Artificial intelligence for data collection and application of the probabilistic-logistic method in ship traffic control systems of seaports

A A Alekseev, V V Popov, A L Boran-Keshishyan

Admiral Ushakov Maritime State University, 93 Lenin Ave., Novorossiysk, 353924, Russian Federation

E-mail: 061202@rambler.ru

Abstract. An increase in the number of ships, their sizes, speeds and displacement increases the number of accidents, especially in places with intensive shipping. Control over the positions of vessels, their movement, identification of intentions is exercised by the vessel traffic control system (VTCS). A new generation VTCS that can predict optimal and safest traffic patterns in water areas requires artificial intelligence and forecasting elements. Currently, the fifth generation VTCSs are being implemented. They can plan optimal and safe traffic patterns in the water areas, depending on various external factors controlled by artificial intelligence. The VTCS is a traffic control body. Due to the intensive ship traffic, the control over water traffic is becoming more and more urgent. The “probabilistic” model and the target-object can stop moving when the signal is lost, and it is impossible to continue moving along the same route with the same speed. This must be taken into account when using software [4,5]. The knowledge base for developing a logistic-probabilistic method is available, but there is no real application, due to the lack of massive implementation of artificial intelligence in the software.

1. Introduction
Vessel Traffic Control Systems (VTCS) in modern shipping with an increasing traffic flow reduce the accident rate. As part of modern VTCS systems, they are combined into computing systems, where all information about ships and maritime situations converges and is controlled by the operator. Currently, the fifth generation VTCS is being implemented. It can build optimal and safe traffic patterns in water areas depending on external factors controlled by artificial intelligence. The VTS is a traffic control body [1].

1.1. Composition of the integrated navigation system composition
The integrated navigation system has a computing unit to which navigation devices are connected. It includes positioning systems - DGPS / DGLONASS; coastal radar stations; AIS; ARPA; NAVTEX; Electronic card.

2. Problem statement
From a practical, logistic-probabilistic point of view, predicting the coordinates of an object makes sense only when it disappears from the ICO radar. Consequently, the last known coordinates can be
used as a basis in calculating its most probable location [2]. Suppose that as the vessel was moving, information about its location was being obtained. At the moment when information about its coordinates is lost, it becomes necessary to predict it.

**Figure 1.** The block diagram of VTCS operation.

**Figure 2.** Object trajectory.
3. Materials and methods

The azimuth angle of the direction to the coordinate can be predicted by formulas:

\[
\theta_{(i+n)} = \arctan \frac{X_{pr}^{i+n}}{Y_{pr}^{i+n}} = \arctan \frac{X_0^n + i\delta_X}{Y_0^n + i\delta_Y}
\]

\[
\delta_X = \frac{2\Delta_X}{N}, \quad \delta_Y = \frac{2\Delta_Y}{N}
\]

where: \(X_{pr}^{i+n}\) and \(Y_{pr}^{i+n}\) - predicted coordinates of an object on plane \(OXY\).

The method is applicable if the object moves uniformly and rectilinearly. However, any object that is located along the course of the vessel moves in this way. Therefore, the applicability of the method is feasible [3].

When the information about the location of the object has disappeared, to clarify the location of the object, it is necessary to calculate the location angle \(\varphi\).

Describe a straight line of motion. Then:

\[
OA' = P
\]

\[
OC' = T
\]

Calculate the trajectory from the arctangent:

\[
OA' = \frac{P}{\cos(\theta_P - \theta_a)}
\]

\[
OC' = \frac{T}{\cos(\theta_P - \theta_c)}
\]

Then

\[
\theta_P = \arctan \left( \frac{-\Delta Y}{\Delta X} \right)
\]

Object coordinates along the axis \(OZ\) at points \(A\) and \(C\) are calculated by formulas

\[
Z_A = P \tan(\varphi_A) = \frac{P \tan(\varphi_A)}{\cos(\theta_P - \theta_A)}
\]

\[
Z_C = T \tan(\varphi_C) = \frac{P \tan(\varphi_C)}{\cos(\theta_P - \theta_C)}
\]

The coordinate increment is calculated by formula:

\[
\delta_Z = \left( \frac{\tan(\varphi_C)}{\cos(\theta_P - \theta_C)} \right) - \left( \frac{\tan(\varphi_A)}{\cos(\theta_P - \theta_A)} \right)
\]

