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Embedded Tracking System for Ground Moving Vehicle

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Abstract: This paper is concerned with design and implementation of embedded tracking system capable of dealing with slow motion ground vehicle, which is carried out to upgrade the second generation anti-tank guided missile system (ATGM), which based on manual target tracking, to third generation ATGM (Fire and Forget system), which based on automatic target tracking. The nonlinear flight simulation model of underlying ATGM system is described in MATLAB environment. The new technology of system on chip embedded systems are a good platform especially embedded system under linux operating system for real time application especially computer vision application. The tracking algorithm is described using C++ programing language and implemented based on Raspberry pi system. Hardware-in-Loop experimental test is carried out to evaluate and validate a methodology of the proposed work for achieving the overall system requirement of accepted flight trajectory and accepted minimum miss-distance.

Keywords: Raspberry pi, ATGM, Hardware-in-loop, Tracking Algorithm

1. Introduction

Second generation of ATGM missiles required the operator to only keep the sights on the target until impact. In this tracking stage the skills of operator is important factor, which effect on the kill probability of overall system [1]. Generally performance of antitank guided missile systems (ATGM) is measured through many points of view, mainly achieving the minimum miss distance and the capability of the missile to overcome target maneuver [2, 3].

Computer vision is an area of computer science, mathematics, and electrical engineering. It includes ways to acquire, process, analyze, and understand images and videos from the real world in order to mimic human vision. Also, unlike human vision, computer vision can also be used to analyze and process depth and infrared images.

System on chip technology is attract many researchers for embedded system application especially for computer vision applications all over the world. A single-board computer system is a complete computer on a single board. The board includes processor(s), RAM, I/O, and networking ports for interfacing devices. Unlike traditional computer systems, single-board computers are not modular and its hardware cannot be upgraded.

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Single-board computers are used as low-cost computers in academic and research settings. The use of single-board computers in embedded systems is very prevalent, and many individuals and organizations have developed and released fully functional products based on single-board computers.Popular single-board computers available in the market include, but are not limited to, Raspberry Pi, Banana Pi, BeagleBone, and Cubieboard.

In addition, evaluation and validation of experimental work must be achieved using development approach methods. One of these methods is X-in-loop development approach, which have different stages to reach complete system test finally [4]. These stages carried out to have a green light to completely system test, in addition increasing the operator experience in interfacing with different analog and digital circuits and saving time and money. In addition, selection of the suitable embedded system for experimental work is mainly depend on different parameters such as processing speed, RAM memory, algorithm complicity, and embedded system technology, which concerned with software, hardware sensors and there interfaces with embedded plate form. One of more suitable embedded platform is Raspberry pi system, which used for implementing tracking system [5].

2. Problem Formulation

The underlying missile system is represented one of the ATGM, surface-to-surface guided missile, wire command-link, and thrust vector control to correct the trajectory path during flight. The block diagram of 6DOF flight simulation model is shown in figure (1) [1].

