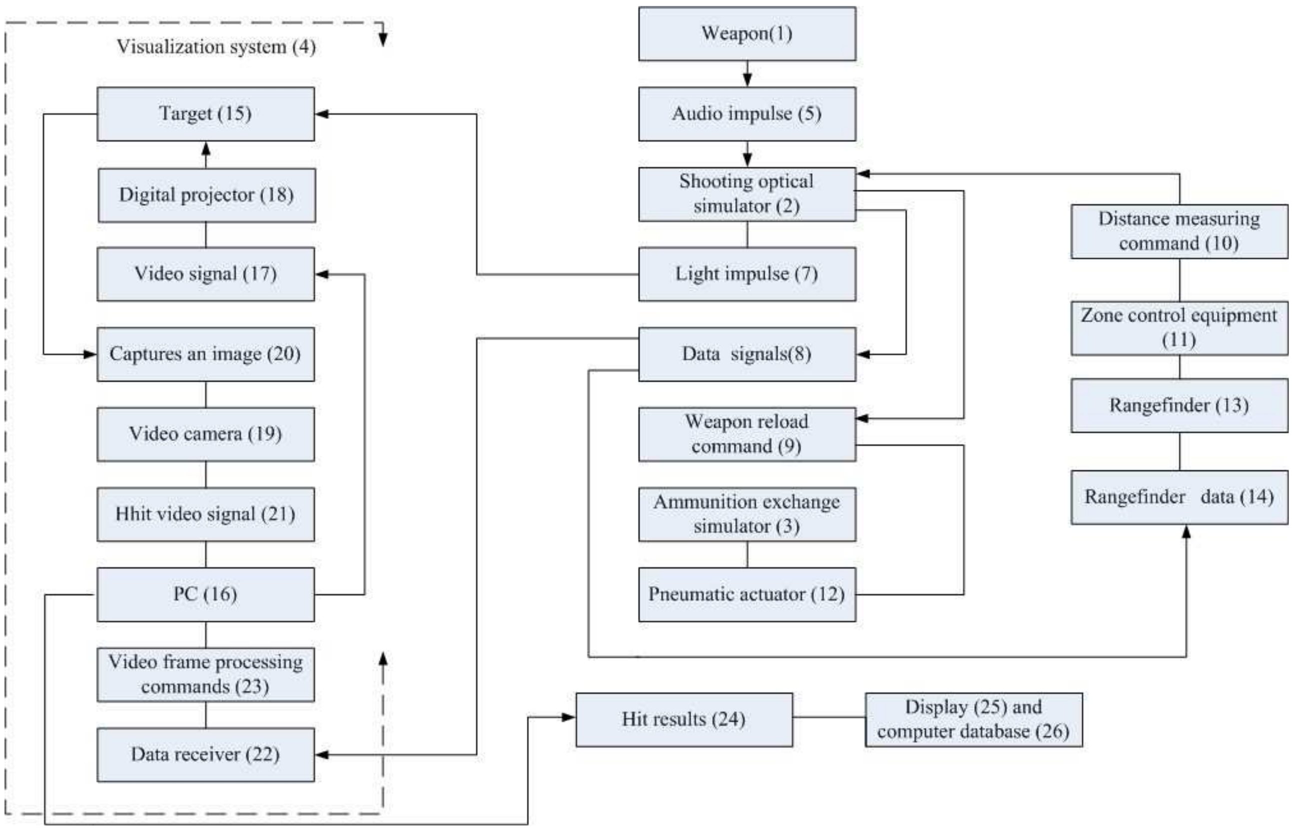


Fig. 7th The shooting simulator's functional scheme

Distance measuring permitting command (10), dependent on the zone control equipment (11), gives authorization to the rangefinder (13) measurements, the data (14) is fed to the optical shot (2) simulator data transmitter for transmission to a computer or local area (weapon) signalizing.

Shot light impulse (7) emitting from the laser transmitter on the shooting simulator's visualization systems (4) on the screen projected target (15).

The shooting simulator's visualization system (4) works as follows (Fig.8) System (4) computer (16) develops the visualization (the objectives and background) video signal (17), which is fed to a digital projector (18), which projects an appropriate shooting simulator target (and background) (15) The image on the screen. The visualization systems (4) video camera (19) captures an image (20) and converts it into a hit on the video signal (21), which is fed to a computer (16). The visualization system's (4) data receiver (22) receives data (shot commands) transmitted signals (8), which converts the video frame processing commands (23), which is fed to a computer (16) providing a target frame on the video signal hits (21) for further processing. Processed by a computer (16) hit results (24) are displayed on the display (25) and stored in a computer database (26).

