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The use of IR camera to detect the points of impact projectiles

Abstract

Multimedia shooting training systems are increasingly being used in the training of security staff and uniformed services. The next stage of the system development is to make possible training by firing in dynamic scenarios, using combat weapons and live ammunition against visible targets moving on a screen. The use of infrared camera for detecting the position of impact of a projectile is presented in this paper. Due to the thermophysical properties of materials used in anti-ricochet covers, heat transfer takes place relatively slowly and thermal trace of impact of the projectile is visible from several seconds to several minutes. To eliminate this problem it has been proposed to use two algorithms in the detection system of Snieznik.

Keywords: multimedia shooting training system, thermovision, projectile.

1. Introduction

Multimedia shooting training systems are increasingly being used in the training of security staff and uniformed services. An advanced practicing–training system SNIEZNIK for simulation of small arms shooting has been designed and manufactured by Autocomp Management Ltd. and Military Institute of Armament Technology for the Polish Ministry of National Defence.

SNIEZNIK (Fig.1) is a stationary device designed to teach, monitor and evaluate the targeting of small arms and to prepare soldiers for:

- firing the live ammunition at open ranges for combat targets and silhouettes
- detection, classification and engagement of real targets upon different terrains, weather conditions and periods during the day
- team work as a squad during the mission by using different types of arms
- suitable reactions in untypical scenarios.

Placed in any room the training set consists of:

- the projection system that generates realistic 3D imaging of the battlefield (such as combat shooting range) in high-resolution
- system that tracks weapons aiming points
- sound system which delivers realistic mapping of acoustic surroundings
- operator station with which the training is conducted and controlled
- central processing unit based on PC computers equipped with specialist software realizing individual system functions
- units of smart weapons equipped with radio communication modules, injection laser diodes and pneumatic reloading system [1].

Fig. 1. System SNIEZNIK

In order to ensure maximal convenience most of the system elements are constructed within one cabinet. The only elements situated beside the cabinet are those for which spatial arrangement is crucial for the functioning of the system (projectors, cameras, speakers). This solution has minimized the amount of space taken up by the information subsystem and the number of cables – not sure what you mean by this.

SNIEZNIK is entirely controllable from the operators station. Here is an application installed that enables configuration of the system, creating, modifying and starting up the training as well as controlling system work.

The software provides the ability to split the screen into any number of independent sections. Each section, used for individual training of a single shooter, has an independently assigned and executed exercise, making it possible to simultaneously train many soldiers using any available weapon types (in terms very similar to a shooting range). What is also possible, is the simultaneous training of many soldiers (working within a group) based on a single imaging (filling the whole screen) with more complex tactical situations simulating real situations of a battlefield. Thanks to the extensible mechanisms controlling the course of the exercise it is feasible to construct any (including nonlinear) variants of action development.

To create more complex configurations of training positions is just a simple case of multiplication of a visualization system (computer, projector, camera) and turn it into a network and set the appropriate parameters. These systems extend the imaging created so you can get a panoramic view of greater complexity or increase the available number of individual shooting positions.

The system is based on PC hardware platform that provides computing power fully sufficient to carry out the required tasks. Due to the modular construction from standard components available on the market, it is also easy to maintain and modernize the system.

The computer system is a set of cooperating applications containing implementations of all modules running on Windows XP Professional, and a set of auxiliary data files and libraries. Software of the SNIEZNIK system consists of several modules implementing the overall functionality of the selected items. Each module is run an appropriate network node, where it implements the designated task. Due to the identical functionality of the visualization systems the modules that are working within them are also identical and are activated with a different set of initial parameters.

On a regular basis, the system creates the appropriate ballistic curves and analyzes their location on a three-dimensional scene. It is based on the type of weapon used, working parameters which are transmitted through it and recorded position of its laser pointer on the screen. This process is properly (pursuant to the velocity of the projectile) extended in time so that the physics of the shot is reflected very carefully (including advance aiming of distant moving targets).

Shooting results are stored in a database where they can be recalled at any time for analysis using the built-in system tools.

The next stage of the system development is to make possible training by firing in dynamic scenarios, using combat weapons and live ammunition against visible targets moving on the screen. By using appropriate materials and structures of the projection surface as well as the development of methods to detect the points of bullet impacts on the screen, it will be possible to precisely locate in real time impacts on images of a virtual enemy that has to be engaged.

2. Experimental testing

The use of combat weapons and live ammunition in an enclosed shooting requires special anti-ricochet ballistic panels which are made of rubber.

Because precision detecting position of impact of a projectile on the screen wasn't sufficient in visible radiation for this reason range of infrared radiation is used.

