Research on Improvement and Simulation of Multi-Point Positioning Technology in Aerospace

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Abstract

With the currently rapid development of China's Aerospace industry, the security pressure on the air traffic management system has also increased. Since the aerospace technology and safety level is not high, the state shall increase investment in the development of new aerospace detection technology and research, especially research on the multi-point positioning technology. The technology has the advantages of precise positioning, low cost and easy installation, and has been widely used abroad. Therefore, this paper deeply analyses the research background, the principle of multi-point positioning of aerospace and the improvement and simulation of multi-point positioning of aerospace. By analysing multi-point positioning technology, it is known that improving the technology has some advantages, and verifies the effectiveness of the algorithm and improves the accuracy of air navigation.

Keywords: Aerospace, Multi-Point Positioning Technology, Improvement, Simulation.

1. RESEARCH BACKGROUND

1.1 Literature Review

With the rapid development of the aerospace industry, varieties of positioning technologies continue to be introduced into the field and have achieved remarkable achievements. In recent years, more and more researches have been done on the positioning system of aerospace, which has reached a certain scale (Cui et al., 2012). Shi Lijuan et al. conducted the in-depth study of from the basic concepts of aerospace aircraft positioning system and operating mechanism etc. In addition, by using of multi-point target positioning method of the coordinate transformation, an accurate analysis is carried out on the aerospace orientation. Afterwards, Shi Lijuan et al. utilized the existing aerospace simulation technology to develop an aerospace simulation system that combined virtuality with reality. Based on the specific application, Shi Lijuan et al. proposed various independent and complete display modes and completed the calculation of aerospace positioning data and data drive function by 3D demonstration, which fully complemented the existing multi-channel demonstration system (Shi et al., 2015). Subsequently, Wan Xintai et al. focused on the specific operating principle and application status of the aerospace satellite positioning system, as well as the characteristics of the field of aerospace safety. The study found that the good flight performance of China's aerospace planes depended mainly on the products’ signal characteristics, and good performance of the aircraft could ensure the flight safety and stable working environment to a large extent (Wan and Wang, 2016). Jiang Liyang et al. proposed a matching positioning method based on the model reconstruction, which by using the offset model’s blade measurement method, not only improved the accuracy of the positioning measurement, but also deformed and positioned aerospace reconfiguration measurement model. Finally, the accuracy of this method was verified through simulation and comparative analysis (Jiang et al., 2016). In addition, Wang Wei et al. carried out in-depth study on the fuselage structure life, manufacturing quality and assembly tightness and other aspects of the new model aircraft and found that the continuous increase of the proportion use of modern aerospace aircraft structures such as composites, carbon alloys and other new materials was conducive to the development of the aerospace industry (Wang et al., 2015). Through the above researches, we can find that the current researches on aerospace technology focus on the basic principles, connotations and concepts etc., and a very small part of them are involved in the research of positioning systems for aerospace technology. Therefore, based on the previous research results, this paper studies the multi-point positioning system in aerospace more deeply and professionally so as to provide some assistance or direction for the precise positioning in the field of aerospace industry.
1.2 Research Purposes

At this stage, the capability of China's aerospace supervisory and surveillance system is continuously improving, and the application of the original space flight supervisory, control and surveillance technology is relatively advanced. The technology of air space surveillance and surveillance has been relatively improved. The aerospace multi-point positioning is a compatible technology that can meet the needs of the original spacecraft and can also handle ADS-B transmission. As aerospace multi-point positioning technology not only meets the current aerospace surveillance infrastructure needs, but also meets the aircraft ADS-B use. Therefore, with full use of multi-point positioning technology, you can add aerospace backup to complete the role of integrated aerospace surveillance systems. Multi-point positioning system does not need to change or add airborne equipment, and aerospace multi-point positioning technology will be used as an important monitoring system for decades. In other words, the system will also be a backup version of the monitoring technology after ADS-B technology dominates the area of aerospace regulation through the use of this technology. For China, since the use of GPS satellites is subject to man-made limitations in the aerospace field, the use of multi-point positioning technology is of great significance for the country to adopt a safe aerospace strategy. In addition, the passive detection of positioning technology is the main feature of aerospace multi-point positioning technology, which has been valued by the aerospace community. Therefore, it is of great practical significance to study the multi-point positioning technology for the safe and steady development of China's aerospace industry.

2. PRINCIPLE OF AEROSPACE MULTI-POINT POSITIONING TECHNOLOGY

The full use of airborne transponders, airborne navigation equipment, and multi-point positioning and monitoring technologies is the most prominent feature of aerospace multi-point positioning technology. In addition, the aerospace multi-point positioning technology is compatible with the ADS-B technology. The positioning system has advantages of lower cost, higher accuracy, better target performance, less system interference, more flexible site configuration, and strong adaptability system monitoring coverage etc. (Liang et al., 2014). Aerospace multi-point positioning technology’s specific application areas are as follows:

(1) Application of monitoring the airport scene area. Through the effective application of multi-point positioning technology, you can give full play to the configuration flexibility of the technology. In addition, they can also be related to external aerospace systems to continually satisfy the needs of the space agency, guiding and controlling the performance requirements of aerospace systems and maintaining the required capacity and safety levels of flights (Wang et al., 2015). Multi-point positioning technology, with its lower cost, is fit for scene detection applications in the aerospace airport with the increased density.