Thus, knowing the increment of the coordinate, the formula for the predicted coordinate taking into account the elapsed time is

\[
Z_{pr}^{i+n} = Z_C + (n \times \delta_Z) = T \times \left[ \left( \frac{\tan(\varphi_C)}{\cos(\theta_P - \theta_C)} \right) + t \times \left( \frac{\tan(\varphi_C)}{\cos(\theta_P - \theta_C)} \right) - \left( \frac{\tan(\varphi_A)}{\cos(\theta_P - \theta_A)} \right) \right]
\]

where: \(T\) - segment \(OC'\); \(t\) - elapsed time projected.

The predicted point of arrival and accompanying points of movement. Point \(D'\) is its projection onto the horizontal axis. The length of this segment can be expressed by formula
\[ D_\text{pr}^{\text{r+n}} = \frac{R}{\cos(\theta_p - \theta_\text{pr}^\text{r+n})} \]  \hspace{1cm} (12)

\[ \tan \varphi_\text{pr}^{\text{r+n}} = \frac{Z_\text{pr}^{\text{r+n}}}{D_\text{pr}^{\text{r+n}}} \]  \hspace{1cm} (13)

where: \( R \) - projection of segment \( OD \) as a predicted value of the location angle.

Thus, after a series of calculations, we have a formula for the final predicted value of the ship's elevation angle, taking into account the permissible errors.

In investigating the methods of probabilistic positioning of objects and observation of ships in the water area of the port zone using VTCS technical means, the terms of intervention in artificial intelligence navigation are applicable. The algorithm for predicting the coordinates of an object will be performed by a special program that will produce and predict coordinates. VTCS operators who provide assistance and support to skippers rely on information from radars and AIS. It is very difficult to calculate independently and predict the movement of objects; this process is included in the risk assessment [4].

4. Discussion

Fujitsu technical development [5] and Fujitsu Human Centric AI Zinrai technology are applicable in the analysis of collision risk conditions. Using elements of artificial intelligence, it is possible to identify and analyze movements of ships, calculate their routes and establish which of them are dangerous. Investigate the ship that is heading to the port according to the TZP; the object moving towards the intersection of the ship route was noticed in advance. The target is taken for escort and "traces" are visible. It is possible to establish that the vessel is moving to the crossing of the strip in violation of the TZP. It is also possible to calculate its route and speed.

![Figure 3. The vessel entering the port.](image)

The VTCS informs about imminent danger. To have reliable information about the location of a lost target, the logistic-probabilistic method can be used.
Following the algorithm, the VTMS software will perform functions to ensure safety of the vessel. Based on the “target-object” observation, the object's elevation angle can be calculated. Thus, the estimated location of the object will be known, which will make it possible to assess the situation and take the correct action to prevent a collision in order to ensure safe navigation of the vessel [6].

5. Conclusion
The Vessel Traffic Management Systems (VTMS) are one of the most important Centers for navigation safety. Due to the increasing ship traffic, the control over the traffic in the water area is more and more urgent. The “probabilistic” model and the target-object can stop their operation when the signal is lost, and there is no chance to continue moving along the same route and with the same speed. This must be taken into account when using software [4,5]. The required knowledge base for developing a logistic-probabilistic method is available, but there is no real application, due to the lack of massive implementation of artificial intelligence.

References
[1] Lentarev A A 2004 Marine areas system ensuring the safety of navigation (Vladivostok: MSU named after admiral G.I. Nevelskoy)
[2] Vagushchenko L L 2013 Modern information technologies in navigation (Odessa: ONMA)

[3] Popov V V 2000 Development problems of large ports in Russia (Moscow: Roskonsult)

[4] Popov A N, Troyeglazov A P, Skorokhodov S V 2016 Modern coastal vessel traffic management systems (Novorossiysk: RIO GMU-Ushakova F.F.)

[5] Dem’yanov V V, Popov V V 1999 Scientific understanding of the experience of creating the GMSSB information network in the south of Russia (Novorossiysk: RIO NGMA)

[6] Fujitsu Limited 15 April, 2020 Fujitsu Verifies AI Technology to Predict Vessel Collision Risks in Marine Traffic Control, Improves Maritime Safety Retrieved from: https://www.fujitsu.com/global/about/resources/news/press-releases/2020/0415-01.html