The experiments have been fulfilled by means of a FLIR A655 sc IR camera (image format 640×480, acquisition frequency 50 Hz). Experimental testing was carried out by shooting from a distance of 2 m to anti-ricochet ballistic panel a thickness of 50 mm (Fig.2). The basic material from which the anti-ricochet panel was made of granulated rubber in black, as it will act also as a screen upon which projected the image will be white. In experiments both unpainted and painted white panels were fired upon. Since the aim of the research was to determine the temperature rise at the point of impact of projectile in relation to the background, but not an accurate temperature measurement, emissivity so it had no significant influence. This was confirmed by results obtained when shooting painted and unpainted anti-ricochet panels. In addition to registering the phenomenon of piercing projectile used by the panel IR camera FLIR SC 7600 (format 640×560, acquisition frequency 400 Hz, up to 1600 images in a sequence) set perpendicular to the flight path of the projectile at a distance of 2 m from the panel.

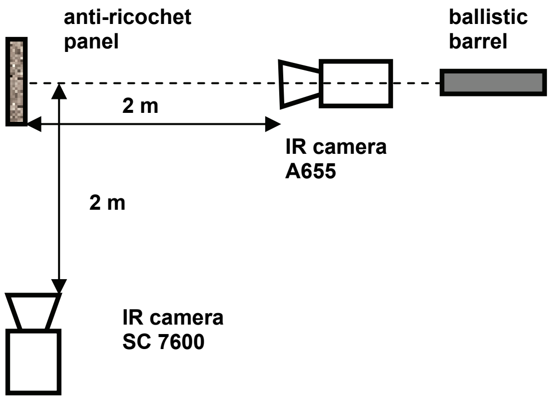

Fig. 2. Experimental set up.

For the test, the company UTM™ (Ultimats Training Munitions) ammunition was used. Shots were fired from three types of ammunition: one of live and two of training ammunition.

Figure 3 shows live ammunition used in the experimental testing.

Fig. 3. Ammunition: a) 9×19mm NATO, b) 5.56×45mm NATO;

Fig. 4. Training ammunitions: a) 9 mm TBR, b) 5.56 mm TBR, c) 9 mm MMR, d) 5.56 mm MMR

3. Results

All projectiles penetrated the anti-ricochet panel but on its surface impact points in visible range cannot be seen, as a result pinpointing these points is not possible. Locations where projectiles penetrated the panel are very well visible on the opposite side of the anti-ricochet panel. The phenomenon of full penetration of anti-ricochet panel by live ammunition caliber 9 mm shown thermogram (Fig.5), who was done by IR camera FLIR SC 7600.

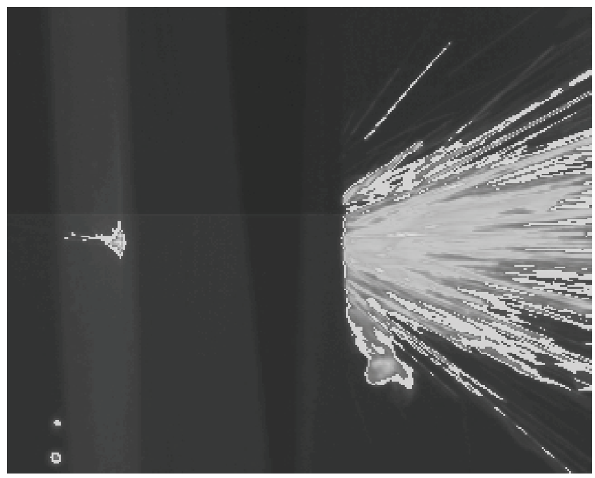

Fig. 5. Thermogram of phenomenon of penetration of anti-ricochet panel through projectile of 9×19 mm NATO

Impact point by projectile is highly visible in infrared radiation. Signal difference of temperature between impact point of projectile (9×19 mm NATO) and background (anti-ricochet panel) of approximately 35°C is visible on temperature profile (see Fig. 6). Similarly in Fig. 7 impact point of training projectile (9 mm TBR) is clearly visible in the infrared range. 9 mm TBR projectile bounces off the panel and does not leave any traces in the visible range.

Any chemical trace is very difficult to see on the panel after impact of 9 mm MMR projectile and the same projectile is beats away from the panel. This is shown on the thermogram (see Fig. 9). The impact location in infrared radiation spectrum can be easily identified, where impact place temperature exceeds background temperature by approximately 2.5°C.