(2) To monitor the aircrafts to ensure its high maintainability performance. Aerospace multiple-positioning technology is receiving machine technology with a variety of basic sites that is suitable for use in at least 4 ground receiving stations, and each site receives the signals transmitted by the airborne answering machine at different time, and the main object's three-dimensional coordinates are mainly calculated to ensure the aircraft's high performance to maintain the system. In addition, the effective use of aerospace multi-point positioning technology can accurately calculate the geometric height of the aircraft. At present, most countries in China adopt AGHME technology and there are 5 sites in the United States. According to relevant experience in other countries, China needs to establish a foundation area monitoring site in the air hub area of cites as Beijing, Shanghai and Guangzhou etc. In this way, it continuously meets the needs of more than 70% of flights, maintains a high degree of surveillance and performance evaluation, and ensures the safe and effective operation of China's aerospace.

(3) To monitor a wide area of aerospace routes. The multi-point positioning technology of aerospace is not only applied to the surveillance of airport scenes, but also mainly used in the surveillance of civil aerospace to complete the multi-coverage of routes in 17 regions of the radar regulatory mechanism, covering terminal aerospace areas, and the regional air routes of western regulatory procedure area, which are cost-effective, and can reduce the various interference of radar system. Therefore, the multi-point positioning technology of aerospace has a very good application prospect in the field of surveillance of aerospace regulation (Zhou et al., 2016).

(4) To manage the environment and the airport. The multi-point positioning technology has the capability of recording each aircraft arriving and leaving port 18 and recording specific time and the route of the flight at any time. These data can be used as legal evidence to deal with noise complaints. In the meantime, airport operators can be provided with effective date of noise, aircrafts and operating aerospace information by using a
multi-point positioning system. As the airport needs to constantly monitor aircraft and other vehicles, only in this way can it fully enhance the efficiency of the supervision and administration of aerospace operations. To give full play to aerospace multi-point positioning technology for airlines and site monitoring personnel can provide real-time aerospace situational awareness. Based on this, the advantage of aerospace boarding supervision and arrangement of boarding ramp shall be given full play to. In general, aircraft aeronautics can be tracked and identified in real time through the use of aerospace multi-point positioning technology to provide managers with adequate information to enhance economic benefits of the airport.

3. AEROSPACE MULTI-POINT POSITIONING ALGORITHM AND SIMULATION ANALYSIS

3.1 Algorithm Description of Multi-Point Positioning Technology

Multi-point positioning technology signals mainly come from aerospace responses or broadcast signals, which are based on the air signals under 1090MHz. Aerospace ground arrangement receiver mainly depends on aerospace practice as the standard. When the spacecraft receives the aerial signal, the estimated arrival time signal is TOA. In the meantime, the received TOA signals are transmitted to the aerospace system site to determine the positioning of the aerospace so as to transmit the received aerospace information to the air surveillance system (Chen and Wang, 2010). The interpretation of aerospace positioning essentially includes the measurement of the optimal positioning of the target in the combination of equations for over-determined, non-linear and multi-dimensional receiver test noise. The positioning settlement mode and TOA estimation accuracy of aerospace multi-point positioning technology are mainly determined by the positioning accuracy. By estimating the TDOA target position, the solution to the over-hyperbolic or hyperbolic multi-point positioning technique is solved. Since the estimation error of aerospace time is a random variable, solving the target position is also an optimal estimation problem (Liang et al., 2014). Chan Algorithm mainly refers to the non-linear equation transformation method, but the variable obtained by this algorithm has a correlation with the measured target coordinates, which uses algebra and maximum likelihood estimation method to overcome Chan's influence on the solution of the correlation results. Taylor series expansion algorithm can be transformed into the traditional algorithm of linear equations. However, this method needs to predict the point close to the target position, and the truncation error of the curve term can be relatively small only after this point is carried out.

3.2 Multi-Point Positioning Technology Evaluation Index

In order to evaluate the positioning performance assurance of aerospace positioning technology, it is necessary to measure and evaluate the accuracy index of multi-point positioning. At present, the commonly used evaluation indicators are positioning solution mean square error, root mean square error and geometric precision attenuation factor. In this paper, the root mean square error of positioning (RMSE) is the evaluation index of the test algorithm, and the root mean square error is RMSE. The formula is as follows:

\[
MSE = E\left[ (X - \hat{X})^2 + (y - \hat{y})^2 + (z - \hat{z})^2 \right]
\]

(1)

\[
RMSE = \sqrt{E\left[ (x - \hat{x})^2 + (y - \hat{y})^2 + (z - \hat{z})^2 \right]}
\]

(2)

In the above equation, \((\hat{x}, \hat{y})\) represents the coordinates of the estimated position; \((x, y)\) represents the actual position coordinates of the target.