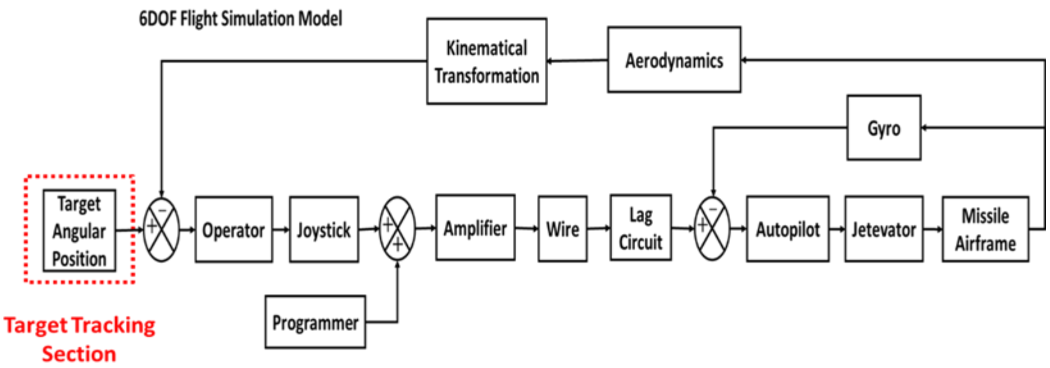

Fig. (1) Non-linear flight simulation model block diagram

The underlying guidance systems utilize a human eye, usually assisted by a magnifying optic with a cross wire, to track the target throughout the engagement. In this manner, the missile tracker is usually looking along the line of the target sight. When the missile launched, as nearly as possible along the LOS, the automatic missile tracker detects any missile deviation from the LOS, and passes it to the guidance computer. This computer determines the correct coded command signal and forwards it to the missile via the command link. During that the operator should be tracked the moving target to have the correct LOS error between missile and moving target. This is mainly depends on the operators skills, and the quality of the manually tracking devices which may be causes reduction in overall system performance.

The present work is concerned with improving the performance of underlying missile system via design and implementation of embedded tracking system without human interface in order to increase overall system performance.

3. Experimental objective

The objective of the presented work is design and implementation embedded tracking system to acquire images, detect and calculate target parameters automatically without human interference, which can be considered as the base of target identified system (seeker). In addition, the proposed system is achieved many advantages such as automatic operation, real time, portable, less weight and size, and low power needed with respect to common systems.

Seeker device is responsible for tracking the required target on board the missile, which used in the third generation of ATGM systems. This upgrading will be increasing to overall system performance and kill probability of the target because once the target identified by tracking algorithm, the missile needs no further guidance during flight (as Fire-and-Forget systems) and the operator is free to retreat.

4. Experimental setup

USB webcam connected to tracking algorithm carried out based on Raspberry pi system, the LOS error send from tracking algorithm to main flight simulation environment using serial communication protocol as shown in figure (2) [6-10].

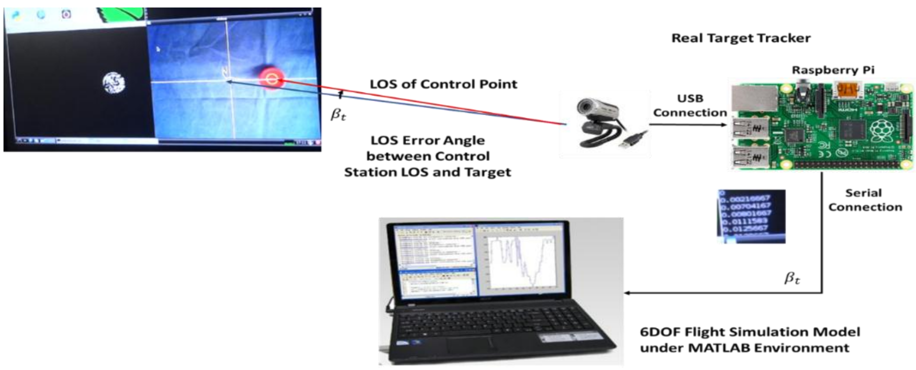

Fig. (2) Hardware tracking system setup

The target scenario is assume target moving in azimuth plane, toward positive Y-axis with velocity 18 [Km/hr.] at distance 2800 [m] along X-axis. In order to have full loop the required target parameters are required to closed the outer loop of flight simulation model in each elevation and azimuth plane (ε_t,β_t). According target scenario, only target angle in azimuth plane (β_t) required to send from hardware system to simulate the real target angle in battlefield, which calculated by human interface. In order to evaluate the proposed tracking system experimental in laboratory condition the output of hardware should be simulated the target scenario as shown in figure (3).