At present production offers a diverse range of small-sized sensors, which enables them to be integrate in many aspects of human activity-related facilities, thereby providing feedback to the user, but practically not affecting the properties of the object itself, without significant dimensions, weight or energy gain. One of the sectors where such a feedback link provides good results is training technology and more accurately simulation technology, as opposed to dealing with real objects, here all the feedback is modeled or imitated. During the simulator operation process sensors can be of two types first to collect information from a real object to create new simulation models, or to inform the model of changes in the simulation process, in this way sensors can be used for shooting simulators, namely, to provide information about the rifleman's weapon and the situation at the time of the simulation. For example, obtaining information about the rifleman's respiratory cycle, it is possible to identify errors related to improper organization of the respiratory cycle during shooting exercises. Obtaining information on the angular position of a weapon, we can adjust the hit points according to possible trajectory of the bullet.

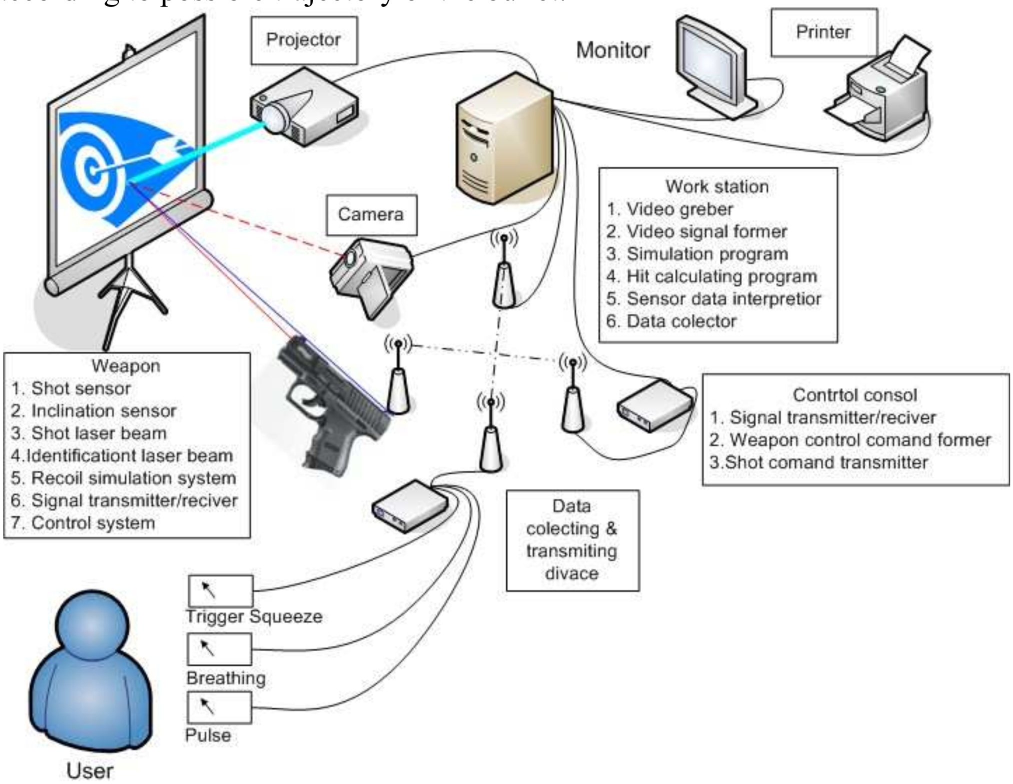


Fig.8. Sensor Integration shooting simulators

Figure 8 shows the possible integration of the sensor circuit. Adding sensors to the simulator, one has to see that their effect on the firing process is minimized as much as possible, so interfacing with a computer or control unit it is recommended to use wireless technology.

In the shooting system we can use a standard element of electronic equipment, comprising of a weapon tilt sensor and the respiration sensor's implementation, but the simulator's additional equipment depends on the simulation target, weapon type and learning tasks. Each weapon has a specific event time histogram, and this chart may differ even within the same type of weapons, depending on their technical design and the technical condition of the weapon. It is for this reason that the simulator would be preferable to specially rebuilt weapons or full-scale layouts.

