Chapter 1

Introduction

1.1 Overview

For a developing country like India, the strengthening of defence is a major goal to place it in the ranks of major superpowers. The technology is evolving each day. A new kind of air attack technology is also emerging. Taking note of that, the importance of air defence has increased several folds in recent times. Tracking of an incoming target while it is moving in a 3-D space, predicting its trajectory and impact point are the major goals. Accurate tracking of an incoming airborne threat is essential for engagement of weapon to destroy that. So the threat destroying probability increases with the accuracy of tracking. Another important aspect is to find out solutions to increase accuracy with the use of optimal resources. Estimating the accuracy of track data, prioritizing tracking sensors accordingly, application of some algorithm to increase accuracy are very much important to make a reliable and efficient system.

Three different kinds of moving object tracking systems are considered in this research work. The Electro-Optical Tracking System (EOTS), the Tracking Radar System (TRS) and the Passive Target Tracking System (PTTS) are three different kinds of tracking systems. Multiple numbers of electro-optical sensor (EOS) track data are considered and applied different techniques for prioritization and finally obtained the most accurate position measurement of the moving target. On EOS track data three different model is established. Erroneous measurement is identified and eliminated then prioritized as per the accuracy of measurement. All the factors that effect the accuracy of measurement of a tracking radar are studied. Error is estimated by considering all the factors and that is used to quantify the accuracy of the measurement. A model is established that takes more than one tracking radar data as input and prioritize them using some unique technique. An time efficient clustering technique is applied for elimination of erroneous measurement. The passive target tracking system consists of a number of electromagnetic wave receiver. Time difference of arrival algorithm is applied for the measurement of the position of the object. Receivers are prioritized to find output the best possible combination that can produce accurate measurement. The model established on PTTS quantifies the error of the measurement and produces a error factor that can be used for prioritisation. To proof all the proposed model a multi-sensor track data generator needs to be established. All models are tested with 100 milliseconds data update rate and can produce satisfactory results. A system is also essential for real-time monitoring and performance analysis of all these models established on three different kinds of tracking system.

1.2 Literature Review

A brief review of the Electro-Optic System, Radar System and Passive Target Tracking System prioritization, clustering and real-time visualization has been described in the following section.

1.2.1 Target Learning, Detection and Tracking

Kalal et al. [1] explained the method of Target tracking, learning and detection. Benavoli et al. [2] elaborated the way of tracking with a-priori information. Janssen [3] explains different coordinate reference systems, datum's and transformations. Rugg [4] explained triangulation method in details. Ottoy and Strycker [5] proposed an improved 2D triangulation algorithm. Ossama et al. [6] established an extended k-means techniques for clustering moving objects.

Viswanath and Sarma [7] improved the k-nearest neighbor classifier. Chomboon et al. [8] carried out an empirical study of distance metrics for k-nearest neighbor algorithm. Dai et al. [9] proposed a method of data transfer over internet for real-time applications. Imtiaz et al. [10] did a performance study of ethernet audio video bridging for industrial real-time communications.

1.2.2 Electro-optic Tracking Systems Prioritization and Clustering

Sharma [11] implemented Electro-Optical sensors in Robotics and Other industries. Target acquisition, localization and surveillance using gimbaled camera is proposed by Quigley et al. [12]. Kim et al. [13] developed an electro-optical system for small UAV.

Position tracking is one of the critical functions of EOSs, the objective of which is to acquire the three-dimensional directions of an object in the geodetic coordinate system. As of now, high-accuracy target restriction has turned into a hotspot in the research.

Maggio and Cavallaro [14] explained Tracking is the process of locating a moving object (or multiple objects) over time at the point when movement is assessed from picture groupings obtained from Electro-Optical sensors (camera), it is called Electro-Optic Tracking.

Ansari et al. [15] defined Electro-Optical Tracking System in short EOTS is an object detection or object targeting system. The term "Electro-Optic" refers to its two working components one is electronic another is optical, both combine works to locate a real object of interest. Cheng et al. [16] categorised EOTS is a type of passive target tracking system. EOTS uses 3 types of tracking methods of an object like edge tracking, centroid tracking, and correlation tracking. It also uses a high-speed camera infra red (IR) camera to detect an object. This device computes the coordinates of the object of interest by the Triangulation method. Patra et al. [17] shown that high maneuvering targets can be tracked using EOTS.

