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THE CALCULATION OF THE OWN SHIP MOTION

The article presents a methodology for the estimation of the own ship motion elements (COG and SOG), by using ARPA. It describes some peculiarities in the methodology for the calculation of the own ship motion elements and its application, depending on the relative position of the ship and her distance to the benchmarks. Based on this methodology, an algorithm is elaborated by using the navigational simulator of the Faculty of Maritime Studies and Transportation of the University of Ljubljana, and which may be realized by means of a PC. The computer may be connected to the ARPA system via a special output device.

Keywords: *Safety of Navigation, ARPA, Course over Ground (COG), Speed over Ground (SOG).*

1. INTRODUCTION

The utilization of ARPA for the determination of the ship course angle and true speed offers the possibility for a full loading of the system (but according to the IMO Resolution A.422) and a better analysis of the situation around the ship by comparing its data with the data obtained from other sources of navigational information. The information processing during the automated surveillance of the standing marine target may be done in two ways: directly by ARPA or by other microprocessor technologies [1].

The elaborated methodology is designed to be used on the bridge of any vessel, sailing near coastal benchmarks. It may be applied in case of failure of the technical devices, determining the course angle and true speed.

The whole process of calculating the course angle and true speed of the own ship is described in an algorithm, which may be modeled and realized by means of a PC.

2. METHODOLOGY FOR THE ARPA CALCULATION

The elaborated methodology has been tested by the author in real conditions on board the m/v AROSIA [2], during a regular voyage in the Mediterranean Sea. Its contents is as follows:

1. A suitable target is chosen in the radiolocation surveillance zone.

In case the target is on a remote distance, its choice must meet the following conditions:

- To be within the bow bearing angles of the ship;
- In case the target is in the traverse bearing gaggles, it must be within 70° before or after the traverse.

At the choice of a coastal target for automated surveillance, the navigator must study the coast configuration in the sailing directions map, and judge:

- at the location of a small island from a great distance, a rock or specific protruding cape, which, of their parts, is the strongest illuminated one on the screen;
- at the location of any other part of the coast, its outlines must be vertical, near the waterline.

2. The marker on the ARPA screen is moved to the chosen target.

3. In a man speed mode, a value of 0.0 knots is set for the own ship Vo = 0.0 kn.

Depending on the ARPA technical solution, new data for the motion elements of the automated surveyed targets will be elaborated after a certain period. According to the IMO requirements in Resolution A. 422 [3, 4, 5], this must be done within 3 minutes from the introduction of the 0.0 knots speed. Then, in a “relative motion” mode the vectors of the standing targets speed disappear from the ARPA screen, the ones of the moving targets acquire the direction of the true movement of each target.

On the digital board for the motion elements of each standing target, the own ship course and speed in relation of the sea bed are depicted. In case of several targets located for simultaneous automated surveillance, the operator has the possibility to compare the calculated data for each target.

In case, due to any reason, the working results of one target are unstable, the data may be transferred to another target, etc. The tests in real conditions have shown that, in case of unstable operation of the ARPA with a certain target, the own ship course and speed data start changing and acquire unreal values. Then the surveyed target must be changed, whereby, upon switching the system over, the operator has to wait for at least one minute before using the data.

The practical application of this elaboration shows that good results are obtained with the use of oil rigs as surveyed radiolocation target. Even at close quarters from the ship, they are classified as point targets, which make them exclusively convenient for measurements.

At location of a coastal benchmark or part of the coast, the operator must inspect the type of image, before its configuration. The experiment showed that when the coast on the ARPA screen is with a relatively constant and stable outlines, the marker on it keeps in place and the received data of the target coordinates are reliable.

The fluctuations of the ARPA calculated values of the own ship course and speed are provoked by several reasons:

- First, the ship is moving around the line, determined by the navigator as a true course, moving left or right of the line. When the helm is not automatically steered, the device operating errors cause irregular deviations of the blade, and, hence, of the whole ship. These fluctuations are especially noticeable in rough seas. In consequence of the irregular movements of the ship's hull, the data, received by the system, are changing and unstable. As a result, the digital board data are inexact.
- Second – if the distance to the target is great, the measurement data are rough and the antenna deviations are negligibly small. However, if the target is near the ship, the fluctuations are important, and thus effecting the final results.
- Third – the results of the ARPA calculations are momentary, i.e. they change with each revolution of the antenna. In order to get an idea of the average values of the own ship movement elements, the navigator must process the data, accumulated for a certain period of time.