4. The Finished Processing System in the Shooting Stimulator and its Research

The data processing system is closely linked to the simulator's physical and logical structure. Therefore, to describe the work developed under operation of the equipment it is necessary to describe in detail the structure and functions of key components. Shown below is a specific shooting simulator interlinking block diagram (Fig. 9)

As shown in Fig. 9 the simulator consists of the following major components: 1. Weapon simulator

The device is intended to mimic the process of firing, mimicking a real weapon's physical characteristics, including size, weight, appearance, function and dynamics. In addition to what was mentioned the simulator is meant for position (location and orientation in a certain space) to ensure recorder sensor operation. 2. Laser light indicator

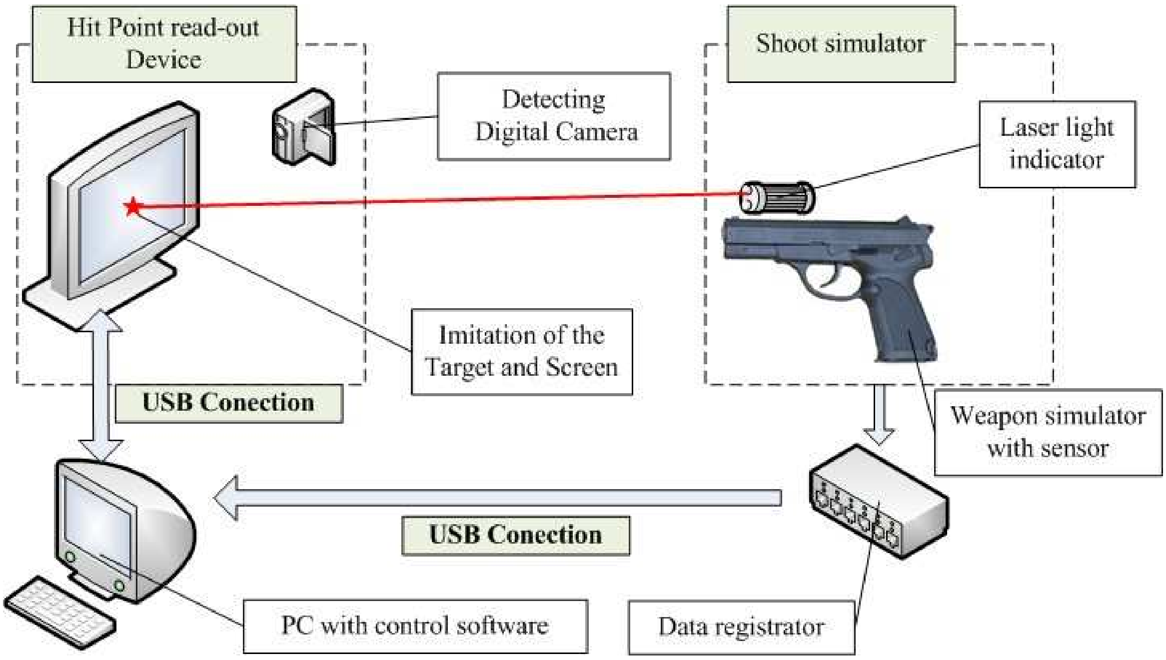


Fig. 9 The shooting simulator block's diagram scheme

Given the nature of the simulator - a short distance shooting simulation with the use of guns, which provides virtually straight projectile flight to the target, as a spot indicator a laser is used. For experimentation needs in the equipped facility is used a visible light laser indicator to ensure a simpler system tuning and debugging process. The hit point read-out device used - digital camera which is capable of detecting the IR (infrared) light. Therefore the machine can use an IR laser so that the simulation process can come closer to real conditions when the hit point is not visible on the target.

Fig. 10 shows the experimental realization when the target established by the direct beam system which consists of a video camera which has a non-transparent semi-transparent body behind the target and the camera is focused on the goal. The establishment of such facilities was the fact that there is no special room where to set up the simulator because the reflected beam projection system requires a machine and camera calibration every time the machine is moved. It is also important to note that the equipment is much cheaper since it is possible to use a video camera with a relatively low resolution, while providing a high level of accuracy in the results.

