A Review Paper on Localization Algorithm for Multilateration System

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Abstract**—***This paper is focused on localization algorithm for multilateration (MLAT) system for the aircraft traffic control (ATC) operations. MLAT is a proven technology that has been in use for many decades. The multilateration system was developed for military purpose to locate the aircraft accurately. The provided localization algorithm locates a source based on intersections of hyperbolic curves, which is defined by TDOA (time difference of arrival) of a signal received by a number of sensors. The mathematical equations of this method, is introduced. Furthermore, the provided hyperbolic localization method performs better than Chan and Taylor series method. In this context, some simulations are performed. As we know localization is very important factor in aircraft applications. In this paper basically we focus on the objectives and problems of previous existing approaches and try to device method to resolve those problems.*

Keywords—Multilateration(MLAT), Time of Arrival(TOA),Time Difference of Arrival(TDOA), Localization, Air Traffic Control

I. INTRODUCTION

Several different position location (PL) technologies present themselves as candidates for a mobile radio PL system. However, radio frequency (RF) PL systems have dominated the field because they offer advantages of relatively low cost, ease of integration and potentially high accuracy. Radio frequency PL techniques also work with the existing cellular/PCS infrastructure, eliminating the need for external network implementations. Furthermore, radio frequency systems operate with limitation .One such case in which RF PL methods completely fail, is when the line-of-sight (LOS) to the source is not available. Radio frequency PLSystem attempts to locate a source by direct measurements on radio signals travelling between the transmitter and the receiver. These RF PL systems use time, phase or frequency measurements to first estimate the direction or range information of the signal propagation path, then utilize estimators that provide PL solutions from the measured data. The most widely used RF PL technique for geolocation of mobile users is the hyperbolic position location technique. The hyperbolic PL technique, also known as the time difference of arrival (TDOA) PL technique, utilizes cross-correlation techniques to estimate the TDOA of a propagating signal received at two receivers. This delay measurement defines a hyperbola of constant range difference from the receivers, which are located at the foci. When multiple receiving stations are used, multiple hyperbolas are formed, and the intersection of the set of hyperbolas 1 2 provides the PL estimate of the source. The hyperbolic position location technique offers the advantages of not requiring additional hardware or software within the mobile unit, ability to resolve ambiguities in the PL estimate and minimizing the effect of noise within the mobile radio channel. Many organizations are developing competing products to comply with the FCC's E-911 mandate, which requires U.S. cellular carriers to provide location information of phone calls, effective from October 2001. The accuracy required is 100 meters or better. Many of these products will implement the above-mentioned time difference of arrival technique for locating a mobile with varying degrees of accuracy. Methods for calculating the TDOA and mobile position have been reviewed previously [1][2]. Some methods calculate the two dimensional position and others the three-dimensional position depending on the degree of simplicity desired.

II. LITERATURE REVIEW

Multilateration is a surveillance technique that is based on the measurement of the differences in distance of two stations at known locations by broadcasting the signals at known times. The measurement of absolute distance or angle, and measuring the difference in distance between two stations results in an infinite number of locations that satisfy the measurement. When this possible location is plotted, it forms a hyperbolic curve. For locating the exact location along that curve, it relies on multiple measurements, so a second measurement taken from a different pair of stations, produces a second curve. This second curve will intersect the first. When these two curves will intersect, a small number of possible locations will be seen.

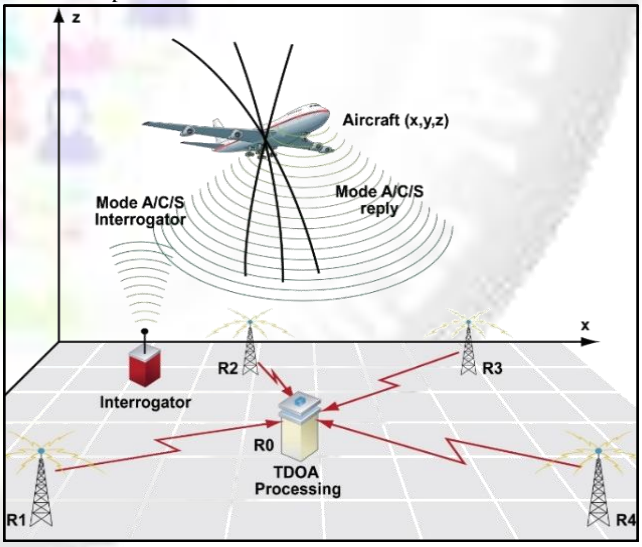

Fig. 1:Multilateration System using in the aircraft

Here, we can see a transmitter on the aircraft. Four receiver R1,R2,R3 and R4 . Here, it uses mode A/C or Mode S signal for interrogation. And R1,R2,R3 and R4 are receiving a signal from the aircraft and a TDOA processing unit(central processing unit) calculating the aircraft position from the TDOA(Time difference of arrival) of the signal at different receivers. When the four receiver detect the aircrafts signal, they will estimate the 3D position of aircraft location by calculating the intersections of the resulting hyperbolas.