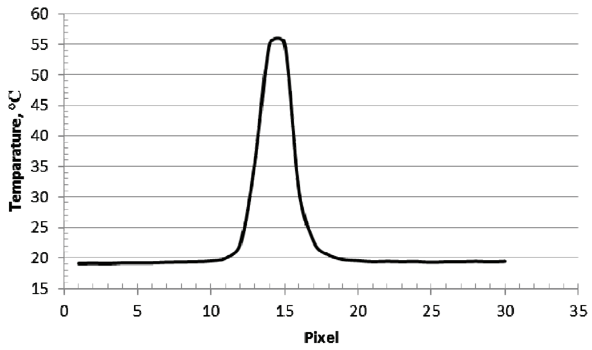

Fig. 6. Surface temperature profile of anti-ricochet panel across impact point of projectile of 9×19 mm NATO

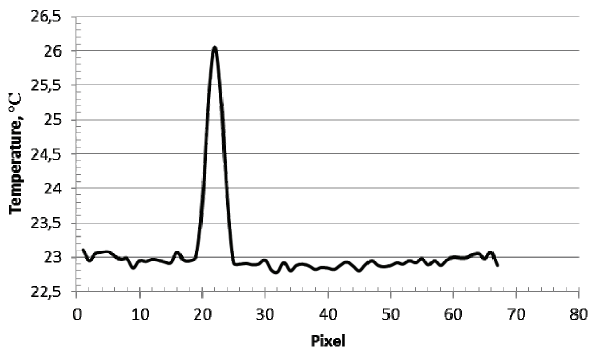

Fig. 7. Surface temperature profile of anti-ricochet panel across impact point of projectile of 9 mm TBR

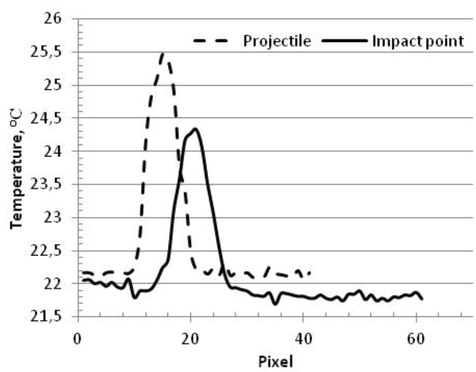

Fig. 8. Surface temperature profile of anti-ricochet panel across impact point of projectile of 9 mm MMR and beat away from panel of projectile temperature

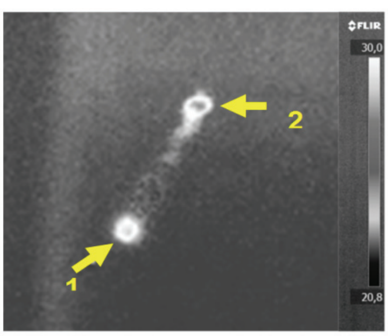

Fig. 9. Thermogram of fragment of anti-ricochet panel during shooting projectile of 9 mm MMR: 1- impact point, 2 – beat away from panel of projectile

4. Summary

As experimental testing has shown through selected results presented in this paper, only application of the use of the infrared range allows the pinpointing of exact locations of impact made by live and training ammunition on anti-ricochet covers made of rubber.

The issue is the length of time the thermal trace is visible at the point of impact.

Due to the thermophysical properties of materials used in the anti-ricochet cover the heat transfer takes place relatively slowly and thermal trace of impact of the projectile is visible from several seconds to several minutes. This makes the registration of impact places and other projectiles near place of previous impact places difficult. To eliminate this problem it has been proposed to use two algorithms in the detection system of Snieznik [2].

The first one allows the control of exposure and then read outs of thermal traces of impact locations of projectiles. Exposure time of thermal traces is regulated by indicating minimum temperature reading at the end of the exposure reading, measured using infrared camera.

The use of this type of detection system allows the creation of an electronic detection system of impact location of projectiles. Short exposure time of thermal traces of impact locations of projectiles on the target make possible register other impacts of projectiles in a short period of time at the same point or nearby. The algorithm also takes into account caliber and type of ammunition, which has a significant influence on the temperature increase in the vicinity of the impact location of the projectile.

A second solution is an algorithm that detects changes in the temperature of a field having a size above 2×2 pixels and value of temperature higher than 2° C above average temperature on anti-ricochet panel. The temperature change appearing on the thermogram visible on the computer screen is automatically recorded by the software as a point of impact and electronically is removed at the next thermogram registered by the thermal imager. Practically the software records only one thermal image from the camera which will be first change of the temperature field. Subsequent changes in temperature fields are recorded as additional impact points of projectiles on a single thermogram. When recording a thermal imager 50 Hz can be registered impact of projectiles with one weapon of 0.02 seconds. The probability that another impact of a projectile in the same location on moving targets on the screen in a time less than 0.02 seconds is practically zero.

These algorithms will be applied to new generations of Snieznik systems developed by MIAT and Autocomp. Due to competition from other companies, we cannot present specific solutions used.

5. References

[1] www.witu.mil.pl
[2] Patent P.412063. Sposób wykrywania i rejestracji miejsc uderzeń pocisków strzeleckich w cel za pomocą kamery termowizyjnej

Received: 05.03.2015 Paper reviewed Accepted: 05.05.2015

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