3. CALCULATION OF THE OWN SHIP MOVEMENT ELEMENTS

With the proposed algorithm, a bilateral evaluation of the ARPA calculation process is performed – comparison of the system results to the results of formulae and to the graphic plotting within a coordinate system with the surveyed target as the center and the coordinate axes X and Y, respectively oriented north-east.

The algorithm essence is as follows:

1. The target coordinates ϕ_o and λ_o are introduced.
2. Provisional time interval T_{av} is introduced, within the limits of which the momentary ARPA values and the calculated course angle and true speed are averaged out.
3. The ARPA measured bearings and distances to the target are continuously introduced.

4. The ARPA measurements are checked for gross errors, and the inexact measurements are rejected. The Student criterion [6] is used for the check, for which table [3] is elaborated.
5. The ARPA calculated values of the own ship course angle and true speed for each revolution of the antenna are introduced.
6. The current coordinate ϕ_i and λ_i of the ship are calculated by the introduced bearings and distances to the surveyed target. All formulas in the flowchart are notorious [4, 5].

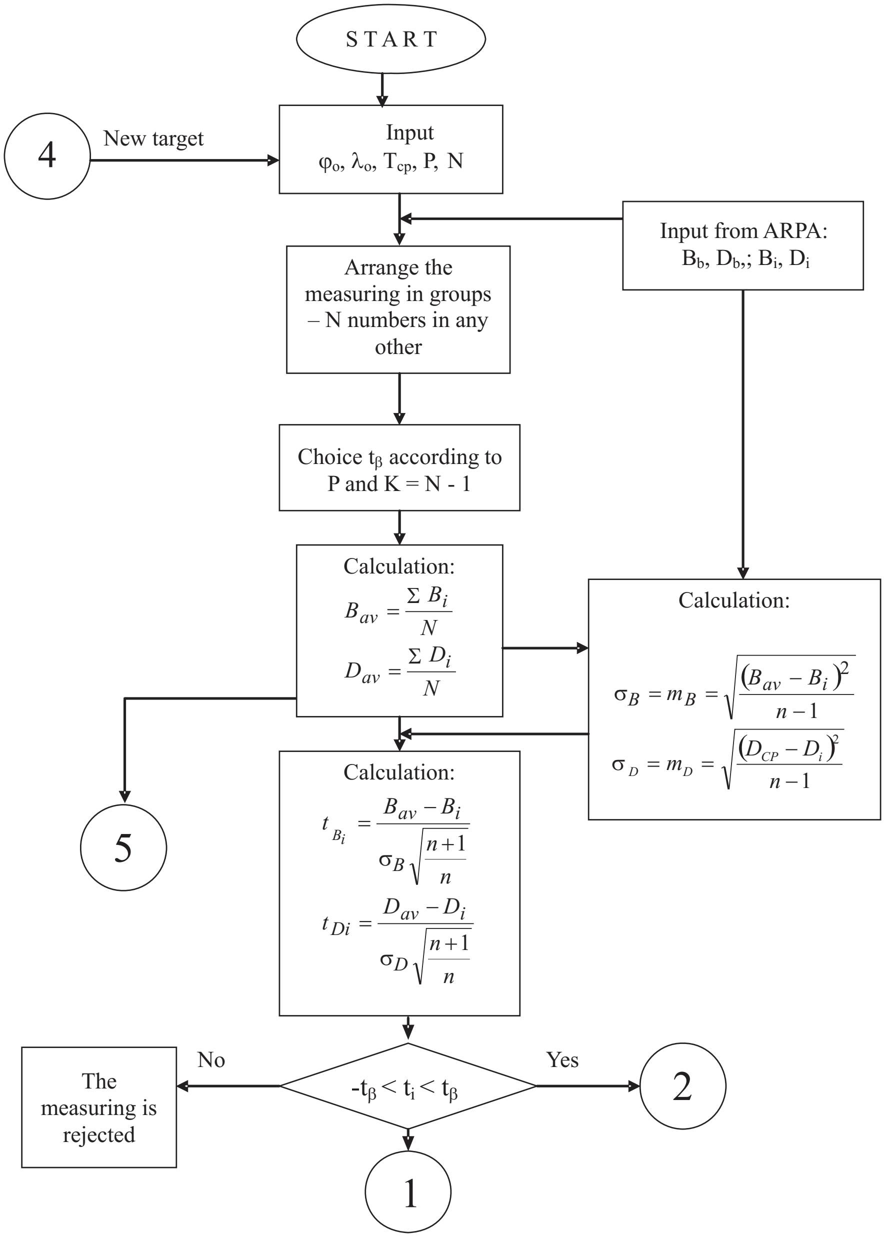


Figure 1: Algorithm for the calculation of the own ship movement elements

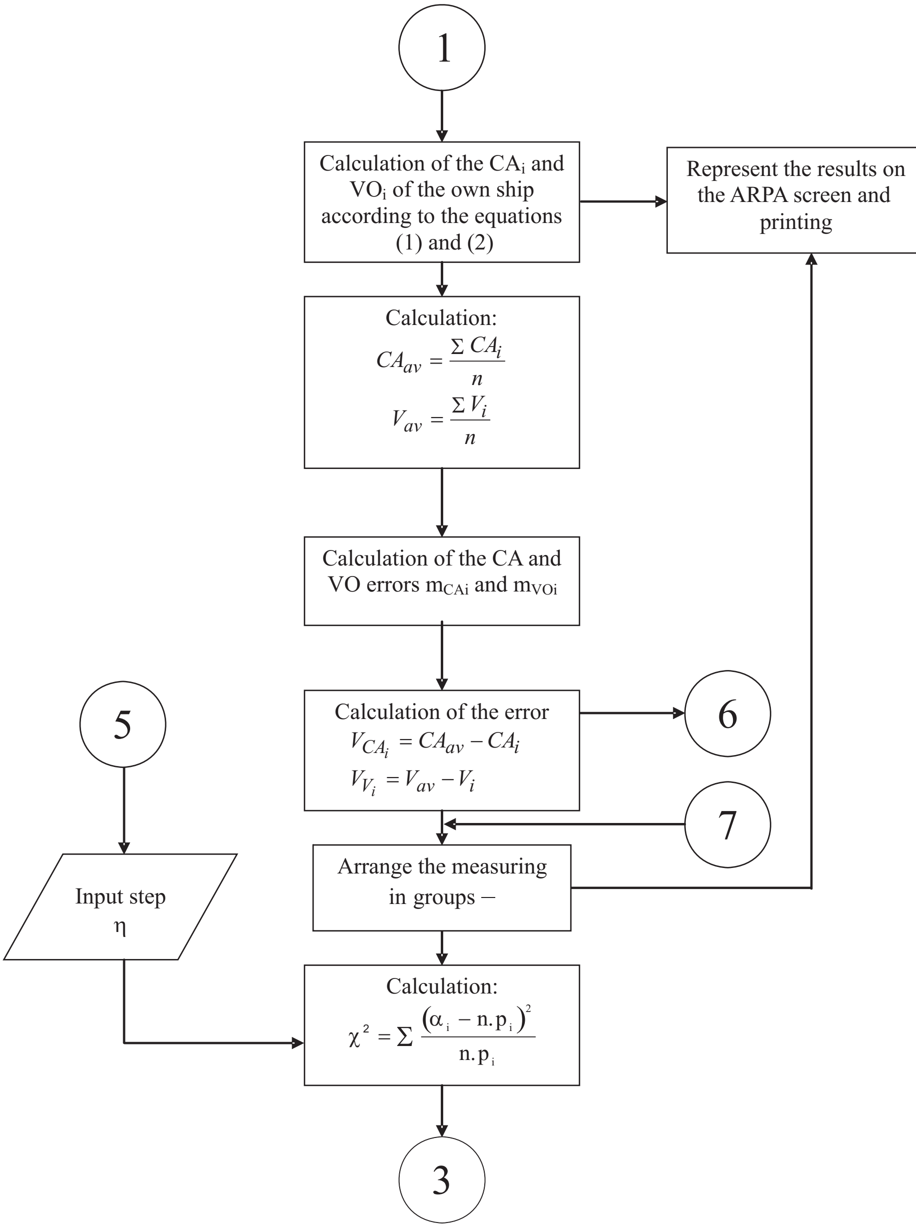
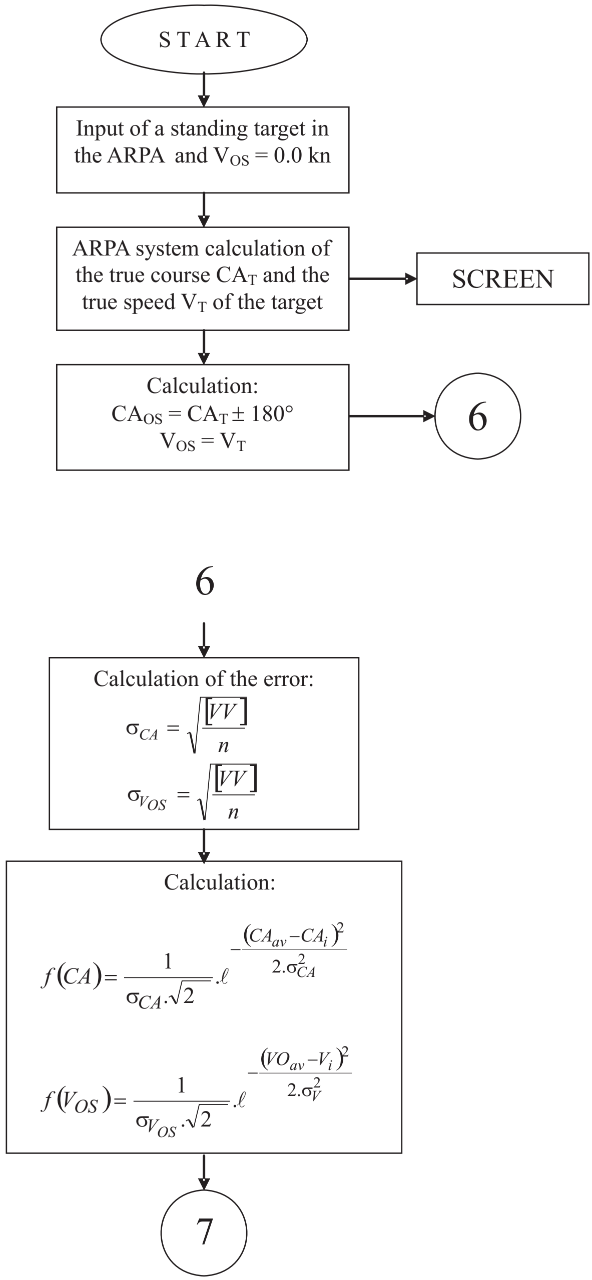


