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A new type of flight simulator for manual command to line-of-sight guided missile

Milos Pavic*, Slobodan Mandic, Danilo Cuk, Bojan Pavkovic

Military Technical Institute (VTI), Belgrade, Serbia

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ABSTRACT

The manual command to line-of-sight guidance system of the antitank missiles requires a human operator in the guidance loop. His task is to track both the target and the missile and to generate commands in order to bring the missile into line-of-sight. The efficiency of the guidance depends on the skill of the human operator. A new type of training flight simulator for manual command to line-of-sight guidance, which realization is based on simulation of the missile silhouette over the pre-recorded videos of the background with fixed or moving target, is given in the paper. Coordinates of the target, read from the recorded videos of the background, are transformed to the real position of the target in the space. These target positions in function of time are input to the mathematical model of the missile movement relative to the target. The calculated coordinates of the missile are transformed to the missile silhouette position on the screen display of the flight simulator. The complete mathematical model and description of the hardware realization are given in the paper.

1. Introduction

The manual command to line-of-sight (MCLOS) guidance system of the antitank missiles requires a human operator in the guidance loop. The operator must track both the missile and the target simultaneously and guide the missile to the target. The missile is steered with a joystick, and its path is observed through a periscope-type telescopic sight. The missiles are usually equipped with a magnesium flare in the base that automatically ignites upon launch and allows the gunner to visually track the fast-moving missile.

In order to efficiently control the missile, the operator keeps the joystick in direction to minimize the missile's distance normal to the target's line-of-sight. When the distance is minimized to half, the operator has to initiate the opposite command in order to control the direction of the missile velocity [1].

The role of the man in the guidance loop has been analyzed excessively in the past. Specially designed flight simulator, for a missile's control system in which an operator controls the missile by stick while watching the target area on television, was described in [2]. A mechanical optical device, driven by an analog computer, projects the target area on a screen, which is viewed by closed-circuit TV. The concept of manual guidance of a launch vehicle from staging to orbit injection with a minimum of computation and display requirements was analyzed in [3]. The guidance scheme consists of three distinct components: computer, operator and display. This man–computer–display system enables the operator to continually generate an optimal trajectory from the vehicle's present state to the desired terminal state.

The MCLOS guidance system requires considerable training and practice for the operator since even a minor disruption in his concentration would likely cause the miss of the target. These guidance systems have limited accuracy on tank-sized targets, even with perfect line-of-sight by the operator. Therefore, this type of guidance requires a training simulator to increase the skill of the human operator and that is not only in the case of military industry but in medical neurological surgery also as presented in [4], pointing out the virtual reality concept. Applications of operator training simulator in nuclear plant and in chemical industry were shown in [5,6], giving opportunity to exercise various scenarios including accident situations.

A training flight simulator design for anti-tank combat simulation and overall CLOS missile simulation model with "6-degrees-of-freedom (6-DOF)" simulation model of short-range missiles have been presented in [7]. The image formation plane was normal to the axis of the camera and moving with the missile. The concept of the simulator treated was based on the transformation of the target position from the target plane to the image formation plane. Accuracy test for infrared search-and-track system that represents one CLOS tracking system was presented in [8] as a form of hardware-in-the-loop simulator.

* Corresponding author. Tel.: +381 11 2051707; fax: +381 65 2425041.
E-mail address: meelos.pavic@gmail.com (M. Pavic).

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Modern electro-optical sensors (cameras) with reliable visual identification at ranges beyond those necessary to even detect the target with the naked eye enable modernization of the obsolete MCLOS guidance system of the antitank missiles. They are entirely passive, sensing energy emitted by target or reflected from the target. With increasing performance and decreasing cost, electro-optical systems are also used into the area of missile guidance. New generation of low-cost "inertial stabilization module (ISM)" provides integrated solution for low-cost inertial "line-of-site (LOS)" stabilization of any payload for mobile platforms including ground, air and sea. Inertial stabilization improves camera images while the camera platform is on the move. The ISM allows real-time computer control during stabilization, enabling closed-loop systems for tracking. The stabilization provided by the ISM allows for the use of higher-zoom cameras for tracking and detection systems aboard moving platforms.

These low-cost inertial LOS-stabilized cameras are used for improvement of the existing MCLOS-guided antitank missile. The operator tracks the missile and the target on the display and generates the steering commands by joystick in order to minimize the difference between the target and missile line-of-sight. The zoom law of the camera is programmed in advance in order to track efficiently the missile and the target for all target positions from minimum to maximum ranges. The sequence of width-modulated control impulses is generated on the basis of the received missile's gyro signal on reference vertical and then it is sent to the missile via the wire link.