Two or more Electro-Optic tracking systems are required for finding the position. Accuracy of measurement is also important. The principle necessity of terminating instruments is to gain the moving target, lock it and consequently track the objective while the host stage itself is dynamic. During war situations, necessities are to seek and track in a unique condition, quick retargeting-exactness pointing, quick and long-range commitment. Long-range and high determination EOSs increment depth of surveillance.

The EOS is outfitted with Global Positioning System (GPS), Inertial Estimation Unit (IMU) and electro-optical payload. During the time spent confinement, reconnaissance video, and telemetry data are transmitted to the ground station by means of the data link and the administrator controls the electro-optical sensor to look through the object, when the intrigue target shows up on the screen, the object position is acquired with a progression of counts through the photographic perception of target point, joined with attitude measurement data of aircraft, position data of GPS, and azimuth and elevation angle of camera.

Specification of the camera depends on target characteristics, target range and environmental conditions. Instantaneous field of view (IFOV) depends on Detection- Recognition-Identification (DRI) ranges. For throughout day/night vision, day camera and night camera are selected. The availability of EOSs operating in a multispectral band increases surveillance capability in terms of duration and performance. Generally, multi-sensors i.e. Day TV camera, SWIR camera Thermal Images are used in the Electro-Optic Tracking System.

First, Position tracking is one of the critical tasks for a moving object. The position tracking using Electro-Optical Sensor is known as Electro-Optical Target Tracking. Electro-Optical Sensor is able to provide the range of the object and the direction of the object but not the actual position of the object. Therefore, it is necessary to use at least two numbers of Electro-Optical Sensors for finding the position of the object. By having the direction of the object, the Triangulation Method can be applied with a minimum of two numbers of EOS. In the case of erroneous sensors, k-means clustering techniques can be applied to discard the effect of those sensors in the final measurement.

Sensors may be clustered together such as on a submarine, which may have several sonars onboard, or may be carried individually by soldiers this is highlighted by Stein et al. [18]. K-means clustering is used to differentiate the target and the background. Omnia et al. [6] presented a novel pattern-based clustering algorithm that extends the k-means algorithm for clustering moving object trajectory data.

Clustering is a process which is used to group similar type of object from the large dataset. Nirmala and Saravanan [19] defined that cluster is a collection of objects which are similar to each other and dissimilar objects belongs to other clusters.

For a moving object, position finding is always an important aspect. Position tracking is one of the critical tasks for a moving object. The position tracking using Electro-Optical Sensor (EOS) is known as Electro-Optical Target Tracking. Electro-Optical Sensor is able to provide the direction of the object but not the actual position of the object. Therefore, it is necessary to use at least two Electro-Optical Sensors for finding the position of the object. By having the direction of the object, the Triangulation Method can be applied with a minimum two numbers of EOS. In the case of erroneous sensors, K-means clustering techniques can be applied to discard the effect of those sensors in the final measurement.

1.2.3 Radar Systems Measuremennt Accuracy Factors, Prioritization and Clustering

Swerling et al. [20] showed the impacts of RCS fluctuations on radar measurement accuracy. Phenomena of scintillation noise in radar tracking system was elaborated by Dunn et al. [21].

After the world war, radar technologies have evolved rapidly. In the past few decades, the developing countries are investing in this for smooth operation in defence as well as their aviation sector. The flying object should be detected well before the re-entry phase in the atmosphere so that actions can be taken well in time. And for this detecting and measurement purposes, a lot of scientists have experimented and given proven theories to maximize accuracy. Some of the approaches have been discussed here.

Due to the non-linearity of the dynamic state equation of the target, a stochastic nonlinear filter approach has been taken by Mehra [22]. For estimating the launch and impact point of a target, the problem has been tested under different hypotheses with available prior knowledge. Some of the factors making it a difficult task, these are the following. Radar Scan time is larger while the target flight time is shorter. The target can go on sudden changes in its path, velocity, etc. The launch-time of the target is unknown. The trajectory followed by a target can vary as per target type.