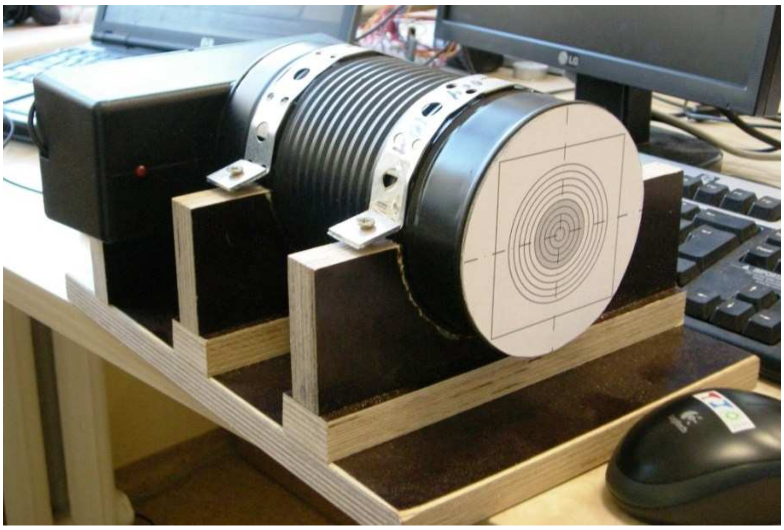


Fig.10. The established target surveillance video system with a semi-transparent screen

For data reading for 4-channel signal recording equipment Velleman 4048 is used which provides sensor signal multiplexing and putting into the computer via the USB port.

Figure 11 shows a Walther pistol P99C pneumatic version used in an experiment. This gun's mechanism ensures the functioning of the CO2 gas canister placed in a gun handle. This weapon is an exact copy of a battle gun which imitates the shooting process and mechanically shifts the shutter frame, thereby providing a simulation of the rebound effect. Under the gun barrel grooves the created grooves make it easy to enhance a variety of accessories. This battle weapon uses 9x19 Parabellum cartridges which are taken into account when determining the corrections on the ballistic calculator.

Fig. 11 A gun with sensors: 1) two-way tilt sensor, 2) a microphone, 3) a laser radiant, 4) Walther P99C pneumatic model

Fig. 12 shows a simple breathing sensor, which works on the principle of resistive impedance changes under respiratory influence. To the belt is attached a potentiometer, which at one end is rigidly attached to one end of the belt, also with the aid of springs a slider is attached so that the spring with a certain resistance can hold the slider in the final state. The slider is connected to the opposite end of the belt using a non-elastic steel string. When the body circumference changes due to (the breathing process) the potentiometer slider moves thereby changing the potentiometer resistance according to the principle of the voltage divider output to the voltage value. In spite the system's simplified structure its work process proved to be most effective.

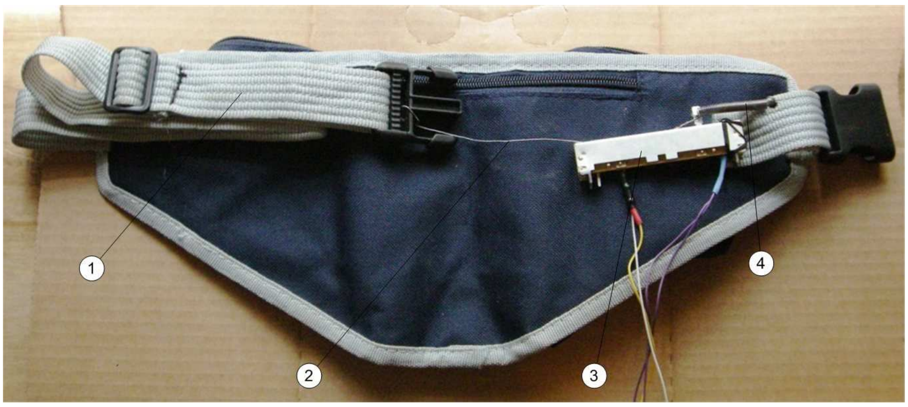


Fig. 12 The breathing sensor acquisition system: 1) Belt, 2) connecting string, 3) the shear stress dividing potentiometer 4) on a slider return spring

The tilt sensor calibration requires a special stand, which also provides the ability to program verification. With its help it is possible to hold the laser beam steadily for a longer period on a certain point on the target surface. Also with the help of the stand target limits are established for receiving the matrix and to set the actual target center.

The sensor equipment operational research should be initiated with target calibration. It is known that the frame size in the receivers' camcorder is A 320 x 240 pixels. On the beam center are fixed actual target coordinates of the center as shown in Figure 13.

