USE OF ECDIS IN ASTRONOMICAL NAVIGATION

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ABSTRACT

This paper deals with the use of ECDIS for plotting position by using celestial bodies. Standard intercept method results in the line of position (LOP) which should be plotted on the navigation (paper) chart or a hand-made auxiliary diagram, where two or more intersecting LOPs indicate the position of the vessel. The navigation (paper) chart is more convenient for direct plotting of LOP than standard blank paper (auxiliary diagram), but the paper charts are being increasingly replaced by electronic chart systems, i.e. the ECDIS (Electronic Chart Display and Information System) that is recognized as an official paper chart equivalent. Accordingly, everything that can be plotted on the paper chart should be also available in the ECDIS. This includes plotting of the astronomical LOPs. Although most of today's ECDIS systems do not support ephemerides nor the possibility of the direct LOP's determination, the available functions of manual drawing of different symbols and objects, combined with ERBL function, enable graphical plotting of LOPs and, eventually, fixing the vessel's position. In addition to the analysis of standard astronomical LOP plotting (for fix and running fix), this work also analyses the ways the ECDIS can assist in approximate position determination when only the azimuths of celestial bodies are known. Certain recommendations for future ECDIS improvements are given as well.

Keywords: **ECDIS, Astronomical navigation, Line of position (LOP), Azimuth**

1 INTRODUCTION

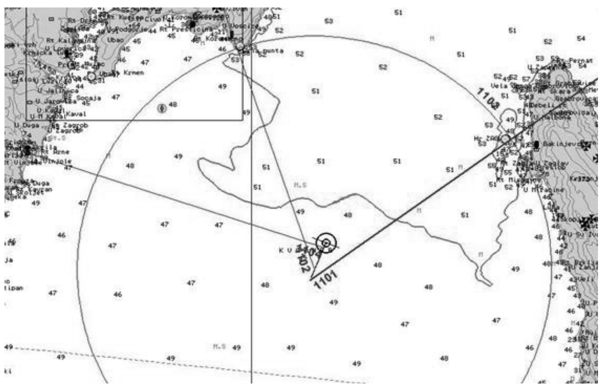
Modern navigation is inconceivable without appropriate electronic devices and systems. One of them is the Electronic Chart Display and Information System (ECDIS), a navigation information system which, with adequate back-up features, complies with the up-to-date charts required by SOLAS Convention. It displays selected information from a System Electronic Navigational Chart (SENC) and positional information from navigation sensors and additional navigation related information if required, thus assisting mariners in route planning and route monitoring (A817). ECDIS is a complex software based system with multiple options for display and integration, primarily designed for sea passage planning and navigation. As required by SOLAS Regulation V/19.2.10, the mandatory introduction of ECDIS onboard vessels is coming into force gradually, in several stages, between 1 July 2012 and 1 July 2018. From 1 July 2018 onward, all cargo vessels over 10,000 GT built before 2013 will have to install ECDIS, whereas for the new build vessels this requirement has applied since July 2013. Likewise, as from 1 July 2012, all passenger vessels over 500 GT and all tankers over 3,000 GT have been obliged to carry ECDIS (SOLAS, Chapter V). The system has been mandatory on high-speed craft since 1 August 2008 (MSC.1/Circ.1503). Mandatory carriage of ECDIS does not automatically mean that paper charts will become superseded. However, it is not likely that the traditional paper charts will stay forever, as SOLAS Convention already allows a vessel to sail without paper charts, provided that the relevant statutory requirements are met

The primary function of the ECDIS is to contribute to safe navigation and to make navigation easier. ECDIS should be able to display all chart information that is necessary for safe and efficient navigation and should reduce the navigational workload as compared to traditional chart work. It should enable the mariner to perform all route planning, route monitoring and continuous plotting of the vessel's position in a convenient and timely manner. Also, ECDIS should have at least the same reliability and availability of presentation as the navigational paper chart. Although the ECDIS system is capable of meeting numerous statutory, technical and functional requirements, there is still room for improvement. Perhaps the best example is the application of astronomical navigation or, generally speaking, when navigating without the aid of any satellite positioning system. Every ECDIS system has the dead reckoning (DR) feature and allows manual record of position, plotting lines, position circles, symbols and text, but all these features are applicable to coastal navigation. The situation is quite different in astronomical navigation as most of the modern ECDIS systems do not enable direct plotting of the astronomical position lines. This paper describes how to draw an astronomical line of position (LOP) given the existing functional capacity of standard ECDIS systems. The analysis primarily focuses on the application of the intercept method and the method of drawing the orthodromic azimuth and isoazimuth. The ECDIS system used in the analysis is Transas Navi-Sailor 4000.