The prior information can be launch-time, position and burn out time. The experiment started with predicting a ballistic flight model. Then assess the influence of the various parameters on the trajectory which is known as a sensitivity analysis. The sensitivity of a ballistic object is mostly time-dependent. The studies shown by Dunn et al. [21] that how the different components of target noise affect the radar tracking performance and how these components determine the choice of a tracking system.

The term scintillation refers to the wave interference phenomena. It occurs when the physical dimension of an illuminated object of complex shape represents many wavelengths. The tracking noise is the deviation of the tracking point from the reflective center of the target. The tracking noise consists of servo noise, receiver noise, angle noise, and amplitude noise. Servo noise and receiver noise generated from the Radar. And both angle noise and amplitude noise are target noise.

Servo Noise generated from movement in gears, the structure of mount and shafts. This generated noise is independent of the target. Receiver noise generates from the input impedance of a receiver. It affects the accuracy of radar measurement in a larger way. Angle noise is a tracking error generated from variation in the apparent angle of arrival echo. It is inversely proportional to the range of the target.Amplitude noise causes fluctuations in the amplitude of the signal returned by the target. Those fluctuations are from variations in propeller rotation and skin vibration.

The impacts of target radar cross-section fluctuations on the thermal noise reduce the accuracy of radar measurement. The variation in range, angle are evaluated for the swirling fluctuation models.

The accuracy is computed as the standard deviation, which is then compared with the no fluctuating state. From the analysis, it is found that compare error on probability basis rather than on their standard deviation is more appropriate.

Radar is object detection and tracking system that is used to identify objects by using radio waves and that is to determine what is the range of unknown objects and what angle is there and what is the velocity of that object. Radar systems come in a variety of sizes and have different performance specifications. Anitha et al. [23] shown that it is widely used in the area of air traffic control, navigation, defence sectors, etc.

Radar was developed before and during world war II by several nations secretly. Ghoghre et al. [24] pointed out that the term RADAR was coined by the United States Navy as an acronym for Radio Detection and Ranging in 1940.

1.2.4 Passive Target Tracking System, Localization Accuracy and Prioritization

Kossonou et al. [25] proposed a non-iterative three dimensional positioning algorithm based on time difference of algorithm. He et al. [26] designed a localization algorithm for asynchronous time difference of arrival positioning system. Friedlander [27] did the accuracy analysis of passive localization algorithm.

A fundamental approach presented by Krizman et al. [28] with respect to TDOA considering basic radio frequency position location strategies. To find source location from noisy instances through range differences was proposed by Friedlander [27]. A weighted matrix was derived for the least square estimator and a simulation formed to analyze the results. The observation was only valid if the range difference measurement was unbiased.

An approach presented by Kossonou et al. [25] is a non-iterative method and has less complex computing based on Chan's method [29] for TDOA. Position estimation is done in two-steps, in first related position parameters of TDOA are computed then applied with position algorithm in the second step. The positioning algorithm should be obtained in a perfect channel.

Asynchronous time difference of arrival positioning system is proposed by He et al. [26] where the position was calculated without time synchronization with all the receiver anchor and target nodes. A positional algorithm is developed for a two-dimensional context, considering there are one transmitter and multiple receivers. A set of equations formed from TDOA measurements is solved by the least square method. Here only TDOA estimation error was considered.

Due to the non-linearity of the hyperbolic equation, the TDOA measurement is uncertain. A comparing study between Monte Carlo based method and the gradient search algorithm was presented using a non-linear least square framework by Gustafsson and Gunnarsson [30].

A detailed derived method was presented by Potluri [31] to find a position with four fixed stations. A derived model was formed from the hyperbolic equation and the simulation result shows the accuracy level of the experiment.