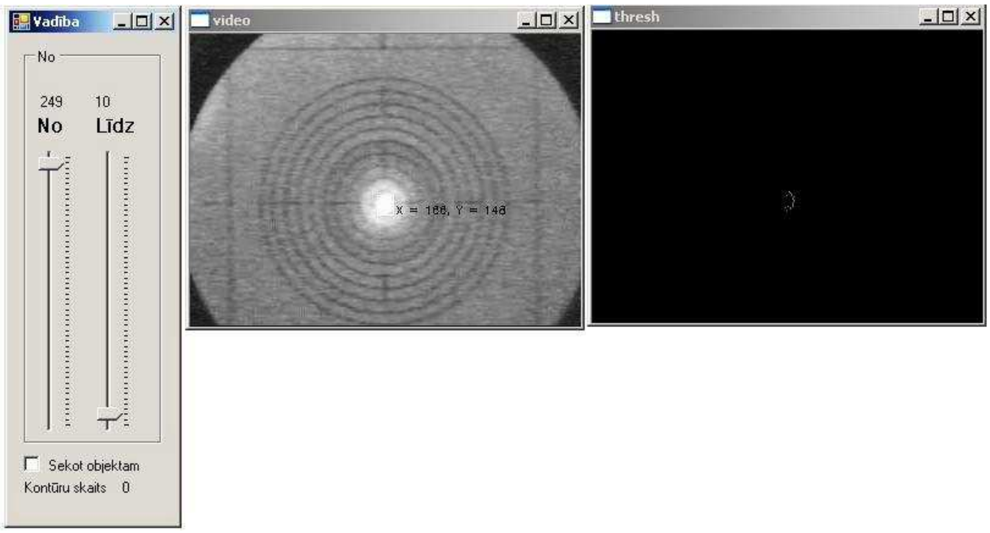


Fig. 13 Target centering with the calibration structure

Similarly, the target circle edge point is found. Since the target is a circle it is sufficient to unambiguously determine its position on the screen, namely, the circle center and radius

The actual diameter of the target on the screen is 5.5 cm, and knowing this with the help of formula 15 you can determine the actual pixel size, which will determine the accuracy of measurements.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad , \qquad (15)$$

where d- is the distance between two points in the plane; $x_1$un x_2- are the first and second point coordinates on the x-axis; $y_1$un y_2- are the first and second coordinates on the y-axis. We get the distance (circle radius) d = 123 pixels. Linear pixel size (5.5 / 2) / 123 = 0.0224 cm => 0224 mm.

According to the data given in section 3 we can determine that the target distance of 30 m is to 15 cm. Consequently, we can say that the imagined distance to the target is 30 m but the ideal target range of 15 cm accordingly pix corresponds to 0122 cm. Multiplying the size in pixels to determine the distance obtained from a hit the target at an imagined distance which is necessary to calculate the deflection using program obtained in section 2.

Keep in mind that the program hits are calculated from zero and are located in the figure’s lower left corner the camera's software coordinates are calculated starting from the upper left corner and therefore all the y-value’s will have a negative sign because this distance is subtracted from the height of the frame in order to get a positive value.