Figure 1: to be continued



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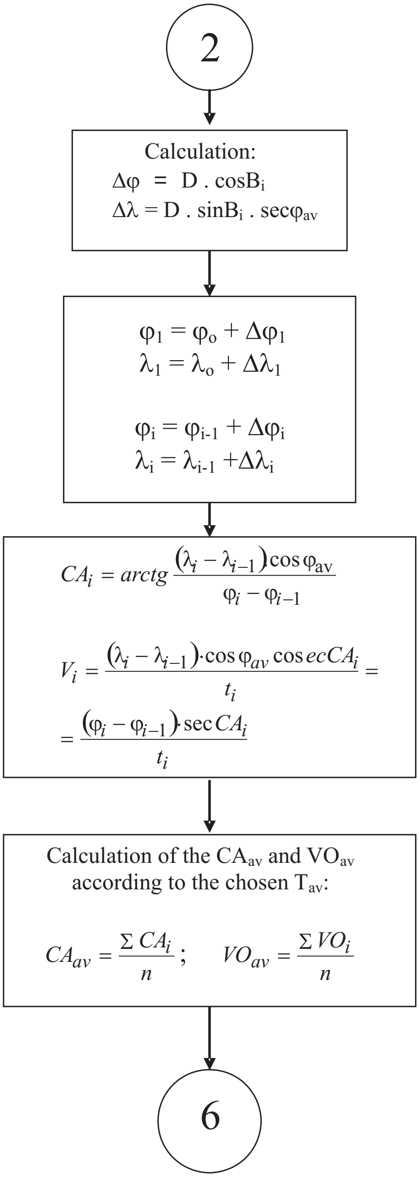