1.2.5 Brief Review of Real Time Multi-channel Remote Visualization System

Dai et al. [9] proposed a method for real-time applications to transfer data over the internet. Similar concepts for transmission can be used for the intranet in a local area network. The performance of a web-based real-time system solely depends upon the efficiency of the data exchange over the internet. Here data priority levels defined by the client are implemented in RMI. As per the data priority level in RMI, server transfer data objects.

In the case study, an industrial reactor process simulator is used. A remote monitoring system is for showing the output at a remote location. And illustrated the proposed data transfer mechanism.

Imtiaz et al. [10] presented the performance of Ethernet video bridging for industrial real-time communication.

1.3 Problem domain

In this section, we would like to discuss the problem domain of this investigation.

1.3.1 Electro-Optic Tracking Sensors

To test the flight behavior of any flying object, it is necessary to track its motion, whether it is moving on the desired path of desired (or planned motion) or not. There are different systems that can track the location like Radar, EOS and Telemetry etc. To measure the position of a moving object Electro-Optic Sensors (EOS) is one of the popular tracking instruments. EOSs are able to find the object in optical domain and produce the direction of the object but not the actual position. A minimum of two numbers of EOS is required to find the object position.

The triangulation method can be applied to get the position of the object with the measurements of direction by at least two EOS. EOS returns the direction of the flying object i.e. azimuth and elevation angles with respect to its own position and local axis. One cannot use this data directly for the triangulation method as each sensor has its own local axis. So all these EOS measurements should be aligned to a common reference axis before applying the triangulation method. The accuracy of position measurements by the triangulation method directly depends upon the direction measurement accuracy and alignment accuracy of EOS. One erroneous EOS input may contribute a huge shift in position measurements. We tried to find out a method of finding EOS measurement accuracy to improve the accuracy of flying object position measurement.

To increase the accuracy of measurement, multiple sensors can be used. There are several data fusion techniques for getting an accurate measurement. The main advantage of choosing multi-sensor data fusion over a single sensor is that it improves accuracy, improves precision and also reduces uncertainty. But the accuracy degrades if the erroneous measurements cannot be identified. Further proper prioritization can improve the accuracy. So the challenge is to identify erroneous measurement, and finding the criteria for prioritizing them.

1.3.2 Tracking Radar System

RADAR is the acronym of Radio Detection and Ranging. Yapici [32] defined RADAR as a device that uses radio waves to determine how far an object is present, velocity and proper positioning of the object. Curry [33] elaborated that RADAR consists of a transmitter that transmits the radio waves and there is a receiving antenna. A receiver is used to determine the properties of the radio waves. Sometimes the same antenna is used for both transmitting and receiving. The radar signals that are emitted touch the object and is reflected back, but some of them gets penetrated. The ones that are reflected make the RADAR work.

Radar is used to identify objects by using radio waves and that is to determine what range of unknown objects is and what an angle it is there and what is the velocity of that object. Radar can be simulated by the small inexpensive Arduino. The main difference between the Radar and the EOTS is that the EOTS gives a high precision and more accurate position of the object in a low range or height.

Predicting the projectile of the target and hitting point should be taken care of by the target acquisition radar instantaneously so that damage can be minimized.

Hence the better accuracy in detecting the target in the re-entry phase, the lesser the damage. Accuracy should be maximized to avoid any kind of disaster.

Accuracy is the degree of observation between the measured position and velocity at a given time with respect to the actual position and velocity. The degree of radar accuracy is determined by the resolution of the radar system. Tracking performances can be expressed in terms of the resolution also. It is the ability to track two different objects which are very close to each other, either in angle or range.

Multiple radar data fusion is the process to combine all the data which are provided from several radars to produce the most specific information. Hall and James [34] explained the application areas of data fusion. Data fusion is an emerging technology applied to the Defence areas such as battlefield surveillance and guidance, automated target recognition, and control of autonomous vehicles. It is also used in non Defence applications such as monitoring of medical diagnosis, complex machinery, and smart building. Radar is a detection system that can easily track a moving object and determine the range, azimuth, and elevation. There are a lot of factors that affect the radar measurement. Establishing radar measurement accuracy model in range, angle and velocity are essential for finding the position measurement accuracy. In multi radar scenario identifying the erroneous radar and eliminating that for further processing will improve the efficiency as well as the accuracy of the system. Prioritizing the radar considering the error contributory factors can further improve the overall measurement accuracy. We looked forward to measure the accuracy of individual radar, criteria for eliminating erroneous radar and prioritize for further processing.