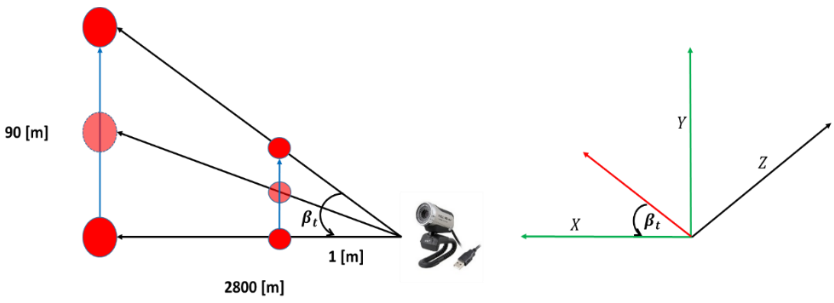

Fig. (3) Target scenario simulation experimental setup

5. Hardware-in-Loop Experimental Test

In order to experimental evaluation, automatic tracking system connected as hardware-in-loop with 6DOF flight simulation model in main simulation MATLAB environment as shown in figure (4).

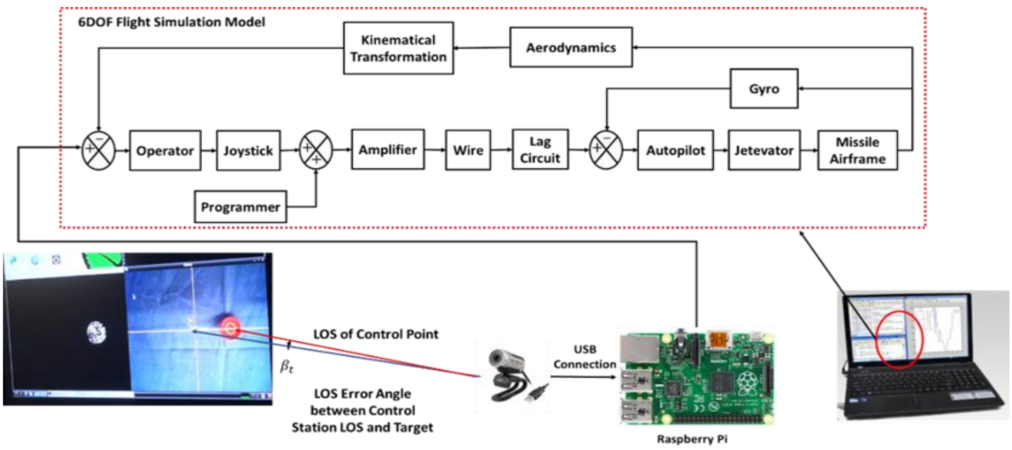

Fig. (4) Automatic target tracking hardware-in-loop setup

The variation of the target angle in azimuth plane between simulation and real target tracking using experimental setup shown in figure (5). According to the target parameters calculated by tracking system, the control action generated to change the actuating system nozzle angle. The variation in nozzle angle causes the change in missile airframe, the nozzle angle variation between simulation and real tracking system as shown in figure (6) and the missile trajectory in pitch and yaw plane represented as shown in figure (7).

