

A RADAR TARGET GENERATOR FOR AIRBORNE TARGETS

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ABSTRACT

Radar is an object detection system which detects the objects and predicts certain target parameters. There is a huge need for real time radar target generator for the evaluation of the Radar Data Processor under various maneuvering modes. Our major aim is to develop automatic radar target generator software for airborne targets. This system consists of a Geographical Information System which helps in the integration of the maps and provides a virtual environment for evaluating the performance of the radar data processor. This is achieved by using an open source software platform called Qt. Automatic Radar Target Generator helps reduce the cost of real time implementation. It also helps us to calculate certain target parameters dynamically based on the scenario that is being loaded in the software.

Index Terms—Airborne targets, Azimuth angle, Elevation angle, Heading, Map Integration, Position, Radar, Radar cross Section, Radar Data Processor, Speed.

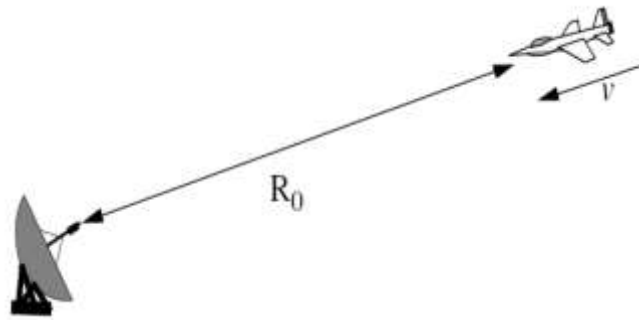
1. INTRODUCTION

RADAR is the full form for Radio Detection and Ranging [1]. Radar was invented in the 1930's and it was first successfully demonstrated during the 1936's, Radar gives out electromagnetic waves in the microwave region which help us to detect the target and other parameters of the target such as the speed, location etc. It radiates energy into the space and detects the echo signals reflected back from an object or a target. This kind of a reflection indicates the presence of an object and also the received echo signals are compared with the transmitted signals in parallel.

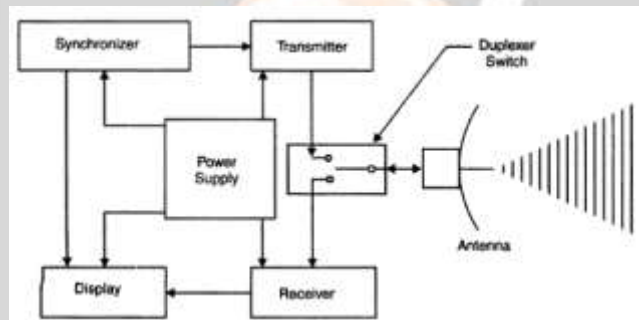
To present the radar data to the operator we use an electronic device known as the Radar Display [2]. The radar display consists of a cathode ray tube, this tube has a electronic gun over its neck. The gun shoots a beam of electron at a phosphorescent screen at the far end. When hit by the electrons, the phosphorescent screen glows. The resulting spot of light can be seen through a glass surface. The circular screen [3] obtained is calibrated in degrees around its edges.

The beam of electron travels out from the center to the edge. The random motion, the trace (electron beam) is matched with the rotational movement of the antenna. When zero degrees is the angle of the trace, the antenna is pointing straight. Each trace at the beginning will match exactly to the point where the radar object lies. Suppose an echo is received [4] it will brighten up the trace for a while. This is known as a blip.

The distance of the blip from the centre of the tube corresponds exactly with the time taken for the radar pulse to travel to the target and come back. So the blip on the screen gives the range and bearing of the target. As trace rotates, a complete picture is made up from the tubes coating. This called as the PPI (plane position indicator) [4]. The PPI is the most common form of presenting radar information nowadays.

**Fig-1: Radar System**

The Radar system mainly comprises of four basic elements and they are as follow: Transmitter, Receiver, Duplexer and Antenna.