1.3.3 Passive Target Tracking System

For measurement of target location, Deligiannis and Louvros [35] explained that there exists several passive target localization techniques likes Time on Arrival (TOA), Angle of Arrival (AOA), Time Difference of Arrival (TDOA), Received Signal Strength (RSS), etc. and also some hybrid techniques which are a combination of two different localization algorithm mentioned above.

Shin and Sung [36] pointed out taht for an exact positional value, the TOA method requires strict clock synchronization between source and receiver station. To address synchronization problem and to improve the accuracy of a target, TDOA technique is used. It is a cross-correlation technique and is also known as hyperbolic position location techniques. The accuracy level of this TDOA technique should be known so that the zone in which object exists can be predicted precisely. The accuracy of the object position measurement depends upon the mutual location of the receivers and the object of interest. Finding the best possible location for setting up the receivers is an important task. We tried to find out the criteria for establishing error factors and prioritizing them for getting best combination of receivers for minimum possible error in object position measurement.

1.3.4 Multi Sensor Track Data Generator

One of the primary objectives of any test related to defence and flight operation is safety, data tracking and success. Those objectives should meet by all means. Simulation plays a pivotal role in the effectiveness of a mission. It is a tool for achieving mission success. It helps before an event occurs as well as in post-mission analysis. This benefits the organization to look into the desired target result before a final test. From the simulation, it can verify that the data displayed are pertinent, easy to analyze and function well with desired procedures. So it gives a prediction about the upcoming results. This importance of simulation motivated us to develop a well-structured simulator for the smooth operation of tracking data, data validation and video display data synchronization.

To do the experimentation an integrated multi sensor simulator is essential. The simulator should able to produce the data as it comes from Electro-Optical Sensor, Radar and passive target tracking receivers.

1.3.5 Real-time Multi-Channel Remote Visualization System

To provide the multi-sensor tracked data in different planes for real time monitoring and analysis different visualization application needs to be developed. Sensors are deployed in different geographical locations. Experts want to monitor from the central location. An integrated system is required that can fulfil the requirement of the operators as well as the experts for visualization and analysis. An efficient solution that is capable of handling ten different plans of views of the multi-sensor tracked data to operate in real-time should be efficient and reliable. Bandwidth usage should also be less and should be capable of handling multicast data frames. Another point needs to be considered that the Maximum Transmission Unit (MTU) defined in the network switches and routers. Overall, making an efficient and reliable real-time multi channel visualization system is an challenge.

1.4 Motivation and Objective of the Thesis

Moving object tracking is an important task for surveillance, performance analysis of any airborne vehicles, detection of any inbound threat, engagement of anti threat equipment, detection of the origin of the enemy threat launch point and etc. There are many well known and widely used moving tracking systems globally. The efficiency of using all kinds of tracking systems and the results of the purpose of using them mostly depends upon the accuracy level of the measurements of the tracking sensors. Some time to get a reliable result instead of one, a number of sensors are used but the main challenge comes in to play when one or more sensor produces erroneous measurements due to any reason.

Electro-optical sensors, Radar and passive target tracking sensors are considered for experimentation. Seven numbers of electro-optic sensor, fifteen numbers of different radar and seven numbers of receivers for passive target tracking system is considered. As all the radar produces output with respect to itself so the first job is to make all the measurements in common reference point. Efficient coordinate conversion formulation is an important task for real-time operation. The formulation of the triangulation method of finding a position with two or more than two numbers of the electro-optical sensor is a challenging task. Localization using hyperbolic equation solving for passive target tracking is a time-critical matter.

In this multi-sensor scenario, separate experimentation is carried out for each kind of sensor. Here I have tried to find out some different techniques for finding sensors with erroneous measurements of all three kinds of moving object target tracking systems. Criteria for eliminating erroneous sensor differ with its working principle. No other previous work focused in this direction for the multi-sensor scenario. Data fusion and K-means clustering techniques are very well known and widely used in different fields. K-means algorithm for eliminating erroneous sensor is an approach for making data fusion more efficient and improving the accuracy.