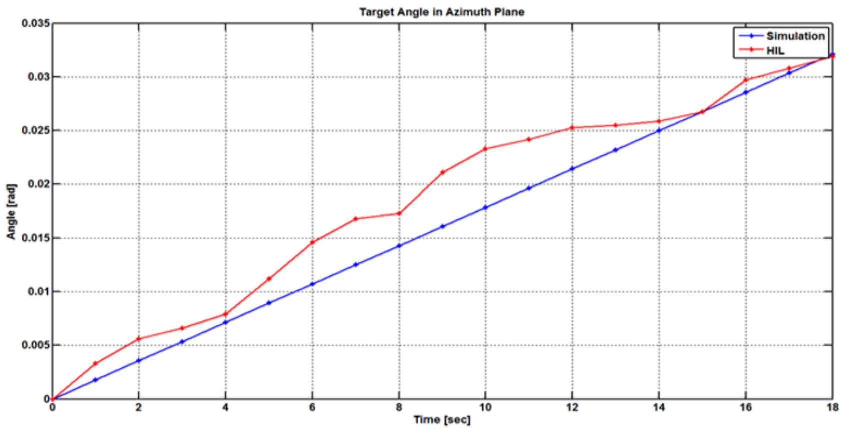

Fig. (5) Target angle in azimuth plane

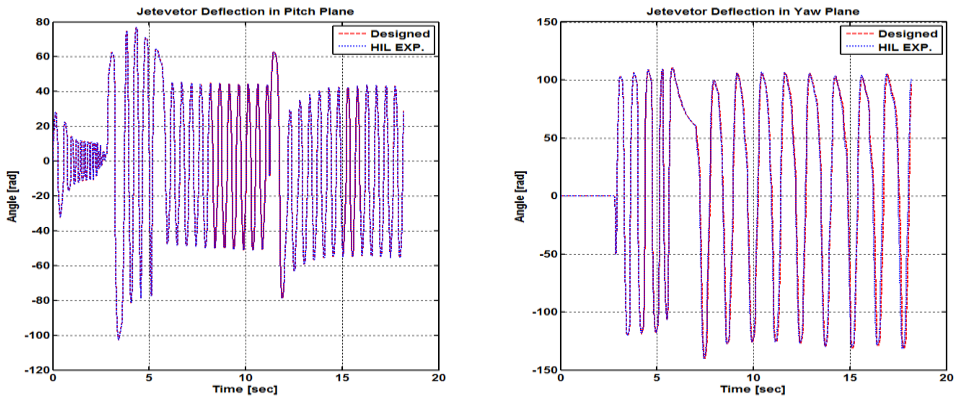

Fig. (6) Actuating system nozzle deflection in pitch and yaw plane

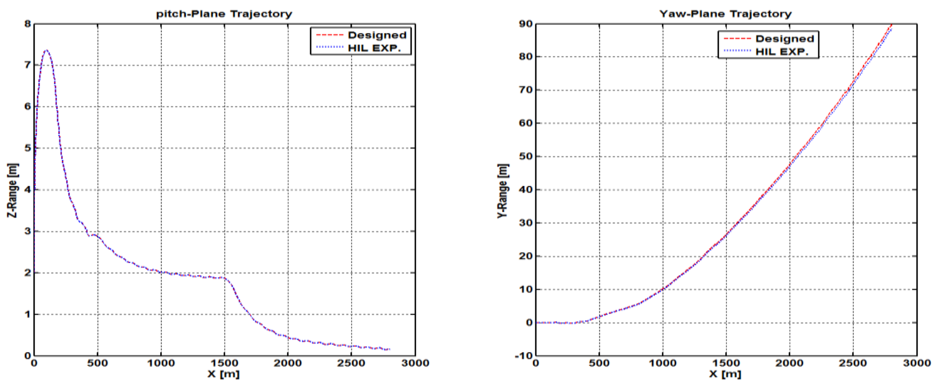

Fig. (7) Missile trajectory in pitch and yaw plane

From the experimental results, the automatic tracking system successes to detect and calculate target parameters in real time, which are send using serial communication to main 6DOF flight simulation environment until the missile impact the target as shown in table (1). The proposed experimental is achieved the requirement of missile performance with accepted flight trajectory and accepted miss-distance. The variation of miss-distance is appeared due limitation of data size transfer between different embedded system and MATLAB environment [6].

Table (1) Automatic real tracking hardware-in-loop results

Moving Target at 2800 [m] with Speed 18 [Km/hr]	Target Tracker	Miss-Distance	Impact Target
Case (1)	Simulated	1.04731	
Case (2)	Real	2.2751	

6. Conclusion

System on chip technology is achieved the designers requirements for embedded tracking system considered as a base of the target identified system (seeker system). Hardware-in-loop is a suitable approach to evaluate and validate the proposed work with non-linear flight simulation model. Raspberry pi system is used for implementation tracking algorithm as a system on chip operate under real time operating system.

7. References

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