**Fig -2 : Radar Transmitter**

- **Transmitter**

Transmitter can also be referred to an oscillator, which is also ‘pulsed’ by the modulator to generate trains of pulses. The transmission line helps to channelize the waveform to the antenna which is then emitted into the space. One antenna can perform the function of both the receiver and the transmitter.

- **Duplexer**

The duplexer protects the damage to the receiver caused by the transmission of high power. It also serves the receiver by transmitting the echo signals which is not done by the transmitter. The duplexer consists of two gas discharge devices, Transmit-Receive and Anti Transmit-Receive. The TR is used during the transmission and ATR directs the echo signal to the receiver during reception.

- **Receiver**

The receiver is of the super-heterodyne type. Low noise RF amplifier is the first stage, such as parametric amplifier or a low noise transistor. The input is fed to the device at the mixer stage. Although a receiver with a low noise front end will be more sensitive, the mixer input can have a greater dynamic range, less susceptibility to overload, and less vulnerability to electronic interference. The mixer and local oscillator convert the RF signal to an Intermediate Frequency (IF). The IF amplifier should be designed as a ‘matched filter’ i.e., its frequency response $H(f)$ should maximize the peak signal to mean noise power ratio at the output. In the IF amplifier, signal to noise ratio is maximized and the pulse modulation is extracted from the second detector and then it is amplified by the

video amplifier to such a level where it can be properly displayed. It is usually done on a cathode ray tube. To provide the range zero, timing signals are also supplied to the indicator. The antennas pointing direction is used to obtain angle information.

- **Antenna**

The radar antenna is the common form of reflectors which is of a parabolic shape. It is fed from source of a point at its focus. The parabolic reflector focuses the energy into a narrow beam. The beam is scanned in space by using a mechanical pointing mechanism of the antenna. Radar also makes use of phased array antennas. In a phased array, the radar beam is scanned by electrically varying current phase across the aperture.

The Radar functions are that it searches and also examines volume of space for potential targets, it detects and determines the target that is present, It measures the position of target range, angular coordinates and sometimes calculates the radar velocity. The tracking, processing and successive measurement [5] of the estimated target is done by the radar. Imaging can also be done by generating two or three dimensional image of targets using processing of the synthetic aperture. Classification, discrimination and identification, determining the characteristics, type, and identity of a target is also done by the radar.

- **Radar Range Equation**

The radar range equation describes the important performance variables of the radar and provides a basis for understanding the measurements that are made to ensure that radar performs optimally. The maximum range of radar is given as follows:

$$R_{\max} = \left[\frac{P_t G_t G_r \sigma \lambda^2}{(4\pi)^3 P_{\min}} \right]^{1/4} \quad (1)$$

Where,

P_t = Power radiated from the transmitting antenna.

G_t = Gain of the transmitting antenna.

G_r = Gain of the receiving antenna.

σ = Radar Cross Section of the target.

λ = Wavelength of the signal.

P_{\min} = the minimum power detected by the receiver.

- **Radar Cross Section**

It is a measure of the radar reflection characteristics of a target. It is equal to the power reflected back to the radar divided by power density of the wave striking the target. For most targets, the radar cross section is the area of the cross section of the sphere that would reflect the same energy back to the radar if the sphere were substituted. RCS of sphere is independent of frequency if operating in the far field region.

The radar cross section [3] can be calculated as shown in the below equation.

$$\sigma = \frac{P_s}{S_i}$$

(2)

Where,

P_s = Total power scattered by the target.

S_i = Power density incident on the target

The Radar has many applications; it is mainly used in the military, scientific and civilian applications. Hence therefore we can say that Radar finds its application mainly in the detection of targets especially in land targets. In our

paper, we are mainly focus on targets which are airborne. We are describing an automatic Radar Target Scenario Generator software. This software can provide the simulated environment for evaluating the performance of the Radar Data Processor. It can simulate the target entities with different flying conditions according to the user input. Such a software may be used by the designers during the development phase and by the validation team during the testing phase.

