Scientific Journals
Maritime University of Szczecin

Zeszyty Naukowe
Akademia Morska w Szczecinie

2013, 36(108) z. 2 pp. 166–169
ISSN 1733-8670

2013, 36(108) z. 2 s. 166–169

Methods of the ship gun control in conditions of varying spatial orientation and position of the gun

Tomasz Praczyk, Piotr Szymak, Stanisław Milewski

Polish Naval Academy
81-103 Gdynia, ul. Śmidowicza 69

Key words: ship gun, method of control, accuracy, spatial orientation variability

Abstract

The article deals with the problem of variability of spatial orientation and the position of the ship gun in time and the impact of this variability on the gun accuracy. In the paper three approaches to this problem are presented. Moreover, the conception of research is presented, which is aimed at verifying each of the approaches and selecting the solution that will guarantee the highest effectiveness of the gun.

Introduction

It is assumed in the paper that to determine the azimuth and elevation of the ship gun (angles defining the orientation of the gun barrel relative to the ship), following tasks are necessary to carry out:

1. Determination of the initial position of the ship relative to the target (using the available sensors for observation) – determination of the ship base reference system, which will be used for further calculations and then setting starting position of the target in this system; this action is initiated when the target is noticed or accepted for tracking;
2. Target tracking (using the available sensors) with simultaneous transformation of the position of the tracked object to the reference system, for this purpose it is necessary to take into account translation and rotation of the ship base reference system, which is related to the observation system; information about rotation and displacement between these systems will be obtained from inertial navigational system INS;
3. Determination of the ship state at the time of a gunshot – displacement and rotation of the ship relative to the ship base reference system;
4. Prediction of position of the target in the ship base reference system in subsequent time points (using information acquired from sensors), including those after the gunshot, in order to take account of the time of reaching target by projectile;
5. Taking into consideration the time of reaching target by projectile;
6. Taking into consideration ballistics and hydrometeorological conditions.

Each of the above tasks except task No. 3 is performed in all artillery systems. Task No. 3 is characteristic for mobile systems, including the sea systems and it is a consequence of the continuous movement of the weapons carrier, that is a ship. Unlike their stationary land counterparts, the gun installed on board of a ship changes its position relative to the reference system accepted for the calculations, and this movement must be included in calculation of the azimuth and elevation of the gun. This paper proposes three approaches to the mentioned above problem with the gun on board of a ship, and also shows the method of verification of each solution, which is planned to be used to determine the solution that ensures the highest accuracy of the ship gun.

Solution No. 1

The simplest solution presented in the paper is to measure spatial orientation and displacement of the temporary ship reference system (using INS) relative to the base reference system, and then to use the measured parameters to calculate the azimuth and elevation. The advantage of this solution with respect to solution No. 2 presented in the next section is that it operates on the basis of the real measured values. Unfortunately, the downside is that calculated angles does not correspond to the gunshot time but they correspond to the time at which they were measured. All calculations lasts a while, and after all the calculations the gun has to perform movements according to the calculations, which also takes a time. The total computation time and the gun movement to the right position is very short, however, even in this very short time, the ship with the gun moves and rotates, what causes that the designated angle parameters for gun will always be out of date. The gun accuracy will depend on the rate of change of the temporary systems relative to the ship base reference system. The greater the rate of changes, the less accuracy of the gun. The rate of change will be depended on the speed of the ship, its manoeuvres and the length and amplitude of the sea waves. The longer the wave, the slower changes and greater gun accuracy. Unfortunately, the Baltic Sea has a very short wave, which will adversely affect the efficiency of the whole artillery system acting in accordance with the solution No. 1.

In order to increase the effectiveness of the gun it is possible to use the prediction of the time instants when the gunshot will guarantee high accuracy. Of course, there will be time instants when the ship will not move at full speed, it will not manoeuvre, as well as the moments in which the angular velocities of the ship will be small, e.g. moments when she is in the maximum position on the side (Fig. 1).

