LDP Video Target Simulator (LVTS) for Testing Mission Software in Combat Aircrafts

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***Abstract*—Combat aircrafts consist of several avionics systems, where each avionics system comprises functionality systems such as LDP systems, INS-GPS, RadAlt, multi functionality display (MFD) etc. Mission computer is the control unit for all the avionics systems in the aircraft. But each of these avionic systems are costly, difficult to procure, and not economical to have one at each facility, therefore this results in a need for a simulation software which comprises all the features mentioned. One of such avionic systems is LDP (Laser Designator Pod). LDP is an avionics system that allows the pilot to pin-point target location using a laser and guide missile systems. This project is to develop simulators to test the mission software using Qt Creator. LVTS is used to test the mission software for the video interface. The results indicate that the LDP video simulator shows realistic and accurate locations on the map, with only a few meters difference from the actual position from the provided parameters. The calculation of other parameters like distance, azimuth angle, slant angle from the simulation results are recorded to be accurate, which is discussed in detail in further sections.**

Keywords-TCP, UDP, LVTS, LDM stub, LDP.

I. INTRODUCTION

Avionics is an abbreviation for aviation electronics. There are several such systems used on a combat aircraft, and each of these electronic systems serve a unique purpose to help the pilot in navigating and managing the aircraft.

One of such systems is the Laser Designated Pod (LDP). LDP is a hardware intensive system which collaborates extremely well with the physical world environment. It is probably one of the most desired and in-demand weaponry sensors available today, which provides precise data for air to surface weapon aiming. As a result, it strengthens the establishment and unification effort towards resolving the weapon aiming algorithms and also meets with the pilot vehicle interface demands.

Collection of such systems are used in combat aircrafts. A mission computer serves the purpose of a CPU in combat aircrafts, by controlling all these systems using mission software. Mission software requires rigorous testing for validating and proof testing hardware components. But these avionics systems are provided by OEMs, which are usually on the expensive side. This promotes building different simulators for testing mission software which can emulate the function of these avionics systems.

The principal objective of this project is to develop simulators which can help test the mission software available at the facility. This is achieved by developing a simulator which emulates the functionalities of LDP generated video, which is called LDP Video Target Simulator. But to use this simulator standalone, it requires data as input which can emulate the functionality of data being received at mission computers from various systems, such as velocity, altitude, GPS, INS etc. These data are simulated using the LDP data simulator. This simulator is used to test the LDP Video Target Simulator, which is the object of this project

II. LITERATURE REVIEW

UDP finds most of its applications for sending data in embedded systems. But it has its own disadvantages, mainly being packet loss. In order to overcome this packet loss, Transmission Control Protocol (TCP) can be used, as there is an assurance of the packets to be delivered. Although TCP has an edge over UDP, users tend to prefer UDP as it is simpler as well as takes up less space in memory when compared to TCP. Paper [1] has also emphasized the pros and cons of the UDP as well as TCP. This paper has emphasized on how a UDP can be optimized to get more reliability and give optimal performance.

The air missiles are regarded to be similar with unmanned aerial vehicles, which are an application of the surface to air guiding system. Paper [2] emphasizes the various applications of these unmanned aerial vehicles in the rotary wing category. The missiles are guided by the laser, which is used in order to reach the target location. Using the same technology, unmanned aerial vehicles are guided by making few changes considering the laser beam riding (LOSLBR) system. To optimize the tracking, an opto-electronic automated tracking system is used. Likewise, all the parameters of the unmanned aerial vehicle are analyzed in this paper, by considering the transmission of the data to and from unmanned aerial vehicles.

The radar processor receives information from the radar transmitter and stores it. This stored information is not good enough in order to get displayed which in turn gives rise to problems such as distinguishing between noises and the objects. This can be solved by grouping the objects that are of the same type, in other words checking the density and grouping the objects, but this method has high complexity hence it is not advisable to use. To overcome this problem an algorithm is proposed in paper [3] to cluster the objects based on the densities and use it with the MBO algorithm.