The Radar Target Scenario Generation software can be used in a synthetic environment which defines the air picture scenarios. It shall be used to define target entities with detection criteria and different maneuvering type such as constant velocity, constant acceleration, level turn, climb, accelerate & climb, accelerate & turn and climb & turn. This software may be used to generate different number and of target entities with different number of path segments. The scenario generation software can be used to store the scenarios in the specified format and it can be used to retrieve the data for input to the other modules.

2. RELATED WORKS

“Radar Target Generator” by **“Steffen Heuel”** [2] , extensive field tests were conducted to test, measure and verify the radar system necessary to ensure both functioning to specification and meeting customer requirements ,which was a very expensive and required a great amount of time. To reduce test complexity and cost, radar target generation becomes more and more important. This paper introduces common approaches for using radar target generators to support research and development, to test and verify existing radars and shows results of measurement equipment operating as a radar target generator. Steffen Heuel completed his study by concluding that fibre optics which was majorly used in many radar tests, lack flexibility in test and measurement. This can be overcome by using the Digital Radio Frequency Memory, However it had some of the drawbacks including the overhead of the cost still lies.

”Research and Implementation of a Testing Method in Target Tracking Based on Multi-Radar Information Fusion” by **“Wang Xiaoxuan,Wang Weimin,Diao Lianwang”** [5], According to the target characteristics in multi-Radar information fusion systems, an index based testing method in target tracking has been proposed. In addition, a testing prototype system has been designed and a testing simulation model has been established. Experimental results indicate the feasibility and rationality of our testing method.

”Tunable Reflect array Cell for Wide Angle, Beam-Steering Radar Applications “[10] by **“F. Venneri, S. Costanzo, and G. DiMassa”**,The antenna is numerically tested and good beam-steering performances are demonstrated within a wide angular range. An electronically tunable reflect array element is proposed in this work to design beam-steering antennas useful for radar applications. A reduced size reflects array unit cell is properly synthesized in order to extend the antenna beam scanning capabilities within a wider angular region. The radiating structure is accurately optimized to provide a full phase tuning range.

“Soft-Core Dataflow Processor Architecture Optimized for Radar Signal Processing” by **“René Broich and Hans Grobler”** [12], efforts are made to overcome the lack of flexibility and performance issues of the current Radar Signal Processors. In this paper, we use an iterative design methodology to propose a novel soft-core streaming processor architecture. The proposed architecture exceeds the clock cycle performance of a commercial digital signal processor (DSP) over a range of typical operating parameters in an RSP application. A custom ASIC implementation of the proposed architecture thus well suites for integration of the transmit/receive modules of active electronically scanned arrays. Multiple-input multiple-output radar systems, enable instant front-end processing mode changes for various operational requirements.

” Advances in Primary-Radar Technology” [13] by **“M.L. Stone and J.R. Anderson”**, adaptive digital signal and data processing techniques to achieve near-optimal target-detection performance. Current primary radars have difficulty detecting aircraft when ground clutter, rain, or birds interfere. To overcome such interference, the Moving

Target Detector (MTD) is used. In addition to achieving near-optimal target-detection performance, it also provides timely weather information.

” **Modern Signal Processing in Radar**” [16] by ” **C. D. Rawat and Anuja D. Sarate**”, reviews the impact of signal-to-interference ratio and resolution on fundamental system goals of detection, tracking and imaging of target by the important core Radar signal processing techniques This paper describes the need and importance of processing techniques in Radar. The various Pulse Compression techniques are discussed and Comparison is known.

”**High Resolution Software Defined Radar System for Target Detection**” [18] by “**S. Costanzo,F. Spadafora,Borgia,H. O. Moreno,Costanzo and G. DiMassa**”, successful validations are presented to demonstrate the accurate target detection capability. Radar systems have been employed for a long time mainly in military operation, like target detection, target recognition, surveillance, and other applications. However, especially in the last recent years, new kind of large-scale commercial applications is requiring the standard radar system operations, but according to significant cost reduction and strong adaptability. A low cost, flexible, compact, and versatile solution to create an L-Band SD Radar system has been proposed in this work.

