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ITJ

ISSN 1812-5638

# INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (22): 6849-6851, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.6849.6851


# Accuracy Analysis of Automatic Identification System Position Estimation

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**Abstract:** Time of Arrival (TOA) and Time Difference of Arrival (TDOA) techniques can be used in automatic identification system (AIS) providing ship position information. Which technique should be selected is decided by its positioning accuracy. This study presents accuracy analysis of different positioning techniques used in AIS, including TOA, TDOA and TOA without time synchronization. Position accuracy is derived and analyzed based on positioning models from a Line of Position (LOP) point of view. According to these analysis results it is hard to say TOA or TDOA has the higher accuracy which is depends on the distribution of the base stations. The accuracy of TDOA is always higher than TOA without time synchronization. The simulation results verify the above conclusions.

**Key words:** Automatic identification system, positioning accuracy, time of arrival, time difference of arrival, time synchronization, line of position

## INTRODUCTION

Nowadays, Global Position Satellite System (GNSS) is the primary means of navigation in many maritime applications, as ship position information is usually provided by a GNSS receiver. However, vulnerability of GNSS is well known. In 2007, the International Maritime Organization (IMO) sub-committee on safety of navigation agreed that there was a need to provide an internationally agreed alternative system for complementing the existing satellite navigation, positioning and timing services to support e-navigation. It is encouraged to the trials and development of new ranging-mode of Automatic Identification System (AIS) to enhance marine navigation into the World Wide Radio Navigation System (WWRNS).

AIS is a ship to ship and ship to shore data broadcast system, operating in the VHF maritime band (Reininger, 2001). IMO adopted a requirement for all ships to carry AIS equipment since 2000. An AIS equipment is capable of exchanging information such as station identity, position, course, speed, length, ship type and cargo information etc. with other ships and base stations ashore (Hu *et al*., 2009).

At present, a variety of positioning techniques have been widely utilized. The three most important kinds utilize the Received Signal Strength (RSS) (Zhu *et al*., 2008), Angle of Arrival (AOA) (Guo, 2012) and signal propagation time (Yu *et al*., 2006) (Li *et al*., 2010), respectively. In general, signal propagation time techniques achieve higher positioning accuracy than RSS and AOA techniques (Jhi *et al*., 2012). The techniques based on signal propagation time can be further categorized by the measurement type such as Time of Arrival (TOA) (Zhen *et al*., 2005) and Time Difference of Arrival (TDOA) (Lee *et al*., 2011). Both TOA and TDOA techniques can be used for positioning in ranging-mode of AIS.

In this study, we argue the accuracy of TOA, TDOA and TOA without time synchronization. Firstly, positioning models of these techniques are presented. Secondly positioning accuracy of them is derived, respectively. Then the comparison of positioning accuracy is illustrated by simulation. Finally, some concluding remarks are given.

## POSITIONING MODEL

In AIS, the ship position estimation can be determined using the latitude and longitude coordinates of the base stations (BSs) using TOA and TDOA techniques. ($\varphi$, $\lambda$) denote the latitude and longitude coordinates of the ship. For convenience, the changes in the latitude and longitude are denoted by the horizontal and vertical increments ($\Delta\varphi$, $\Delta\varphi$), as shown in Fig. 1. ($\varphi$, $\lambda$,) and ($\Delta\varphi$, $\Delta\varphi$) satisfy the following equations.

$$\begin{aligned} \varphi' &= \varphi + \Delta\varphi \\ \lambda' &= \lambda + \Delta\omega \sec\varphi \end{aligned} \quad (1)$$

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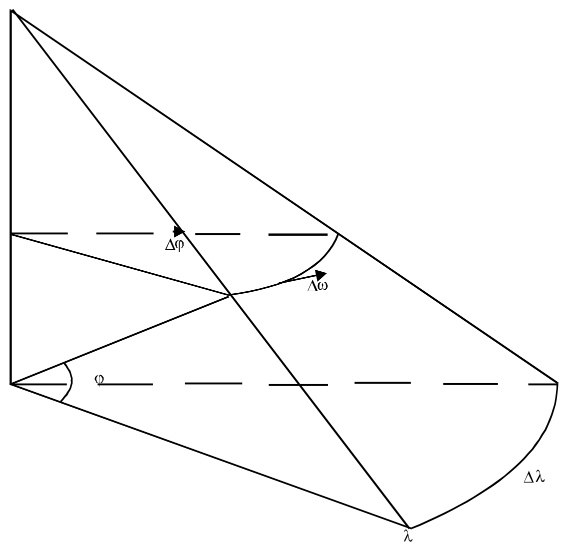