The avionics systems have evolved through the recent years, making the aircraft more reliable with these avionics systems. The complexity of these avionic software has also increased when compared to previous years, thereby increasing the prices and the time required to produce these systems considerably. Paper [4] emphasizes on reducing the complexity of these systems along with reduction of the certification constraints, the SPL has offered its help in order to reduce the certification endurance by giving out schemes that provide various management tools.

Paper [5] proposes an experiment where measurement of a wireless relay network is conducted using an unmanned aerial vehicle and the performance of UDP and TCP are compared in terms of their throughput and delay. The experiment is carried out in urban areas as well as non-urban areas. The results conducted in urban areas shows that it is difficult to ensure the wireless link of line-of-sight between the unmanned aerial vehicle and ground access points, whereas results conducted in non-urban areas, show that it is easy to realize the wireless link of the line-of-sight between unmanned aerial vehicle and ground access points, since there is no a high building/obstruction. The numerical results of TCP and UDP performance based on usage scenes are tabulated. It is observed that the UDP packets have a better performance over TCP in terms of throughput, over the wireless relay network that the unmanned aerial vehicle is used from the tabulated results.

III. THEORY AND FUNDAMENTALS

1. Avionics Subsystems

A combat aircraft consists of several avionics which assist the pilot in performing various tasks, which are controlled by a mission computer. Some of these avionic subsystems are represented in Figure 1.

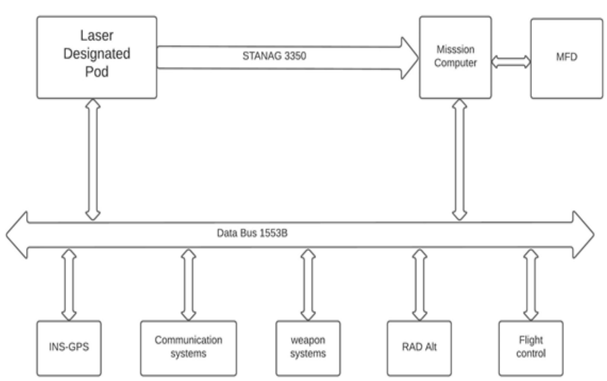

Figure 1: Communication between different avionics systems

1.1 Mission Computer (MC)

The mission computer is developed to take care of mission, sensor and display processing along with information management. It is basically an embedded system used to carry out general-purpose input-output, video, voice, and graphics processing. Communication is established over several buses including MIL-STD 1553B, fiber optic cable and local PCI. The MC is the manager of the avionics system.

1.2 Data Bus 1553B

Data Bus 1553B is a military standard bus. It was originally designed to be used in military avionics, but it is utilized in handling data of subsystems, in both military and civil aircrafts. Bus is designed in such a way that if at some single point failure occurs it should not be a problem for the functionality of the other systems, it has time division multiplexing feature, half-duplex command/response protocol and it can handle up to 31 remote terminals.

1.3 Laser Designated Pod (LDP)

A Laser Designated Pod (LDP) is an avionics system where it projects a laser onto the target location and gives a video feed to the pilot through the MFD so that the pilot gets a clear view of the target location. The laser helps in guiding the missiles onto the target locked by the pilot. The LDP simulator provides slant range, azimuth, elevation, position of the target, distance between target and current location etc. to assess the weapon algorithm performance. It mirrors the characteristics of the original sensor in the simulator provided by the OEMs as closely as possible with realistic outputs. This simulator consists of other avionics and weapon systems and follows the rules laid by actual military standard protocols and Ethernet protocols. The LVTS system receives the current aircraft position and the altitude data from the aircraft's RadAlt, GPS and navigation model (INS) systems as input. This is simulated by using a LDP data simulator. Detector model that receives a laser beam convergence point with respect to the sea-level-altitude and evaluates the target azimuth and elevation angles. Actual slant range is computed using the ground terrain database available in the environment model. Finally, the LDP simulator transmits the datagrams consisting of target position in terms of latitude, longitude, altitude, range, azimuth and elevation to Mission Computer through MIL-STD 1553B.