Hence, by the study of all papers listed above, we can say that the existing system contained A radar display specific to air targets, a Display of stationary radar along with the targets and Views provided were A-Scope and PPI. The major drawback of all the above systems were A radar display specific to land targets, display of stationary radar along with the targets, views provided-were only A-Scope and PPI, we were not able to view targets out of horizontal range of a land-based radar, problems in mapping the real coordinate to screen coordinate and the absence of a Map mode.

In our proposed system, we plan to achieve the capability to generate targets in real-time from stored scenarios, a GIS map integrated Plan Position Indicator (PPI) Radar Display. an interface with a Radar Controller through UDP or TCP/IP, display the path of the moving targets and beam position, support configuration of Radar, Display, Map and Beam parameters, a system to compute various parameters of the target, display of the computed values in a tabular form, support for saving the scenario images & logged data in files.

3. A MAP INTEGRATED RADAR TARGET GENERATOR FOR AIRBORNE TARGETS

A.Qt

Qt [6] is an application framework which is cross platform that is widely used for developing application software that can be run on various software and hardware platforms with little or no change in the codebase, It still retains its state of native application with the capabilities of speed and efficiency. Qt is currently being developed both by the Qt Company i.e., subsidiary of Digia, and the Qt Project under open-source governance, It involves individual developers and firms who work on the advance Qt. Qt trademark and copyright is owned by Digia. Qt is available as an open source and is easy and progressive to work on. Qt is used mainly for the developing of the application software's .This software contains a graphical user interface which helps the user to create interface applications. Qt uses standard C++ with extensions which includes signals and slots that will simplify the handling of event and this also helps in the development of both GUI and the applications related to the server which receive their own set of event information and should process them respectively. Qt also provides the capability for compiling GCC as well as the Visual Studio Suite.

Qt also provides Qt Quick, it includes a declarative scripting language called as the QML which will allow the using of JavaScript to provide the logic. With Qt Quick, rapid application development for mobile device was possible, although logic can be written with the native code as well to achieve the best possible performance. Qt can be used in several other programming languages through language bindings. It runs on the major desktop platforms

and some of mobile platforms. It has extensive support for internationalization. Non-GUI features of the Qt software include SQL database access, XML parsing, thread management and network support.

The Qt Application will contain the main window; The main window shows the icons for the IDE Overview, user Interface, Building and running an example application, and Start Developing in your workspace. Under normal conditions, this is to make you see the source code you have written to the left-hand side contains several icons that lets you select views into your application.

B. ArcGIS

ArcGIS is a Geographical Information System(GIS) that is used for working with maps, creating and using the maps; compiling geographical data; analyzing map information, sharing and discovering geographic information and managing geographic information in a database. The ArcGIS Engine is an ArcGIS software engine, a developer product for creating custom GIS desktop applications. ArcGIS Engine provides application programming interfaces (APIs) for COM, .NET, Java, and C++ for the Windows, Linux, and Solaris platforms. The APIs include documentation and a series of high-level visual components to ease building ArcGIS applications.