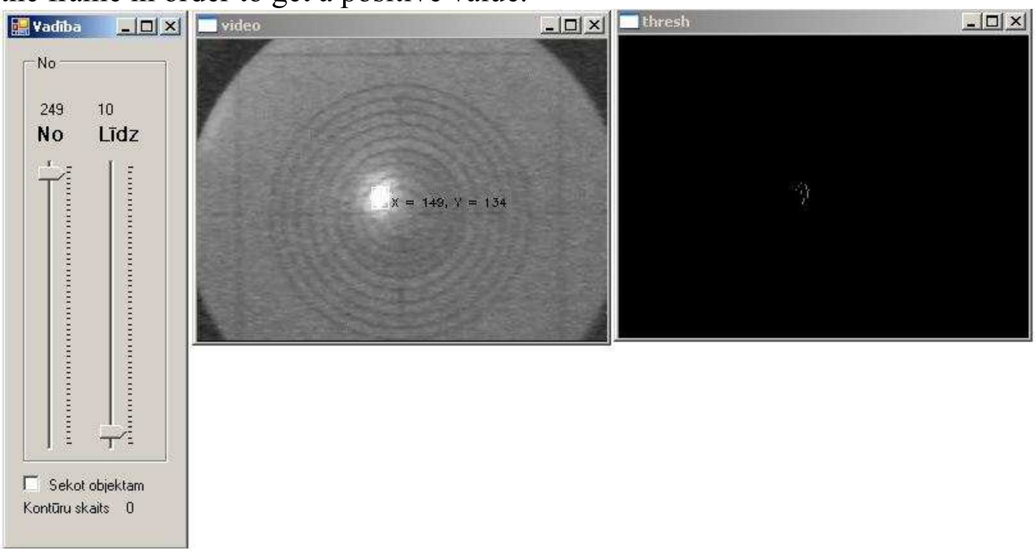


Fig.14. Fixed camera shot image

Figure 14 shows the fixed image of the target at the moment of shooting but it is not the final shot result because the bullet flight ballistic reports are not taken into account. The black image shows all the filter points by which the coordinates are determined on the screen. During the shooting simulation, parallel to the hit picture the sensor readings are determined which are displayed as a text file. Measurements are taken with 0.01 s intervals.

To determine the angle formula 16 is used with the tilt sensor KAS902-04.

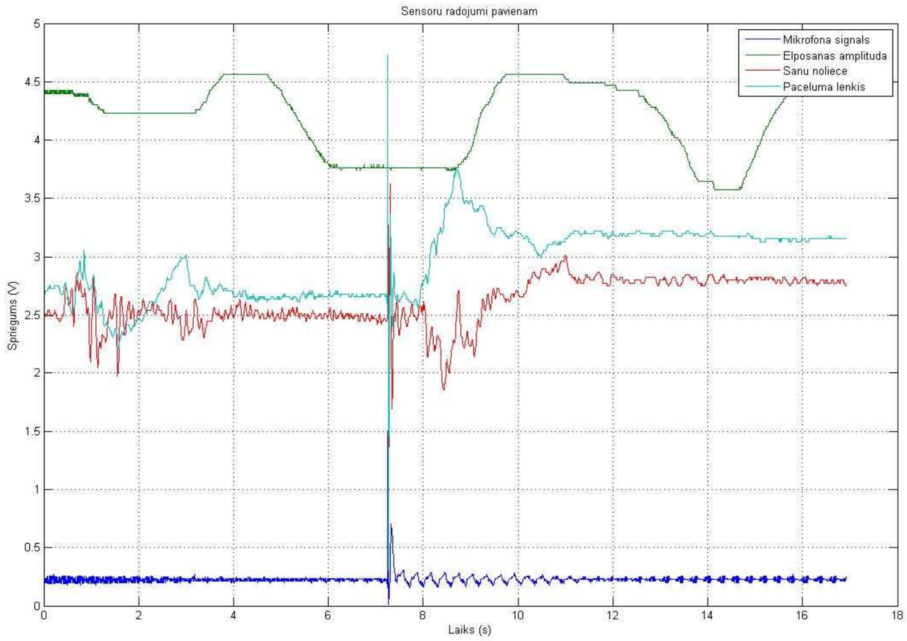
$$a = \arcsin(\frac{V_{out} - 2{,}5}{S}) \quad , \quad (16)$$

where the a-angle in degrees;

s - the sensor sensitivity of 4 V / degree;

V_{out} - output voltage (V).

To check the system set up trials were conducted sensory studies in real simulation of shooting conditions. Fig.15. shows the sensor output signal chart of one shot. The light blue line shows the goal-oriented weapon elevation tilt sensor signal. As shown, the shooting time is slightly above the zero line of 2.5 V. Lateral inclination - red line - is close to zero.



Fid.15.Is focused on the target weapon sensor readings at the time of shooting

From the measurement results it can be concluded that the shot was made in the range of 7.23 to 7.24 seconds. To determine the lateral deflection and elevation angles before you have to record the sensor output at 7.23 s. Fair point hit calculations are calculated under real purpose of shooting time series data as summarized in Table 4.2.