As all the sensor works in real-time and located in different geographical locations an efficient system is required to visualize all sensors measurements in different plans and from the different locations. For this motivation came to develop an efficient real-time visualization system with multi-channel of views as per the viewer's choice.

1.5 Contribution of the Thesis

A major contribution of this research work may be categorized into four different parts. Three different kinds of moving object tracking sensors are considered for experimentation and one real-time remote monitoring system is designed for visualization. A different approach is applied to all three kinds of object tracking sensors for prioritization. Using this sensor priority, erroneous measurements are discarded and the accuracy of the object location is improved.

1.5.1 Prioritization and Elimination of erroneous sensor using perpendicular distance method

For experimentation, seven numbers of electro-optical sensors are considered. Firstly all sensors measurements are considered for triangulation for finding the object location. The projection is drawn on each sensor's measured direction of the object. Then perpendicular distance is calculated from object location to the measured direction of the object for all the sensors. Now all the sensors are prioritized as per the perpendicular distance. If the perpendicular distance is above the threshold accuracy level then that particular sensor is eliminated and fresh triangulation method applied on the rest of all sensors measurements. So the more erroneous measurement is eliminated and accurate object location is achieved.

1.5.2 Application of clustering algorithm for the elimination of erroneous sensor

In this experimentation also seven numbers of electro-optical sensors are considered. All sensors measurements are considered for triangulation and object location is measured. K-means clustering is applied to all the seven measurements. The centroid of the largest cluster is considered as the object location. The erroneous data from other sensor are automatically eliminated.

1.5.3 Improvement of object location measurement accuracy with triangulation and Clustering techniques

The triangulation method takes a minimum two numbers of sensor measurements for calculating the location of the object. A total of twenty-one combination is obtained from seven number of sensor measurements taking two sensors at a time. Accordingly, twenty-one number of object location measurements are calculated with only seven numbers of physical sensors measurements. K-means clustering algorithm is applied with all the twenty-one object locations and it produced an improved result of object location measurement. The accuracy achieved in this approach has been quite satisfactory.

1.5.4 Factors and their impacts in Radar measurement accuracy

In multi radar scenario, primary task is to find out methods of converting measurement of all radars into a common frame of reference. We tried to find out the factors and their impacts in the radar measurement accuracy. Error model is established by considering range, angular and velocity measurement error factors. Some environmental effects that leads to measurement inaccuracy is also studied and assessed their impacts in measurement accuracy. So all factors and their impacts in radar measurement accuracy is used for prioritizing radars and further that priority can be used for further applications in multi radar scenario.

1.5.5 Clustering technique for elimination of erroneous measurement and improvement of accuracy

Another major contribution to radar measurement focuses on data fusion using the clustering algorithm. The centroid of the largest cluster is considered as the object location. The erroneous radar measurements are automatically estimated. A total of fifteen radars are considered of different measurement accuracy levels with added random measurement noise and bias in all range, azimuth and elevation measurement. Implementation of the K-means clustering algorithm is successful and it produces accepted results in all different cases.

1.5.6 Prioritization of passive target tracking receivers for minimum possible error boundary hence improves accuracy

The passive target tracking system is simply a group of electromagnetic signal receivers. There are different kinds of passive target tracking system available. In this experimentation Time Difference of Arrival (TDOA) approach is considered. All the receivers are time-synchronized at the nanosecond level. After receiving the signals, it is time stamped. Then that time stamped signal is passed to the server for co-relation. By co-relating all the signals, time difference between them is calculated. Taking input from four receivers position of the transmitter ie the target is calculated by solving hyperbolic equations. A total of seven numbers of receivers is considered for experimentation. So a total of thirty-five combinations are obtained from seven number of receivers taking four at a time. In this approach total, thirty-five object positions are calculated and for each of this position measurement, average range difference error is calculated. A unique relation between target position measurement errors with the average range difference error is established.