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) still requires that all officers in charge of a navigation watch have knowledge to use celestial bodies in order to determine the ship's position in the open seas, but the Convention also states that the use of appropriate celestial navigation calculation software and electronic almanac is allowed.

2 ECDIS AND MANUALLY FIXED POSITION

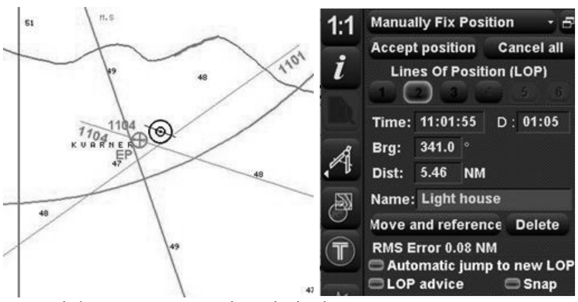
Today's standard ECDIS systems provide the feature of manual plotting of the position. The procedure includes manual insertion of a selected azimuth (or distance) (Figure 1), moving the displayed line of position (LOP) to the reference object, repeating the procedure for another object (plotting another LOP), and fixing the position (Figure 2). As the system has an internal clock, the time of fixing an LOP is automatically set, although it can be also done manually, with certain restrictions). The system keeps record of the time difference between taking bearings of the current and the first LOP, which enables the calculation of the travelled distance. After taking bearings of the relevant reference objects and insertion of parameters, it is necessary to place the LOPs on the bearing objects (or move them, taking into account the ship's speed and course), which is enabled by the tool "Move and reference" for each LOP respectively.



Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 1: Position by two azimuths and one distance

All lines of position can be seen on the ECDIS display, along with the times when their bearings were taken (Figure 1).



Source: (Transas Navi-Sailor 4000 ECDIS)

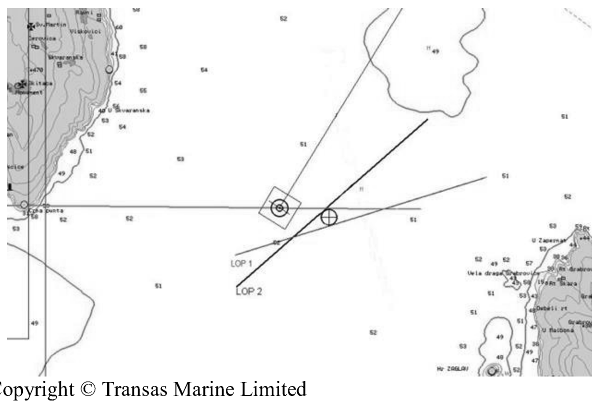
Figure 2: Manually plotted estimated position (EP)

After moving the LOPs, it is necessary to confirm the position by the tool "Accept position". The system then displays the time of fixing the new position and enters the new position into the Ship Logbook. The system accepts and marks the new position as the estimated position EP (Figure 2) (Transas Manual, 2011), regardless of the primary position fixing method (DGPS or DR) that was previously used. These procedures are performed with the help of the tool "Manually Fix Position" (Transas ECDIS).

3 USE OF ECDIS AVAIABLE TOOLS FOR MANUAL PLOTTING

There are "Maps" and "Man Corrs" functions in Transas ECDIS that allow manual insertion of symbols, lines, circles, text, selection of their colour and outline, etc. With this features it is relatively easy to plot the circles and lines of positions. For transferring the lines of position at time intervals, the user can select the option "Shift", within the function "Edit", which allows the user to move the entire LOP to any distance in the desired direction. All that time the ECDIS display shows the values of the LOP's transfer, from its initial position (distance in NM / meters and azimuth). The azimuth of the transferred LOP must correspond to the steered course and the distance must correspond to the distance travelled. The intersection of the LOPs determines the ship's position in required time (Figure 3). Drawing of circles is used for drawing the LOP distance.

When the ECDIS, apart from "Man Corr" option, features an additional tool "Maps" for inserting the symbols, then the function "Maps" has to be used for manual plotting (if the "Manually Fix Position" function is not in use). The "Man Corr" tool is designed for correcting hydrographic data in ECDIS charts. These changes are permanently visible – even when the user erases the changes by using the function "Delete", they can be retrieved and called back on the display subsequently. If the "Man Corr" tool is used for manual position plotting, it is possible to limit the time of appearance of the symbols on the display when inserting them. In this way, the plotted position will be erased from the system after the time limit.