C. ARCHITECTURE

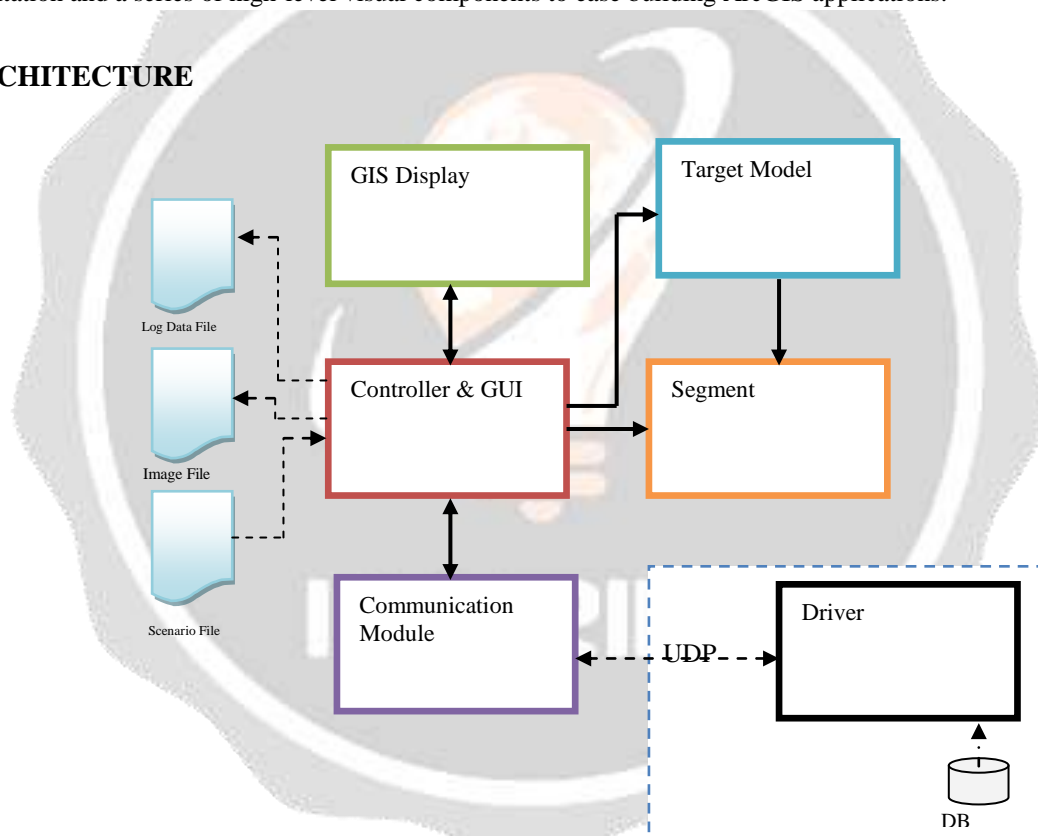


Fig -3: System Architecture

- **Main Module:** The Main Window of the application and is the master controller. It provides the necessary components of the GUI like Menu Bars, Tool Bars & Status Bars to the user for making the interaction with the software.
- **Target Module:** This module defines the Target Model [1]. It encapsulates all target related parameters.
- **Segment Module:** This module captures all Segment parameters. It performs computations for various maneuvering modes as well.

- **Communication Module:** Radar Target Generator [2] software has to interact with a Radar Controller in Real Time to supply target parameters as per request. It enables the UDP/TCP communication which is a two-way connection with the Driver/Radar Controller. This communication has to be run uninterrupted till the Radar Controller is activated, it has to run on a separate thread. Thus communicating Module has to implement a QThread [6] .
- **Radar Controller / Driver:** The actual Radar Controller is not actually made available to the team of development, a generator which produces the request has to be developed in order to supply the data of request to the Target Generator [2] software. This Module will serve that purpose. A request from the Radar Controller will have 3 parameters: time, azimuth [7] & elevation [8]. Targets meeting this criteria should be identified and their parameters are to be computed.
- **GIS Display Module:** This module mainly provides the environment for the display [9] which helps for the visualizing the scenario. This module displays the scenario that is loaded over the 2D GIS map with the information of the latitude and the longitude .It also displays targets' present positions in real time in an animated manner. Thus helps us to display the computed values of the target entities in a tabular column and records the history of the target parameters that are detected as well.

The GUI classes include RTRTG, SettingsDialog, communication dialog, TargetModel, TargetVelocity Target Header, Target Position, UDP socket, TCP/IP server. It has Menu Bar, Tool Bar, Status Bar. Scenario Display [9] extends QGraphics View and displays a PPI [4] diagram in the main window. The system architecture is as shown in fig 3. The Target generator produces programmable test targets which considers three parameters such as azimuth angle [7] , the elevation [8] angle and the. These parameters are used in Radar data Processor to predict the velocity, objects location, speed and other attributes. The display majorly contains the stored scenarios. These scenarios are in the XML format which can be retrieved and modified by the user. The data is sent from the target generator to the display by using the UDP or TCP/IP.