With the help of this relation, receivers are prioritized and four high priority receivers could be placed in best geographical locations. By considering four high prioritized receivers minimum target position measurement error is achieved. An attempt is focused to draw the error boundary and error factor of target position measurement with the range of the target. Experimentation results show that the error factor is varying linearly with the range of the target.

1.5.7 Multi Sensor Track Data Generator

To establish any technique, several sets of input data is required. But sometimes it is difficult to get real data for evaluating the propped model due to security. Best solution for that is to use a simulator. In our experimentation multi sensor track data is the input for each of the model. Existing simulator are capable of generating only one sensor tracked data at a time. Multi sensor tracked data should be generated for the experimentation. Importance of simulation motivated us to develop a well-structured simulator for the smooth generation of multi sensor tracked data. The developed multi-sensor tracked data generator simultaneously produces twenty numbers of electro-optical tracking sensor tracked data, twenty numbers of radar tracked data and forty numbers of passive target system tracked data. It operates in 100 millisecond update rate.

1.5.8 Real-time multi channel remote visualization system

Three different kinds of sensors are considered and all these moving object tracking sensors work in real-time. All of them can produce output at 10 Hz. It means update rate is 100milli seconds. All the sensors are located at different geographical locations. There are different important measurement parameters needs to be monitored. So visualization at operator console as well as at a central location in different planes is required for monitoring and analysis. Proposed real-time remote visualization system is capable of showing a total of ten different views simultaneously as per the interest of the viewer. It can be deployed as many number of locations as required without overloading the bandwidth of the network as it transmits multicast packets. Packet sequencing and image processing technique is adopted to make the system more efficient and thoroughly tested for reliable real-time performance.

1.6 Organization of Thesis

In this thesis, three different kinds of moving object tracking systems are considered namely the Electro-optic system, Radar system, and Passive target tracking system. To improve the measurement accuracy different techniques are adopted to prioritize the tracking sensors. Real-time visualization of tracking sensor measurement is done through Display on Demand system. An ontology knowledge base is a build-up for further future improvement. The whole work in this thesis is subdivided into seven chapters.

Chapter 1 (Introduction)

This chapter provides a brief overview of Electro-optic, Radar and Passive target tracking systems, literature review, research objectives, a summary of contributions and organization of the thesis.

Chapter 2 (Research Methodology)

In this chapter, position measurement techniques of different moving object tracking systems have been described. Different co-ordinate system and conversion technique are discussed. Triangulation algorithm, Data fusion, and clustering techniques are presented in this chapter.

Chapter 3 (Electro-Optical Tracking System)

Electro-optical sensors are electronic detectors that convert light rays, into an electronic signal. They are used in many industrial and non-industrial applications. Electro-optical tracking system uses electro-optical sensors and by triangulation method finds the position of a target. Third chapter consists of three different proposed models related to electro-optical tracking system prioritization, elimination of erroneous system and improvement of measurement accuracy.

Chapter 4 (Tracking Radar System)

This chapter is related to Tracking Radar system. In this chapter two models are proposed. One is for the establishing error model and prioritization on the basis of measurement accuracy. Another model is focused for finding the technique for elimination of erroneous system and improvement of accuracy.

Chapter 5 (Passive Target Tracking System)

Fifth chapter is related to passive target tracking system. Minimum four passive receivers are required to calculate the position of the target by time difference of arrival algorithm. We considered seven such passive receivers for our experimentation. A model is established for finding a group of receivers for best possible error boundary and achieving more accuracy.

Chapter 6 (Multi-sensor Track Data Generator and Real-time Visualization System)

Sixth chapter is consists for two support systems those are used for successful experimentation of all the above mentioned proposed models. First one is the multi-sensor track data generator. It produces the track data of all the three kinds of tracking sensors. It has the provision to control the data flow rate and selection of numbers of active sensors. Another model is for visualization of all the track data for real-time monitoring and analysis.

Chapter 7 (Conclusion and Future Scope)

Seventh and last chapter draws the summary of the proposed research work, limitation of this research work. Also draws the conclusion of the whole research work and shows the path for further research.