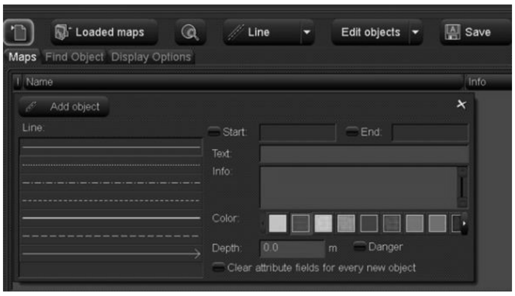
Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 3: Position fixed by three azimuths, plotted by using "Maps" function tools

On the other hand, the "Maps" tool enables deletion of the drawn symbols without setting their time limit. This function is not used for entering permanent changes of hydrographic data but for entering all other data relevant for the navigation which have to remain visible in the chart. This information has only a short-term importance and must be deleted upon completing the voyage. "Maps" and

"Man Corr" tools offer an identical selection of symbols and equal functionality for manual plotting (Figure 4).

a) Panel "Man Corr"



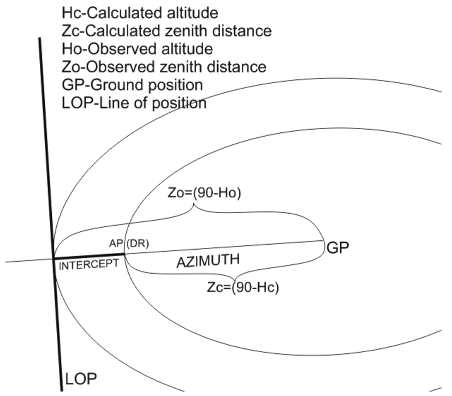
b) Panel "Maps"

Source: (Transas Navi-Sailor 4000 ECDIS)

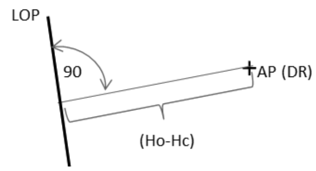
Figure 4: Panels "Man Corr" and "Maps"

4 LINE OF POSITION (LOP) IN ASTRONOMICAL NAVIGATION

To obtain an LOP (line of position) in astronomical navigation, the most common method is the intercept method, also known as Marcq St. Hilaire method. The essence of this method lies in plotting the LOP for calculating the transfer from the dead reckoning (DR), i.e. assumed or approximate (AP) position. It must be noted that the final part of this procedure is performed graphically in the navigational chart or plain sheet of paper (Figure 5). Other (older) methods, such as the Sumner line of position, longitude methods and ex-meridian method, also require graphic work in the final stage of plotting LOPs. Of all astronomical navigation methods that are used today to manually fix the position without graphic drawing is the Dozier method (Čumbelić, 1990) which directly gives the intersection coordinates of two circles of equal altitudes. However, this procedure is rarely applied in manual plotting as it is impractical when fixing the position by three or more celestial bodies (Figure 6).



a) Small scale view

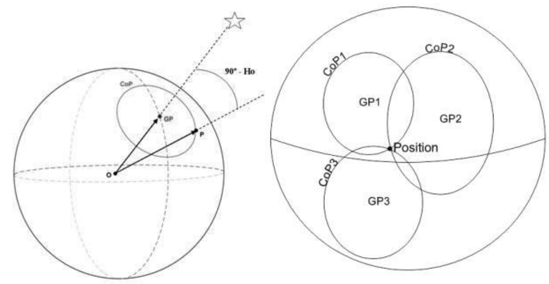


b) Large scale view

Source: (Authors)

Figure 5: LOP by Marcq St. Hilaire (intercept) method[1]

As a rule, ECDIS systems do not feature ephemerides or special software applications for the automatic calculation of the position in astronomical navigation. Therefore, the only remaining solution is to improvise with the options such as Manually Fix Position, Maps and Manual Correction (Man Corr) (Transas ECDIS). Moreover, we can only measure the altitudes and azimuths of celestial bodies, so that only these values can be used for plotting the line of position, i.e. fixing the vessel's position.



a) *CoP* b) *Position by three CoPs*

Sources: Fig a (http://fer3.com/), Fig b (Authors)