This paper presents a new type of the training flight simulator for MCLOS guidance, based on drawing of the missile silhouette over the prerecorded videos of the background with fixed or moving target. Coordinates of the target, read from the recorded videos of the background, are transformed into the real position of the target in the space. These target coordinates in function of the time are input to the mathematical model of the missile movement relative to the target. The calculated coordinates of the missile are transformed to the missile silhouette position on the screen display of the training flight simulator. The complete mathematical model of training flight simulator of the MCLOS-guided antitank missile is given in the paper.

2. Concept of the training flight simulator

The manual command to line-of-sight guidance principle is shown in Fig. 1. The angles φ and φ_T are angular position of the missile and target line-of-sight in inertial space, respectively. The position of the missile relative to the target LOS is proportional to the angular misalignment between the missile and target line-of-sight $L = R(\varphi_T - \varphi)$, where R is the distance from the camera to the missile.

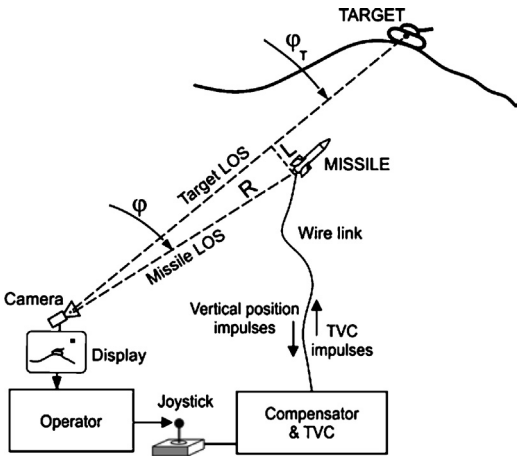

Fig. 1. Camera-supported MCLOS guidance.

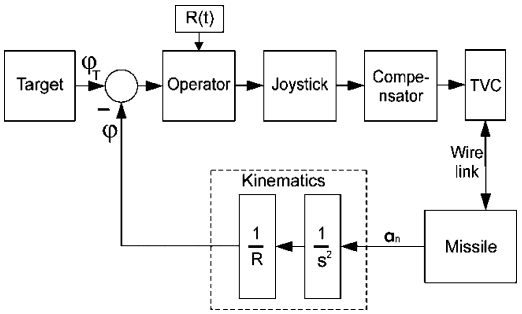

Fig. 2. Block diagram of MCLOS guidance closed-loop.

The block diagram of MCLOS guidance system is given in Fig. 2, and it is very like schematic diagram of the control structure in [9]. Since this guidance loop is unstable, it is necessary to add compensator in the guidance loop [1].

Since the concept of the training flight simulator considered in this paper is based on the video recorded by camera, the target plane is normal to the camera axis, located at the target position in the space. The simulator of the MCLOS-guided antitank missile with prerecorded videos of the background requires image formation of the missile on the target plane. The missile position relative to the line of sight is transformed to the missile projection on the target plane (Fig. 3). The target (T) and the fixed landmark (FL) are given on the target plane. The position of the line of sight relative to the inertial fixed landmark axes system $Ox_0y_0z_0$ is defined by angles χ_{LOS} and γ_{LOS}.

The training flight simulator of the manual command line-of-sight (MCLOS) antitank missile consists of:

- standalone computer,
- two displays (instructor and operator),
- operator joystick,
- data acquisition system.

The block diagram of the training flight simulator is given in Fig. 4.

The missile's steering commands from the operator joystick, being analog signals, are measured by the data acquisition system. These commands are input to the numerical simulation of the missile flight. Based on the calculated missile coordinates in the space, the missile silhouette is drawn on the display monitor over the prerecorded video.

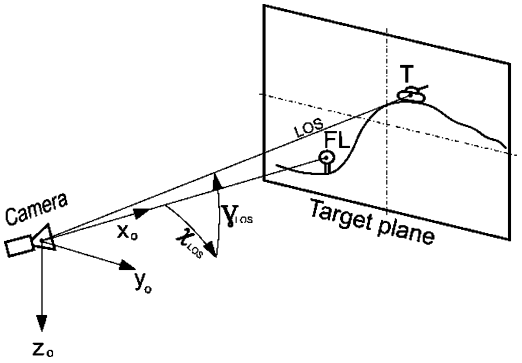

Fig. 3. Angular position of the fixed landmark and target line-of-sight.