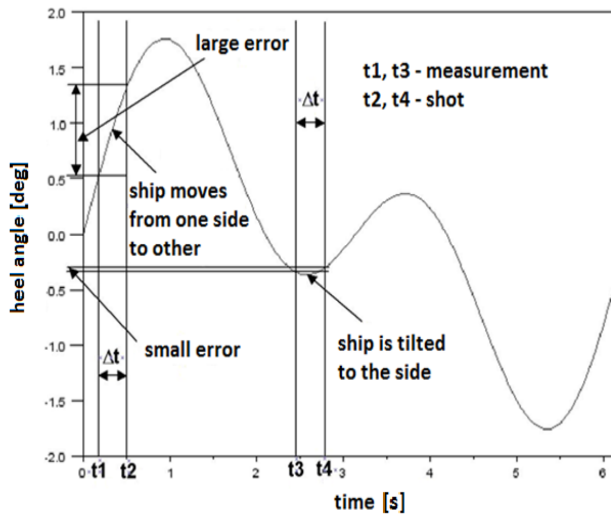

Fig. 1. Illustration of errors made using solution 1

Solution No. 2

In this case we have prediction of the spatial orientation of the ship and its displacement relative to the base reference system. Prediction is applied not only to the target and its location in the base system, but also in relation to the ship. Predicting the ship behavior in the subsequent time points, we can use this information to set the gun exactly at the moment of the gunshot. Each parameter determining the state of the ship in the base reference system is predicted individually (a total of six parameters should be taken into consideration: three angular and three linear motions). The future orientation and displacement of the ship is determined based on further indications of the INS system.

The advantage of this approach compared to approach No. 1 is that in the case of accurate prediction of the ship behavior we will be able to set the gun in the position corresponding to the time point of the gunshot. The disadvantage of this approach is that (contrary to the solution No. 1) setting of the gun is based not on the measured data but on the predictions which are usually with error (Fig. 2).

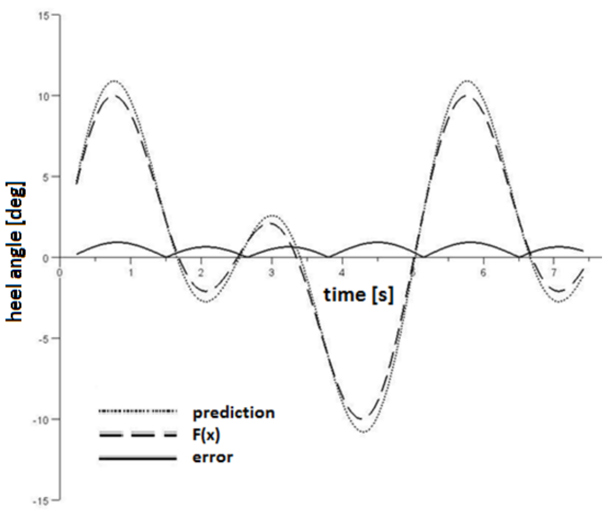

Fig. 2. Errors of prediction

Solution No. 3

For the prediction of the spatial orientation of the ship and its displacement in the ship base reference system we can use various regression methods, e.g. linear regression [1, 2, 3], linear regression with correction [4], non-linear regression [5, 6], or neural networks [7]. Preliminary studies using simulated data based on prediction of the heel angle of the ship (prediction was carried out on the basis of subsequent measured values of this angle) showed that the greatest errors of prediction, regardless of the used method, is most common in areas with large non-linearity of sinusoid describing the change of angle it the time – these are the places where the angular velocity is the smallest (Fig. 2).

This situation is completely opposite to the solution No. 1, where for the largest changes of the ship state the errors are also the biggest. Therefore, we can assume that we have two complementary solutions. Solution No. 1 should be used for small changes of the ship state, while the second solution for rapid changes e.g. movement from side to side, movement from bow to stern, etc. This approach corresponds to the solution No. 3.

Verification

Verification of the effectiveness of the solutions described above is planned to be carried out in two phases. In both phases will be used real data obtained from measurements at sea. For registration of these data will be used measurement system consisting of three INSes (Fig. 3), and three or four high-precision GPS phase receivers.

During the research, the data from these systems will be used to imitate the ship behavior at the sea. GPS receivers, in turn, will be used to estimate the accuracy of the INS system.