IV. MODEL IMPLEMENTATION AND TESTING

(A) Working of LVTS:

The working of the proposed LVTS is depicted in Figure 2 The LDM Stub replicates the LDP Data Simulator (available at test facility) to generate aircraft parameters such as aircraft latitude, longitude, target information and slew functionality. LDP Video Target Simulator block simulates the video from actual LDP using the data from LDM Stub. UDP socket programming is used to establish communication between the LDM Stub and LDP Video Target Simulator. The LVTS block is programmed in such a way that it acquires the parameters from the stub as shown in figure 3, target location data, and any slew movement (in order to change the target location), is given through the LDM stub to test the video. The output of the LDP is in the form of VGA which needs to be converted into STANAG3350 format in order to send the data from the LDP to the mission computer this is because the video feed coming from the LDP is a high-quality video hence it is tedious to send it through a VGA hence a stanag3350 is needed for the transmission of video from LDP to the mission computer (which is done at the test facility) is beyond the scope of this project.

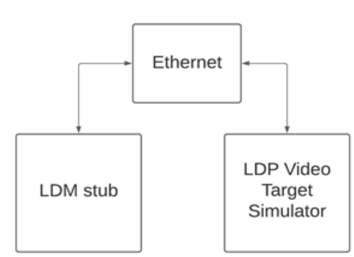

Figure 2: Working of proposed architecture for LDP data and video simulator

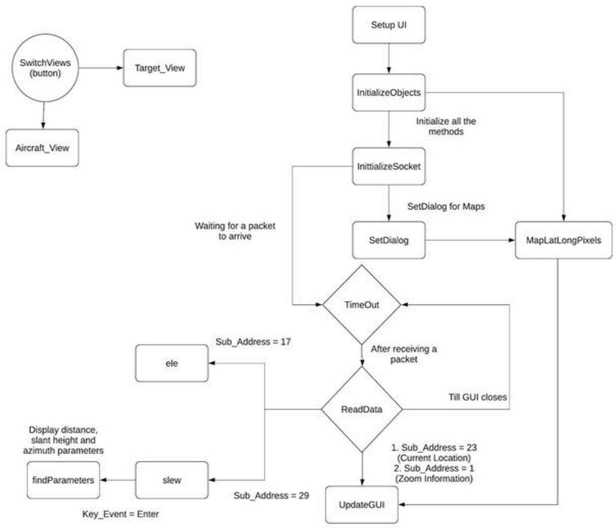

Figure 3: Flow chart of LVTS

(B) LDM Data Simulator (LDM_Stub)

The working of different methods and slots in the LDM_Stub is mentioned in Figure 4. The whole process starts with the Debug Button (also called Setup UI). Slots are methods which depend on a signal generated from an external source. This external source can be a press of a key or press of button on the GUI or an in-built system call sending signals. After these slots are called and executed, the remaining methods are called as mentioned in the flowchart. Different characteristics of this data simulator are realized using various methods.

This simulation window consists of two buttons, one being Start Simulation and the other being *Target_Data ()* which are displayed using an oval in the flowchart. Each of these buttons play an important role in the LDM data simulation.

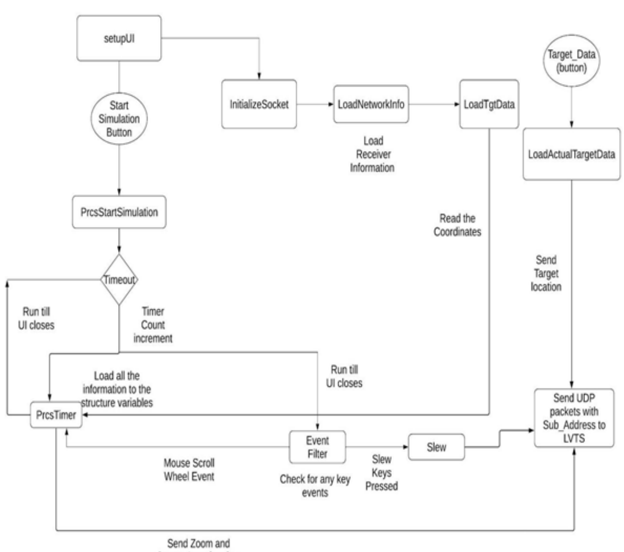

Figure 4: Flow chart of LDM data generator

(C) Data Collection:

1. Satellite Maps: Data used for both LDM Stub and LVTS are fetched from open-source software available online. Offline satellite maps of certain places in Bangalore are retrieved using an open-source website called USGS, which allows any authorized user to fetch the data by defining the boundaries of the required image or the corner parameters (latitudes and longitudes). The satellite images can be retrieved from USGS in various formats. One of such formats is *.TIFF* (expansion for Tag Image File Format), which was chosen only after testing with other file formats. The main advantage of this file format for this project is the ability to view the images with a better resolution even after zooming into the image by varied levels, with an added advantage of reduced file size. Another advantage of TIFF is that it is useful for archiving images for further editing, transferring, and saving without losing image quality. All of these lead to use of this file format over other formats. This map is used to indicate the current location of the aircraft in the simulation as well as to indicate the position of the target that is fed by the LDM data simulator. The image resolution plays an important role while pin-pointing the location of both aircraft and target.

2. Terrain Map: In order to find elevation parameters in LVTS, a .hgt file can be used**.** A file with the HGT file extension is known as a Shuttle Radar Topography Mission (SRTM) Data file. HGT files are comprised of digital elevation models (DEMs), which represent 3-dimensional structures of a surface, usually a surface of a celestial entity and are obtained via the Shuttle-Radar-Topography-Mission (SRTM) by NASA and the National-Geospatial-Intelligence-Agency (NGA). The fundamental use of a HGT file is to generate earth's topographic image and analyze the same. DEMs consist of pixels (raster) or either points (vector), with each pixel or point having an elevation value. DEMs come in different file formats ranging from .csv to .dem to .txt, and can forward lots of other information - like contours or 3D surface models.

"HGT" is the short form for "height". The file is usually named with the longitude and latitude that the image relates to, having a resolution of one degree. For example, the file N12E077.hgt would indicate that it includes data for latitudes 12 to 13 North and longitudes 77 to 78 East. HGT files contain signed integers that give the height of each cell in the grid, usually spread from west to east and north to south.

A sequence of 16-bit signed values makes up a file which is then stored in big-endian byte format, ordered in row major style. This ensures that the samples corresponding to each row are stored consecutively. The dimensions of the dataset held by each file are dependent on the total number of values. For 1 arc-second resolution data is represented by 3601 * 3601 values and 3 arc-second resolution data is represented by 1201 * 1201 values. This project's elevation data is obtained from the 3 arc-second resolution dataset which is represented by 1201*1201 values. Each value corresponds to the elevation measured in meters referenced to the WGS84 geoid.

To find the distance between two coordinates on the surface of the Earth, Haversine's formula is used given as

$$a = sin^2 \frac{d_{lat}}{2} + \cos lat1 * \cos lat2 * sin^2 \frac{d_{lon}}{2} \quad (1)$$

$$c = 2 * atan2(\sqrt{a}, \sqrt{(1-a)}) \quad (2)$$

$$d = R * c \tag{3}$$

(Where R is the radius of the earth, mean radius of the earth, mean radius = 6371km)

Where,

$$d_{lon} = lon_2 - lon_1 \tag{4}$$

$$d_{lat} = lat_2 - lat_1 \tag{5}$$

'lat' and 'lon' are variables that represent latitude and longitude represented by Eq.4 and Eq. 5. a, c are intermediate variables represented by Eq. 1 and Eq. 2 respectively and store the values needed to calculate d as shown in Eq. 3. Eq. 4 and Eq. 5 are used to calculate a.