D. IMPLEMENTATION

• Development Approach

The cross platform framework Qt [6] along with MingW compiler is used for the development, considering the GUI aspects and capability of working under different operating system (Linux/Microsoft Windows/Mac). The development is done completely with the C++ 11 programming language. An object oriented approach using UML 3.0 is followed in this development. The development environment includes Qt Creator & Designer IDE, which is part of Qt C++ Toolkit 5.5.

• Implementation

This section mainly deals with the implementation. Here the implementation is done by using the iterative model [12]. Here the examination and the re-examination of the statement given in the requirement stage is done in order to ensure it is being properly implemented. Several of the implementation procedures are elaborated. The operating system choice, the programming choices and details of the coding are also explained. The implementation phase of any development is as important as it yields the terminal solution, which solves the problem at hand.

The implementation phase involves the actual materialization of the ideas, which are expressed in the analysis documents and developed in the design phase. Implementation should be perfect mapping of the design document in a suitable programming language in order to achieve the necessary final product. Often the product is ruined due to incorrect programming language chosen for implantation or unsuitable method of programming. It is better for the

coding phase to be directly linked to the design phase in the sense if the design is in terms of object oriented terms then implantation should be preferably carried out in a object oriented way.

A multitude of algorithms are used in this application. They include azimuth computation algorithm, heading computation algorithm, Elevation computation algorithm, Ground Range computation algorithm, Polar to Cartesian & Cartesian to Polar Conversion algorithms, algorithms for computing velocity components V_x , V_y & V_z , altitude, Probability of Detection and algorithms handling different maneuvering cases to compute the segment duration under various kinematic conditions and other segment related parameters. A discussion on these algorithms is beyond the scope of this paper. The constants that we consider include earth radius, pi, minimum and maximum range, minimum and maximum azimuth, minimum and maximum elevation, minimum and maximum altitude, acceleration, climb, range, duration and other constant values.

E. TESTING

Unit Testing

Unit testing includes the design of the test cases that verifies the internal program whether the logic is functioning properly or not and it also checks whether the program is generating valid outputs or not. This also includes the validation of whether all the decision branches and the code is working properly or not. This is a testing of the structure that relies on the knowledge of its foundation and is inventive. Unit tests includes basic tests at both the component level and something that is specific to a business process, application and system configuration. It also ensures that business perform accurately as per the specification of the document and defines inputs as well as the accurate expected results. Each component is tested independently, without other system component.

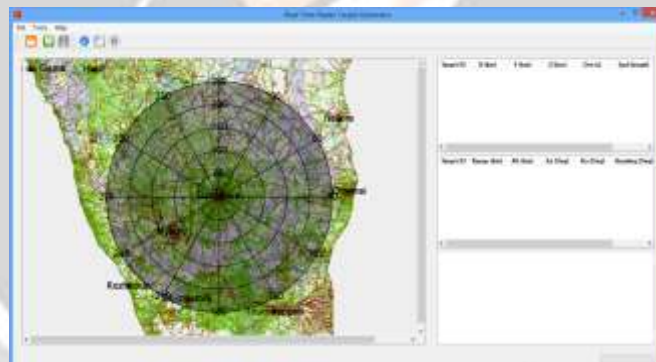


Fig -4: Display of the Main Window

The application when invoked should be able to display the main window displayed in the figure 4 and should be able to display the corresponding tools respectively. The Main window should contain the Menu Bar which includes File, Tools and Help. The Tools Bar should contain the icons corresponding to several functionalities that supports our application. The main window should contain the PPI with a map integration located at a default location [15]. The right side should contain the Tabular Column and a log space which will contain all the computed parameters when the connection is established.