Registered data will be analyzed to eliminate measurement errors that may occur during the tests at sea. After pre-processing the data will be used to verify the effectiveness of solutions presented in the paper. The resulting measurement data will contain the angles of rotation of the ship, as well as its displacements in the reference system in the subsequent time points.

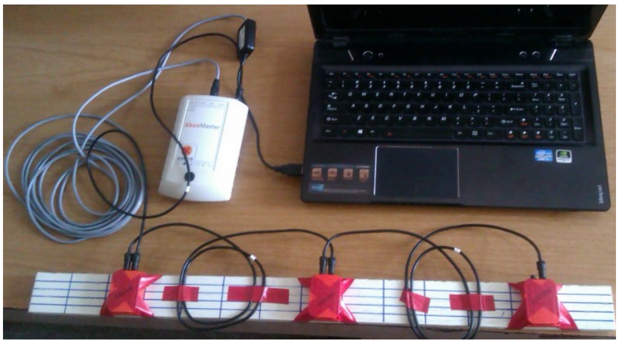

Fig. 3. Measurement system of ship dynamics consisting of three INSes type MTi from Xsens company

It is assumed that during the verification tests the target position will be known and it will not change in time. Knowing the target position and spatial orientation and movement of the gun in the ship reference system it is possible to precisely determine the elevation and azimuth of the gun in the way to point it exactly to the target.

In the first phase of the tests, for each time point and the data recorded at this time, reference angle parameters for the gun and angle parameters assuming the lack of knowledge about these data will be calculated. Depending on the accepted solution, settings of the gun (in conditions of the lack of knowledge of the measurement data in the gunshot time) will be calculated from the measured data from the previous time point (solution No. 1) or based on prediction of spatial orientation and movement carried out on the basis of data from previous time instants (solution No. 2). Errors obtained in each case in many subsequent moments of time allow for determination of the rules or

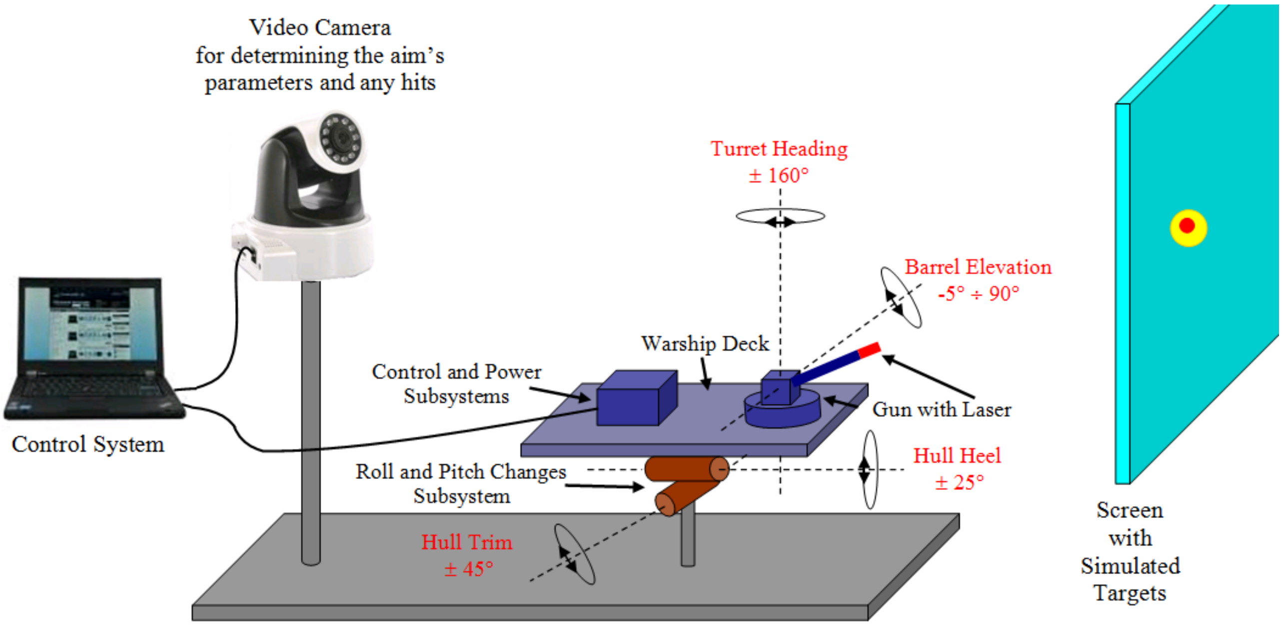

Fig. 4. Physical model of the ship gun – conception

a system of switching between solutions No. 1 and 2 to achieve output system with the highest possible efficiency (solution No. 3).