Fig. 1: Relationship between (φ, γ) and (Δλ, Δφ)

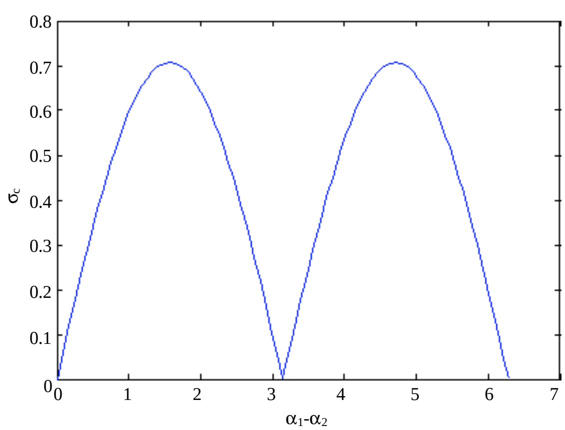


Fig. 2: Mean square error of the positioning error for TOA

Fig. 2. The minimum of $\sigma_c$ is $\sqrt{2}$ when ($\alpha_2$-$\alpha_1$) = $\pi\sqrt{2}$ or $3\pi/2$. That is to say, two lines through the ship and the BSs are vertical. The maximum of $\sigma_c$ is $\infty$ when ($\alpha_2$-$\alpha_1$) = 0 or $\pi$. That is to say, two BSs lie along a straight line passing through the ship.

**TDOA technique:** For TDOA, at least three BSs are required for the ship position estimation. Three dimensional plot of $1/\sigma_h$ with ($\alpha_i$ -$\alpha_1$) (i = 2, 3) are shown in Fig. 3.

The minimum of $\sigma_h$ is 0.9189 and the maximum is $\infty$. When at least two BSs lie along a straight line passing through the ship, $\sigma_h$ is maximum.

**TOA technique without time synchronization:** In this situation, the clock bias augments the two dimensional location vector forming a three dimensional state vector.

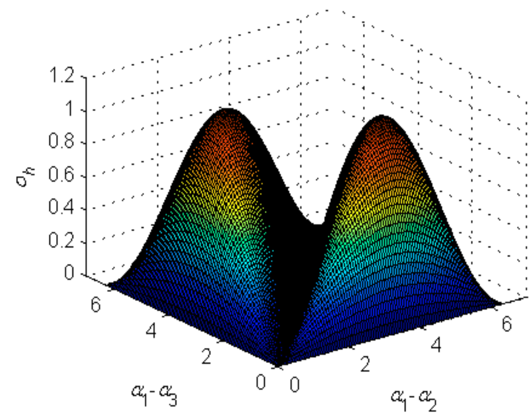


Fig. 3: Mean square error of the positioning error for TDOA

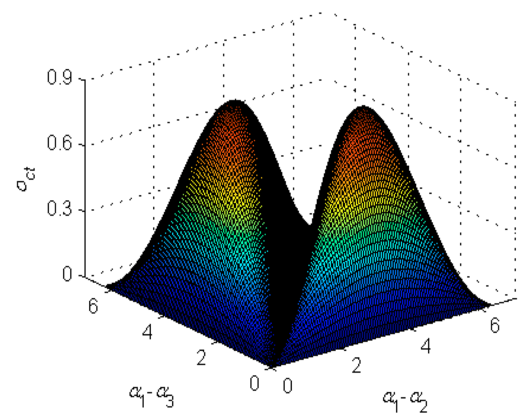


Fig. 4: Mean square error of the positioning error for TOA without time synchronization

Thus, to estimate the ship position, more than three BSs are required. $1/\sigma_{ct}$ changes with ($\alpha_i$-$\alpha_1$) (i = 2, 3) shown in Fig. 4. The minimum is 1.1551 and the maximum is 8. $\sigma_{ct}$ is maximum in the same conditions as TDOA.

**Positioning accuracy comparison:** The mean square errors of the positioning error are compared for TOA, TDOA and TOA without time synchronization from the accuracy point of view when n = 3 shown in Fig. 5.