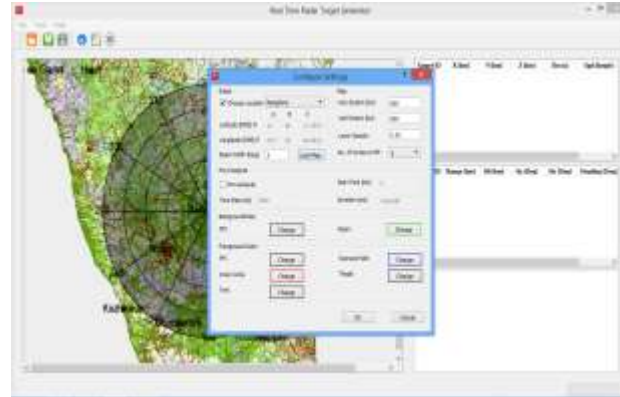


Fig -5: Configure Action

The above is the result of pressing on the Configure which will help the user to configure the necessary parameters of the targets. This mainly is to customize the features available according to the users interest. The application should be able to respond with the necessary changes such as change of the PPI [4] position, Change of the Opacity, Changing the background and the foreground colours, changing the number of circles as well as other parameters. The tests are carried out by inputting several latitude and longitude values so that the PPI can go to that particular corresponding region [12]. Other tests like whether the application takes in invalid values for the beam width [10], latitude, longitude, horizontal and vertical extent is also checked which resulted in the display of a corresponding error message.

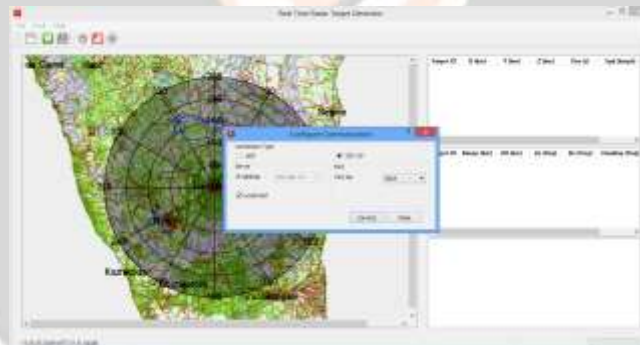


Fig -6: Establishment of connection

The Figure 6 above shows the testing of the connection functionality of the application. The user can connect to a radar operator through either UDP or TCP connection [16]. The user should input the necessary required IP addresses and Port Numbers in order for it to work in an efficient manner. This is tested by inputting both right and wrong attributes which should be given a response to by the display of respective error messages.



Fig -7: Snapshot of beam traversing the scenario

The above figure 7 shows the test carried out to check whether the beam is traversing the scenario and is able to give back the corresponding values to the main window for it to be verified. The output of the test should be in such a way that the beam should move from the start position of a target and should trace only the portion covered by the movement of the beam. The beam width [10] depends on the users input and the values which are read has to be computed by implementing several algorithms and has to be displayed in the tabular column and should be updated as the beam moves from one target to another. The log area should be such that it should contain all the targets information irrespective of whether the beam has already traversed its path or not.

4.RESULT

```

<?xml version='1.0' encoding='UTF-8'?>
<SCENARIO>
  <DATETIME> 29.06.2016 11:47:2 am </DATETIME>
  <MAXRANGE> 250 </MAXRANGE>
  <MINRANGE> 10 </MINRANGE>
  <CONVFACT> 0.9145456 </CONVFACT>
  <CENTREX> 458 </CENTREX>
  <CENTREY> 324 </CENTREY>
  <TARGET>
    <TGHEADER>
      <TGID> 1 </TGID>
      <SGCOUNT> 8 </SGCOUNT>
      <TGTYPE> 1 </TGTYPE>
      <TGSTIME> 0 </TGSTIME>
      <TGRC5> -4.3160 </TGRC5>
      <TGPPID> 2e+08 </TGPPID>
      <TGPRNTID> -12851 </TGPRNTID>
      <TGPARSGID> -12851 </TGPARSGID>
      <TGCLSFN> -12851 </TGCLSFN>
    </TGHEADER>
    <TGPOSN>
      <TGRANGE> 181.833 </TGRANGE>
      <TGZM> 321.116 </TGZM>
      <TGELVN> 2.33744 </TGELVN>
      <TGALT> 10 </TGALT>
      <TGGNDRNG> 181.682 </TGGNDRNG>
      <TGX> 141.423 </TGX>
      <TGY> -114.051 </TGY>
      <TGZ> 7.41602 </TGZ>
      <TGRC5> 1 </TGRC5>
    </TGPOSN>
    <TGVEL>
      <TGSPEED> 900 </TGSPEED>
      <TGHDRNG> 68.7495 </TGHDRNG>
      <TGVMX> 90.6117 </TGVMX>
      <TGVMY> 233.001 </TGVMY>
      <TGVMZ> 0 </TGVMZ>
    </TGVEL>
  </TARGET>
</SCENARIO>