Table 4.2 Hit scoreboard

Nr.	Hit Coordinates (pix)		Hit Coordinates (cm)		Inclination angles values (V)		Inclination angles values (grādos)	
	x	y	xj	yj	al	teta	al	teta
1	161	150	19,642	10,98	2,447	2,682	-0.7592	2,6079
2	137	114	16,714	15,372	2,471	2,4	-0.4154	-1,4325
3	180	134	21,96	12,932	1,788	2,494	-10.2533	6,445

4	217	101	26,474	16,958	2,353	2,353	-2.1061	-2,1061
5	137	183	16,714	6,954	2,451	2,263	-0.7019	-3,3968

Modification of the ballistic calculator 30m distance - 0.2 cm at 15 °C and atmospheric pressure 750 mm Hg using a standard 9x19 Parabellum ammunition with bullets weighing 7.45 g ball starting speed 390 m / s and the ballistic coefficient of 0.47. Will get the results graphically as shown in Figure 16.

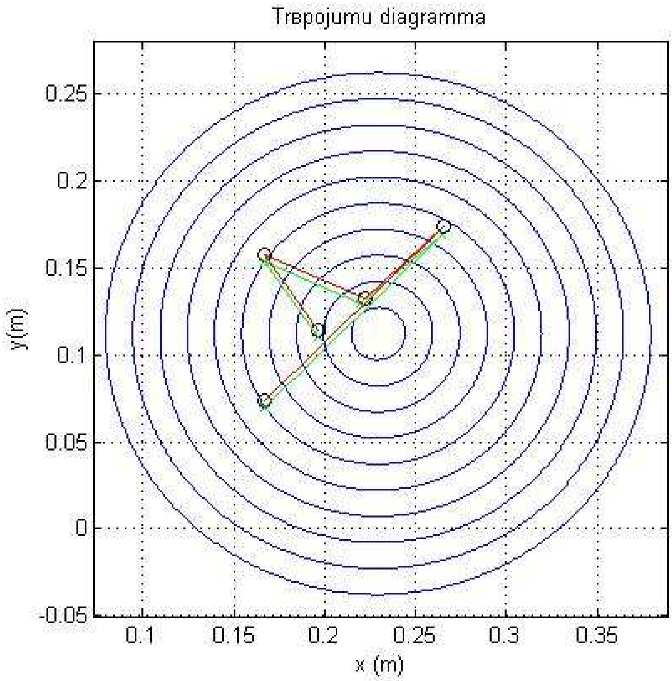


Fig.16. Shooting series of graphic display of results

In addition the following results were obtained:

Average hit point coordinates, respectively - Sx = 0225 cm, Sy = 0.147 cm

Average distance to an average hit point Ds = 0292 cm

The average distance to the target center Dc = 0146 cm.

In addition, by automatically analyzing the respiratory sensor chart with the help of the program, it would be possible to automatically determine whether the trainee shall observe the principles of proper breathing.

From the foregoing it is apparent that the firing simulator system’s integrated devices are operational and capable of trainees and instructors with reliable information. The results obtained can be used to analyze the process of shooting. Each simulator in addition to the equipment depends on the technical characteristics of the weapon and training tasks.

Conclusions of the Job

1. Existing computerized shooting simulation systems containing sensors that indicate the weapon and the shooter's firing position at the time, as a result of the systems are not educational in nature, allowing the shooter to analyze their own errors without the assistance of qualified instructors because the system does not provide feedback between the results and errors.

2. The analysis shows that to achieve the goal - to realize the system with feedback and links - must have at least a weapon leaned against the firing axis sensors for lateral and vertical deviations. In addition, it would be advantageous to install a respiratory control sensor, which is particularly important for training at an early stage.

3. To quickly evaluate the sensor signals a hit program system should be developed for in the system’s deviation as a function of lateral and vertical tilt under classical ballistic methods and the introduction of the computer program.

4. The created computer program allows you to get feedback from the weapon and shooting results, as shown experimentally carried out in the shooting trainings.

5. The established experimental shooting simulator system with feedback is active and with some links it can be applied in practice. Selected sensors show a good performance.

6. The data lock step with the selected 10 ms is sufficient to obtain satisfactory results in the interpretation of the shooter. If one would reduce this step one would get a lot of extra information, but this does not lead to the desired effect, only increases the amount of data.

7. Analysis of the results obtained suggest the possibilities for the interpretation of results - to assess the shooter shot at the time - dynamic effects on the weapon trigger, recoil simulation actions and others.

8. The developed system has been integrated into the existing shooting simulator model system, such as is used in the Latvian SAIKU-8. In addition, the simulator will be able to carry out such exercises in shooting, which with conventional methods are not feasible, such as shooting a gun with a variety of elevation angles, which requires the military structures of densely populated areas.

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