3.3 Chan Algorithm Analyses

Chan algorithm is the algorithm which refers to the intermediate measurement variables, removes the quadratic term of the target position coordinates, and directly calculates the aerospace measurement target position. The signals obtained from setting up the ground station \(\hat{i}\) at the airport are as follows:

\[
u_i(k) = s(k - d_i) + \eta_i(k),\text{ and among which }i = 1, 2, \ldots, M, \text{ and } d_i \text{ means the delay time corresponding to the receiving station } i, s(k) \text{ means the signal transmitted by the target object, } \eta_i(k) \text{ means the additive noise. The TDOA of the first signal receiving station as a reference is expressed as follows:}
\]
\[ d_{ij} = d_{i,1} - d_{j,1} \quad i, j = 2, 3, ..., M \]  

(3)

\((x,y)\) are the target position coordinates; The sum of the square of the distance between the target and the receiving station is expressed as follows:

\[ r_i^2 = (x_i - x)^2 + (y_i - y)^2 \]

and among them, \(i = 1, 2, ..., M\)  

(4)

Through the above formula, the following formula is as follows:

\[ r_i^2 = (r_{i,1} + r)^2 = 2r_i r_1 + r_1^2 = k_i - 2x_i x - 2y_i y + x^2 + y^2 \]  

(5)

Based on the above transformations, a reference measurement \(1r\) is introduced to derive a nonlinear equation that measures the position of the target, transforming the organization into a set of linear equations, i.e. \(G_a Z_a = h\). Among them, \(Z_a = [z_1^T, r_1]^T, Z_p = [x, y]^T\). The maximum likelihood estimation of \(Z_a\) is expressed as follows:

\[ Z_a = (G_a^T \phi^{-1} G_a)^{-1} G_a^T \phi^{-1} h \]

(6)

### 3.3 Improvement and Simulation of Multi-Point Positioning Technology in Aerospace

The simulation of aerospace multi-point positioning technology mainly uses the measurement error of TDOA, the specific principle is subject to the best Gaussian distribution, the average value is 0 and the standard deviations are 10 m, 20 m, 30 m, 40 m and 50 m respectively. Among them, 10 \& 4 aerospace measurement targets are selected randomly within a radius of 5 km, so as to simulate the fixed-point positioning technology. The number of base stations participating in the multi-positioning of aerospace is represented as 5 and 7 respectively, and the target positioning of several base stations on the ground of the aerospace site is conducted. Moreover, the accuracy of the air positioning is evaluated by the root-mean-square-error RMSE. Through the simulation, the relationship between TDOA measurement error of initial conditions high precision iterative target positioning technique and location root mean square error is constrained.

<table>
<thead>
<tr>
<th>Number of base stations</th>
<th>Algorithm</th>
<th>(\sigma_{TDOA} = 10)</th>
<th>(\sigma_{TDOA} = 20)</th>
<th>(\sigma_{TDOA} = 30)</th>
<th>(\sigma_{TDOA} = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=5</td>
<td>Taylor</td>
<td>9.92</td>
<td>7.22</td>
<td>7.33</td>
<td>7.32</td>
</tr>
<tr>
<td></td>
<td>Chan</td>
<td>0.94</td>
<td>0.92</td>
<td>0.92</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>Chan and Taylor</td>
<td>1.38</td>
<td>1.40</td>
<td>1.42</td>
<td>1.43</td>
</tr>
<tr>
<td>N=7</td>
<td>Taylor</td>
<td>8.29</td>
<td>8.52</td>
<td>8.36</td>
<td>8.44</td>
</tr>
<tr>
<td></td>
<td>Chan</td>
<td>1.03</td>
<td>1.04</td>
<td>1.06</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>Chan and Taylor</td>
<td>1.59</td>
<td>1.81</td>
<td>1.74</td>
<td>1.63</td>
</tr>
</tbody>
</table>

By comparing the algorithm of multi-point positioning technology (as shown in Table 1), the aerospace multi-point positioning technology is effectively improved by using the Taylor Algorithm and the Chan Algorithm. When the number of base stations \(N = 5\), the result by the Taylor Algorithm is the best, and the result obtained by the Chan Algorithm is general. When the number of base stations \(N = 7\), the aerospace multi-point positioning technology obtained by the Taylor Algorithm is the best, and the result obtained by the Chan Algorithm is general. When the number of base stations \(N = 5\), the combined effect of Chan Algorithm and Taylor Algorithm in aerospace multi-point positioning is effective. However, when the number of base stations \(N = 9\), the multi-point positioning technology in aerospace is the best.
4. CONCLUSION

In a word, China’s aerospace industry develops rapidly. In order to ensure the safety of aerospace, and improve the efficiency of the aerospace industry, the research and application of surveillance systems have been overwhelming. Through the research on the multi-point positioning technology of aerospace, it is found that the multi-point positioning technology has obvious advantages. From its application in different fields, it can be seen that it includes applications in the fields of monitoring the airport scene, the aircraft's high maintainability, extensive air routes, management of environment and airports. In addition, the basic principles and characteristics of multi-point positioning technology are sorted out. Finally, the simulation results show that the algorithm is correct and the positioning accuracy is improved.

REFERENCES