MLAT application provides a source of airport surveillance information for safer and more efficient management of air traffic at airports. Concerned airport ground station need to be equipped and informed, along with the aircraft, about the position of the aircraft. MLAT supports ground conflict detection by providing frequent updates of aircraft positions. The MLAT system is used by different organizations such as commercial, general and military aviation.[35] Multilateration System is becoming an important surveillance and identification system for large airports. The advantages of MLAT over conventional SSR (Secondary surveillance radar) is that, it is cheap and easy to install and maintain. It is more accurate than others are and it works better, where other conventional radar has problem with its large rotating antenna.

A. Multilateration System Development History

In aviation history, there has been little but finite chances of two aircraft colliding in the air or on the airport. Early safeguard procedures included flying in daylight and maintaining a “see and avoid” vigil for nearby aircraft.[3] With some development in technology pilots started using radios to inform controllers of their respective positions. The controllers maintained a situational awareness of all the aircrafts in the controllers airspace and gave necessary directions to aircraft when required. Multilateration system, commonly known as hyperbolic positioning system, was developed during World War I. The first application based on hyperbolic positioning principle was called Hyperbolic Audio location System. This was based on the relative time measurements of sound signals. This system was also used for locating hidden cannons in battlefield.[4]

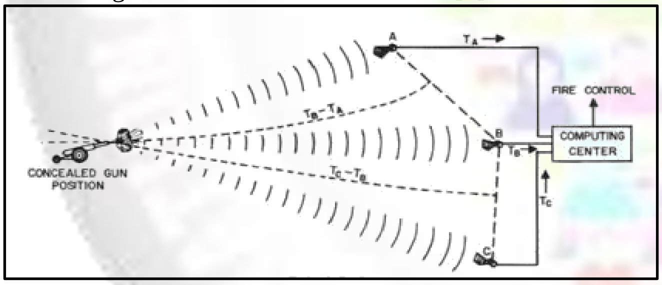

Fig. 2: The first hyperbolic positioning system: Hyperbolic Audio Location System

B. Multilateration Principle

Multilateration system consists of a number antennas and a central processing unit. The antennas receive the signal from the aircraft and a central processing unit calculates the aircrafts position from the time difference of arrival (TDOA) of the signal at the different antennas. Mathematically, TDOA between two antennas corresponds to a hyperboloid in three-dimensions indicating a range of positions of the aircraft. When four antennas detect the aircrafts signal, each of them create a hyperbola of locations then we can estimate the aircrafts three-dimensional location by the intersection of resulting hyperbolas. When three antennas are available, a 3D position cannot be estimated directly, but if the target altitude is known from other source (like-Mode C) then the target can be located. This is actually referred as a 2D solution. With more than four antennas, then extra information can be used .Verifying the correctness measurements or calculating an average position from all measurements, a small error may be present.[5]

Position location systems can be classified into two broad categories: direction finding (DF) and range-based PL systems [4]. Each of these systems can be classified as a satellite or terrestrial based system, depending on whether the base station is located on the surface of the earth or in an orbit around the earth. Direction finding systems estimate the position location of a source by measuring the direction of arrival (DOA) or angle of arrival (AOA), of the source's signal. The DOA measurement restricts the location of the source along a line in the estimated DOA. When multiple DOA measurements from multiple base stations are used in a triangulation,the location estimate of the source is obtained at the intersection of these lines. Consequently, direction finding PL systems are also known as direction of arrival or angle of arrival PL systems. Range-based PL systems can be categorized as a ranging, range sum, or range difference PL system [6]. The type of measurement used in each of these systems defines a unique geometry, or configuration, of the position location solution. Ranging PL systems locate the source by measuring the absolute distance between a source and the receiver. Range measurements are determined by estimating the time-of-arrival (TOA) of the signal propagating between the source and receiver. The TOA estimate defines a sphere of constant range around the receiver. The intersection of multiple spheres produced by multiple range measurements from multiple base stations pro- vides the 5 6 position location estimate of the user. Consequently, ranging systems are also known as TOA or spherical PL systems. Most practical ranging systems are unable to measure the range between the user and a base station directly, and as a result, measurement of the range and a bias term is commonly performed. This bias term can be calculated using an additional range measurement by an additional base station. Ranging systems of this type are often called pseudo-range systems. Range sum PL systems measure the relative sum of ranges between the source and receiver respectively. These systems measure the time sum of arrival (TSOA) of the propagating signal between two base stations to produce a range sum measurement. The range sum estimate defines an ellipsoid around the receiver, and when multiple range sum measurements are obtained, the position location estimate of the user is at the intersection of the ellipsoids [7]. Consequently, range sum PL systems are also known as TSOA or elliptical PL systems. Range difference PL systems measure the relative difference in ranges between the source and receiver respectively. These systems measure the time difference of arrival (TDOA) of the propagating signal between two base stations to produce a range difference measurement. The range difference measurement defines a hyperboloid of constant range difference with the base stations at the foci. When multiple range difference measurements are obtained, producing multiple hyperboloids, the position location estimate of the user is at the intersection of the hyperboloids [8]. Consequently, range difference PL systems are also known as TDOA or hyperbolic PL systems.