From two GPS coordinates (Point 1: latitude lat1, longitude long1 & Point 2: latitude lat2, longitude long2) the formula to calculate azimuth (from Eq. 6 to Eq. 9) is given as:

$$azimuth = atan2(y, x) \tag{6}$$

$$atan2(y, x) = \frac{2 \arctan y}{\left(\sqrt{(x_2 + y_2)} + x\right)} \tag{7}$$

$$x = \cos lat_1 * \sin lat_2 - \sin lat_1 * \cos lat_2 * \cos long_2 - long_1 \tag{8}$$

$$y = \sin(long_2 - long_1) * \cos(lat_2) \tag{9}$$

V. RESULTS

Figure 5: Selected area of Bangalore in TIFF File

Figure 5 shows the selected area of Bangalore used in the simulation. This image has been selected in order to perform the task of integrating offline maps. The image here is a TIFF file. TIFF file format was chosen for this project because it resulted in better image quality (resolution at high zoom levels) over other file formats while testing. This map is used to indicate the current location of the aircraft in the simulation as well as to indicate the position of the target which is fed from the LDM data simulator.

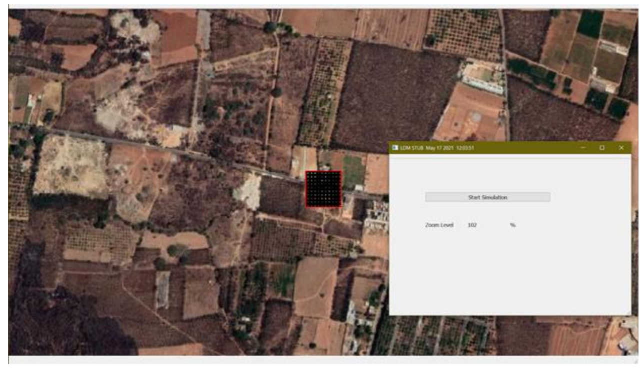

Figure 6: Zoom functionality

Zoom functionalities to the image during simulation is shown in Figure 6. The zoom in function is provoked when the user uses the scroll button on the mouse to zoom in or to zoom out the image when the user scrolls the mouse upwards the image zooms in by 0.05% and when the user scrolls down the mouse the image zooms out by 0.05% (these zoom levels can be changed to various values). Figure shows a zoom in percentage of 102% from the original resolution.

Figure 7: GUI with target data

The GUI used for LDP data simulation is depicted in Figure 7. This GUI helps the user perform tasks such as starting the simulation. This window also allows users to implement zoom functionality as well as the ability to add slew movement. The user can zoom in and zoom out based on the scroll movement on the mouse. The slew functionality is designed by using W, A, S, D keys. The last button in the simulation window is the *Target_Data* button, which fetches the location of the target location (latitude and longitude) and sends the corresponding packet.

Figure 8**:** Obtained parameters with respect to target location

Figure 8 depicts the output when the start simulation button is pressed. The simulation starts by showing a checkered box (with yellow background), which is the current location of the aircraft in the simulation. And when the *Target_Data* button is pressed a second checkered box (with red background) pops up which represents the target location. The UI window also displays parameters such as elevation above sea level of target location, distance between current location and target location, azimuth angle obtained along with slant height. This window also allows users to switch the views from the aircraft's view to the target's location.

Figure 9: Obtained parameters with respect to target location after moving the slew

The Figure 9 shows the slew functions implemented for changing the target location. The target location can be changed by using W, A, S, D keys to move the location along the map. This also updates the parameters displayed relative to the change in target location.

VI. CONCLUSION

The functionality of an actual LDP system is simulated by considering two software components, an LDM stub and LVTS developed by using an open-source software known as QT. The required parameters such as aircraft and target location, target elevation; distance, slant height and azimuth angle between the target and aircraft; and slew functionality are calculated in LVTS. This data is then communicated back to LDM Stub. In conclusion, the validation of LVTS provides the advantage of not having expensive systems to test the mission computer; thereby reducing the R&D costs significantly.

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