It can be seen from Fig. 5a, sometimes $\sigma_h$ is larger than $\sigma_c$ while sometimes $\sigma_h$ is smaller. It is hard to determine the performance for TOA and TDOA which one is better. It is depends on the distribution of the BSs. It

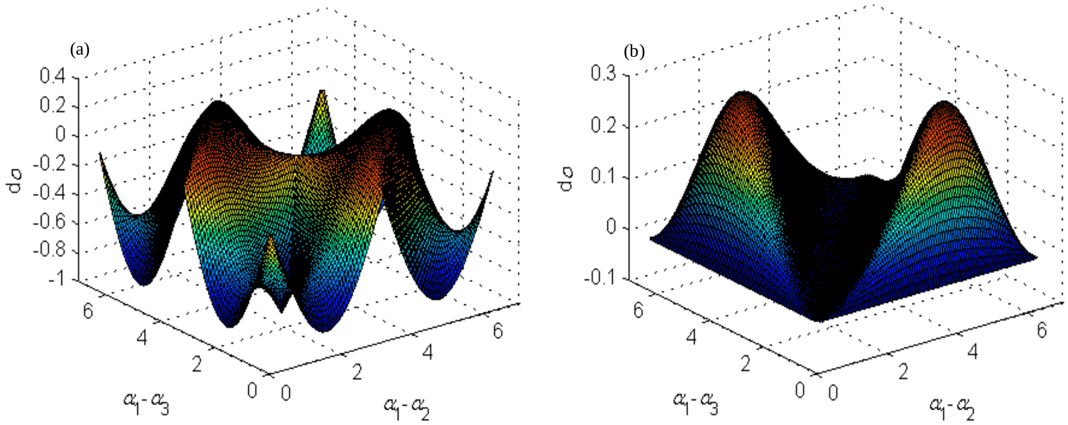


Fig. 5(a-b): Positioning accuracy comparison, (a) Comparison for TOA and TDOA and (b) Comparison for TOA without time synchronization and TDOA

can be seen from Fig. 5b that $\sigma_{ct}$ is always larger than $\sigma_h$. That is to say, the performance of TDOA is always superior to TOA without time synchronization.

## CONCLUSION

Accuracy analysis of ship position estimation using different techniques in AIS is investigated, including TOA, TDOA and TOA without time synchronization. Positioning models for these techniques are given. Positioning accuracy is derived and compared. It is hard to decide which one has the higher accuracy of TOA and TDOA which is depends on the distribution of the BSs. The accuracy of TDOA is always higher than TOA without time synchronization.

## ACKNOWLEDGMENT

This work is partially supported by the Chinese National Science Foundation with Grant No. 61231006, the National Key Technologies R and D Program of China with Grant No. 2012BAH36B02 and the Fundamental Research Funds for the Central Universities of China with Grant No. 3132013307.

## REFERENCES

Guo, L., 2012. Scatterer distribution based on TOA/AOA and TOA/AOD. J. Convergence Inform. Technol. Adv. Inst. Convergence Inform. Technol., 7: 83-91.

Hu, Q., S.F. Zhang, J.B. Zhang and E.S. Wang, 2009. A new automatic identification system (AIS) model-MIP-AIS. A cta Electronica Sinica, 37: 1185-1191.

Jhi, H.L., J.C. Chen, C.H. Lin and C.T. Huang, 2012. A factor-graph-based TOA location estimator. IEEE Trans. Wireless Commun., 11: 1764-1773.

Lee, H.K., H.S. Kim, J.Y. Shim and M.B. Heo, 2011. Analytic equivalence of iterated TOA and TDOA techniques under structured measurement characteristics. Multidimensional Syst. Signal Process., 22: 361-377.

Li, C., W. Liu and Z. Fu, 2010. GPS/TDOA hybrid location algorithm based on federal kalman filter. J. Convergence Inform. Technol. Adv. Inst. Convergence Inform. Technol., 5: 42-48.

Reininger, S., 2001. AIS: The Next Necessity. Vol. 106, Simmons-Boardman Publishing Corporation, Marine Log, New York, pp: 23-29.

Yu, K., J.P. Montillet, A. Rabbachin, P. Cheong and I. Oppermann, 2006. UWB location and tracking for wireless embedded networks. Signal Process., 86: 2153-2171.

Zhen, J., X.H. Ma and S.F. Zhang, 2005. TOA-based combined location positioning algorithm in NLOS propagation environment. J. Dalian Univ. Technol., 45: 599-602.

Zhu, Y., D. Huang and A. Jiang, 2008. Network localization using angle of arrival. Proceedings of the IEEE International Conference on Electro/Information Technology, May 18-20, 2008, Ames, IA., pp: 205-210.