The accuracy of target localization is mostly determined by TOA measurement errors and multilaterationsolving algorithm. TOA is defined as the time of signal from the transmitter to the receiver which is composed with two parts: time from transmitter to target and time from target to receiver. Target position is obtained through the solution of the TOA equations [9]. There are T R path between transmitters and receivers, whereT is number of transmitters and R is number of receivers. Therefore the number of equation is T R and far more than the unknown variable, target coordinates. So TOA is redundant comparing with target localization. Accumulation of TOA measurements errors may lead to worse accuracy than a single TOA measurements error. On the contrary, offset of TOA measurements errors may obtain better accuracy. Besides, the TOA equations are nonlinear and over determined. To solve the nonlinear equations, a simple way is to substitute them with approximate linear equations. Taylor expansion is a classical method to solve nonlinear equations and was used in[10]-[14]. Since target location is unknown at the beginning, the point of Taylor expansion is too uncertain. So the initial target position should be estimated by other methods used in tracking. After target coordinate is calculated from TOAs, other parameters, e.g. distance, direction angle, elevator angle, speed, .etc can be drawn from coordinates. In [15], parallel factor analysis is used to solve detection and location of multi-target. In [15], the phase errors in coherent processing and the Cramer–Rao lower bound (CRLB) are discussed. Doppler-shift and angle information are exploited in [16] and target position is found by searching the desired area using the grid search method. In this paper, we observe the path from a receiver, as shown in 0, and then set a transmitter as reference station. Letting TOA from any transmitter subtract the TOA to reference station, the TOA equations are change to TDOA equations. Since all paths from transmitter to receiver share same path between the receiver and the object, the localization is same as passive localization after the subtraction. Then some classic localization methods can be done.This work was supported by the China National Science Foundation under Grant 61079006. used. For each receiver we can obtain similar equations in the same way. Averaging these equations on all receiver leads to averaging on TDOA measurement errors which can decrease the variance of TOA measurement errors.[17]-[20]

III. Research gap & future objective

In this age of advanced technology and communication, position location technique is of great importance for both military and civilian purposes. Accessibility of accurate information from the basic and manual system is difficult. Sometimes data can be mismatched. So, estimating the position of different moving sources is difficult to measure.

To estimate the position of the target depends upon the measurement of TDOA (Time difference of arrival).
This research, therefore, seeks to find a suitable and efficient localization algorithm forMultilateration system. It provides extensive studies on hyperbolic localization algorithm in Multilateration system, in which several concerns are investigated. A detailed analysis of its performance study, which is based on GDOP, HDOP, MSE. Finally a comparison with other two-localization algorithm.

A. Future Objectives

To get the general idea of this thesis we propose the following particular objectives:

– To provide, adapt and apply some measurements technique, in order to provide algorithm that can be applied in the design of the MLAT system. This method will allow designing MLAT systems more efficiently, which has more accuracy than other methods. The algorithm provides for reduction of time and economic cost, which were concerns of procedures based on trial and error approach.
– To provide an explicit solution. The solution in closed form, which is valid for both close and distant sources.
– To simulate and evaluate its efficiency in terms of GDOP, HDOP, MSE.
– To provide and adapt the mathematical theory of this method. The resulting equations also allow us to reduce noise.

IV. Conclusion

The technique provided localizes source from set of hyperbolic curves defined by TDOA. Hyperbolic method and Chan and Taylor series method results were simulated. The study is based on accuracy in localization of source.

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