In the second phase of tests, verification of solutions presented in this paper will be carried out by means of a physical model of the ship gun shown in figures 4 and 5. This model enables you to imitate rotational movements of the ship from side to side and from the bow to the stern and gun control in the range (–160°, +160°) of azimuth and (–5°, +90°) of elevation. In order to determine the aiming point of the gun, a laser pointer was installed inside its barrel.

Fig. 5. Physical model of the ship gun – implementation

During the verification tests subsequent ship-model states will correspond to the states of the real ship registered during the measurement at sea. In this case, only those movements of the ship, which are possible to perform by the model will be taken into account. As in the first phase of the study, for each time point reference position of the gun and the reference aiming point will be defined (a point indicated by the laser after setting gun according to the reference settings calculated on the basis of precise measurement data, that is based on the real spatial orientation of gun-model).

Then, the solution No. 1 will be tested. During test settings of the gun will be accepted according to the measured spatial orientation of the previous time point. Error of the solution will be measured by the distance between the reference point indicated by the laser gun and point indicated by setting of the gun according to the solution No. 1.

In the next step, solution No. 2 will be checked. In this case, the angle parameters of the gun will match the expected spatial orientation of the gun calculated from the measured data of the previous moments of time. As before, the error of this solution will be determinated as the distance between the reference point and laser indication according to the result of prediction. Of course, the whole procedure described above will be carried out repeatedly for all registered data.

At the end, solution No. 3 will be verified (more precisely speaking the system of switching between solutions No. 1 and 2 will be verified). The expected result of using this system is the selection of solution that gives smaller error of the gun at any instant of time or at least in the most instants.

Conclusions

The paper presents three solutions that enable efficient use of the ship gun subjected to continuous movement during gunshot. Of course, due to the limitations of each of the solutions, the performance of each of them depends on the conditions of their use.

Analysis of the first two solutions presented in the paper shows that they seem to be solutions that are complementary – the greater effectiveness of one of them corresponds to the situation of the smaller effectiveness of the second solution and vice versa. This property of two solutions makes that their combination into single unit could lead to a solution which is characterized by greater accuracy than the component solutions, and moreover, we see the possibility of wider using – combined solution will be characterized by less limitations than components. Solution No. 3 presented in the paper is the combination described above. Its effectiveness, however, depends on whether it will be able to properly switch between component solutions in a given situation to achieve greater accuracy.

In addition to the solutions presented above, the paper presents also conception of verification tests of each solution. The research will be carried out based on the real data and using a physical model of the ship gun.

References

1. Barlow J.L.: Chapter 9: Numerical aspects of Solving Linear Least Squares Problems. In Rao C.R. Computational Statistics, Handbook of Statistics 9, North-Holland, 1993.
2. Draper N., Smith H.: Applied Regression Analysis. John Wiley, 1998.
3. National Physical Laboratory, Chapter 1: Linear Equations and Matrices: Direct Methods. Modern Computing Methods. Notes on Applied Science 16, Her Majesty's Stationery Office, 1961.
4. Praczyk T., Szymak P.: Prediction of spatial orientation of 35 mm gun ship. 5th International Conference on Scientific Aspects of Unmanned Mobile Object, Dęblin 2013.
5. Schittkowski K.: Data Fitting in Dynamical Systems. Kluwer, 2002.
6. Seber G., Wild C.: Nonlinear Regression. John Wiley and Sons, New York 1989.
7. Praczyk T., Szymak P.: Prediction of the Spatial Orientation of a Ship by Means of Neural Networks. Solid State Phenomena, Vol. 210, 2014, 223–233.