```

Fig -8: XML Scenario File

A Scenario file named An XML file was used to verify the various capabilities. Here 5 Targets were being loaded. These Targets were drawn using Line and Arc segments.

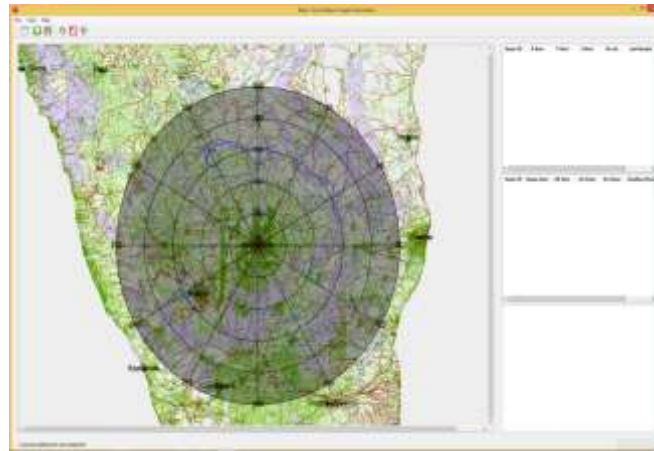


Fig -9: Display of the loaded Scenario

The first target had 8 segments. The first segment of this target was a steady flight (constant velocity). In the second segment, the Target was in an acceleration mode. In the third segment, it took a co-ordinate turn. The fourth segment Target was in a Climb and Accelerate mode. In the fifth segment Target was in Acceleration and Turn mode. The sixth segment Target took Co-ordinate turn. The seventh segment Target was in Climb and Acceleration mode. In the eighth segment the Target took Climb. In all the scenarios the values generated matched the values produced by the operator.



Fig -10: Snapshot of Computation of the target parameters

The scenario file was loaded and the connection was established with the radar operator successfully. Upon establishing the connection, the targets path was traced and the corresponding values were computed. The above figure 8 shows the snapshot of the same.



Fig -11: Snapshot of the radar operators terminal

The above snapshot shows a terminal containing the duration, azimuth and the elevation values. This terminal represents the values computed by the radar operator whose values, we are verifying by using our application.

5. CONCLUSION AND FUTURE WORK

A system for Real-time Radar Target Generator was developed as part of this paper. The Radar Target Generation software shall be used a synthetic environment which defines the air picture scenarios. It shall be used in conjunction with an In-house developed Radar Target Scenario Modeling software to validate Radar Data Processors. The Scenario Modeller defines target entities with detection criteria and different maneuvering type such as constant velocity, constant acceleration, level turn, climb, accelerate & climb, accelerate & turn and climb & turn. This software can generate different number and types (Helicopter, Commercial Aircraft, Transport Aircraft, Fighter, etc.,) of target entities with different number of segments. Most parts of the system are implemented as reusable software components to encourage reuse. Modern application programming paradigms allowed us to achieve high system modularity and better interaction between the user and the system. The system was successfully tested under various target maneuvering conditions and is fully functional as per our aim.

Our future enhancements can be in the implementation of the ArcGIS. The ArcGIS SDK used in the development is a trial version and can be used for development purpose only. Once a licensed version is available the license details have to be included in the code. As an actual radar controller was not provided and the format of interface between RDP and Radar Controller is confidential, the interface used in this project uses only the minimal parameters required for communication and data transfer. The actual interface has hundreds of parameters. Thus the interface has to be modified when the Target generator is used in conjunction with an actual Radar Controller. We can also implement this in the three dimensional framework and also can provide security to the user by providing authentication.

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