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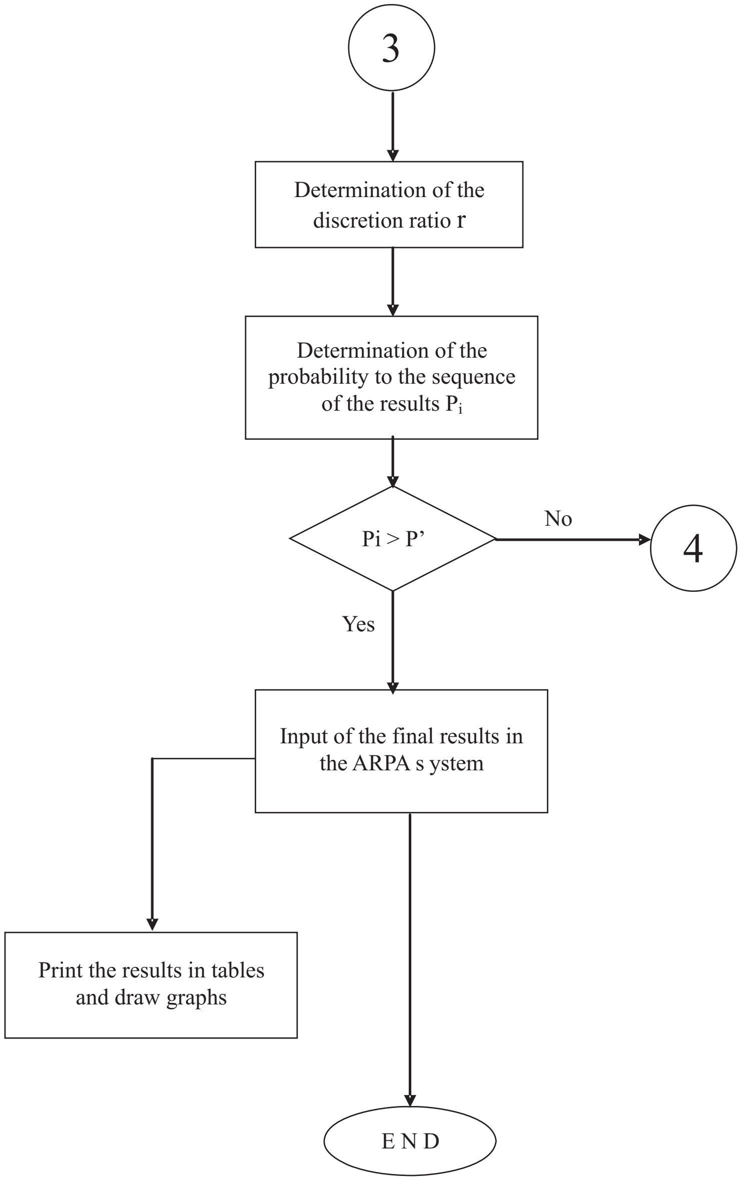

Figure 1: to be continued

7. CA_i and VO_i are calculated by means of the introduced bearings and distances according to the equations:

$$CA = B_1 + \arcsin \frac{D_2.\sin\delta}{\sqrt{D_1^2 + D_2^2 - 2.D_1.D_2.\cos\delta}} \tag{1}$$

$$VO = \frac{\sqrt{D_1^2 + D_2^2 - 2.D_1 D_2.\cos\delta}}{n.\tau_A} \tag{2}$$

whereB_1, D_1 and D_2 are the measured bearings and distances to the target;

$\delta = B_2 - B_1$ – difference between the measured bearings at the beginning and at the end of the measurements;

n - number of the ARPA antenna revolutions;

τ_A - time of one revolution.

8. For the chosen time interval $T_{av,}$ the values of CA_{av} and VO_{av} are calculated for the series of measurements, entering each channel.

9. The average quadratic mean m_{CAi} and m_{Vi} are calculated for the so determined values of CA_{AVi} and $VO_{AVi.}$

10. The results are evaluated by concordance per criterion χ^2 [4, 6]. For this purpose the quadratic mean deviations are distributed into groups in the direction of increase, where the separation is of step ή, which depends on the value of the quadratic mean error of the measurements. The step (encircled number) must be the same for the whole period of research. The algorithm in the so far described order is represented graphically.

4. CONCLUSION

The realization of the described methodology offers the navigator the means for an independent determination of the own ship motion elements. The utilization of ARPA for the determination of the course angle and the true speed of the ship must be effected in regions of not heavy ship traffic. At the manual introduction of $V_O = 0.0$ knots the screen image changes and the solution of the problem for passing is canceled.

The evaluation of the ARPA data exactness, performed by comparing three results, offers a possibility for the evaluation of the surveyed benchmark correctness, the measuring exactness and system calculation, as well as for the evaluation of the influence of the weather conditions around the ship.

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Sažetak

IZRAČUN KRETANJA BRODA

U članku se opisuje metodologija izračuna elemenata kretanja broda kursom preko dna i brzinom preko dna pomoću ARPA sustava. Navedene su i neke posebnosti u samoj metodologiji izračuna elemenata kretanja broda i njegovoj primjeni u praksi, što prvenstveno ovisi o relativnoj poziciji broda i njegove udaljenosti do različitih točaka označenih na radaru. Na osnovi te metodologije i koristeći navigacijski simulator Fakulteta za pomorstvo in promet Univerze u Ljubljani, izrađen je algoritam koji se, pomoću osobnog računala, može lako koristiti. Računalo se može spojiti na ARPA sustav preko posebnog izlaznog uređaja.

Ključne riječi: *sigurnost plovidbe, radar s automatskim ucrtavanjem (ARPA), kurs preko dna (COG), brzina preko dna (SOG)*

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