Figure 6: Circle of equal altitudes (CoP) and the position by three CoPs

4.1 Use of *Manually Fix Position*

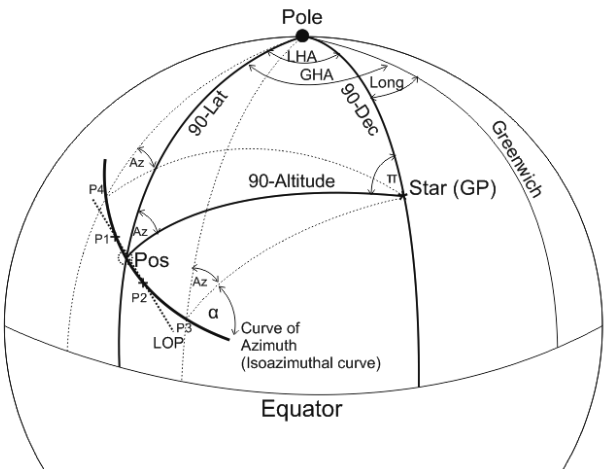
The problem of using the "Manually Fix Position" tool in obtaining the LOP in astronomical navigation lies in the fact that the azimuth of a celestial body is a part of the great circle (orthodrome), while the great circle on the Mercator navigation chart is not a straight line, but a curve. Basically, the azimuth of a celestial body is an orthodrome from the point of the observer to the point of the Geographical Position (GP)[2] that is defined by the declination and Greenwich hour angle (Figure 7). Direct

[1] For additional details see: (Čumbelić, 1990) and (Bowditch, 2002)

[2] Geographical Position (GP), also called Ground or Terrestrial Position, is the place having the body in its zenith (Bowditch, 2002)

plotting of the orthodromic azimuth in the navigation chart, i.e. approximation of the orthodromic azimuth with the loxodromic azimuth (LOP) is feasible only in short distances, which is not the case in astronomical navigation. On the other hand, it is possible to directly draw a circle as a line of position only if the ECDIS system features the display of the circles of equal altitudes (Figure 6) of the observed celestial body (in the shape of ellipsoid, cosine or parabola in the Mercator navigation chart).

Figure 7 shows the basic astronomical triangle whose three main points are the Zenith (Z), the Celestial Pole, and the celestial body (star). The projection of the triangle on the Earth gives s spherical triangle whose points are the Position of observer (Pos), Pole and the projection of the celestial body on Earth (GP). The main angles are Azimuth (Az), Local hour angle (LHA) and parallactic angle (π), while the main arcs are the complement of Latitude (90-Lat), complement of Altitude (90-Alt) and complement of Declination (90-Dec).



Source: (Authors)

Figure 7: Astronomical triangle and isoazimuth curve

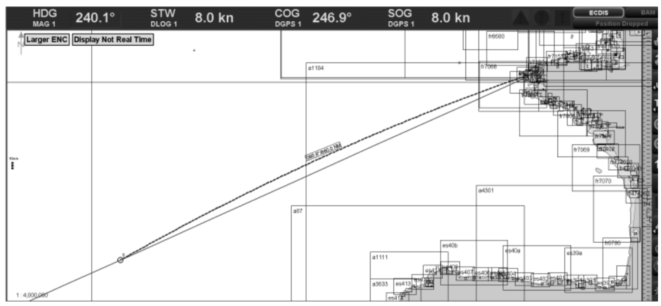
By knowing the Equatorial coordinates (Greenwich hour angle – GHA and Dec) and the observer's position, it is possible to determine the horizon coordinates (altitude and azimuth), which forms the basis of the intercept methods most commonly used in astronomical navigation positioning today. This task can be solved in a numerical or graphical way. Figure 7 also shows the isoazimuth curve whose each individual point closes the same orthodromic azimuth to the reference point, i.e. the celestial body. In the immediate proximity of the real position (Pos in Figure 7) the isoazimuth curve can be replaced by a line, i.e. it can represent a line of position. Its construction requires two points in the close vicinity of the dead reckoning (DR). The points can be obtained by calculating respective geographical longitudes for two estimated latitudes, or vice-versa (points P1 and P2 in Figure 7)[3].

a) Use of the line of position

At short distances from the observed objects (up to around 50 NM), there is no significant difference between the loxodromic azimuth and orthodrome so that the orthodromic azimuth is plotted just as the loxodromic one. At medium distances, ranging from 50 NM to 150 M, it is possible to replace the orthodromic azimuth with the loxodromic one, taking into consideration an appropriate correction[4], while at distances over 150 NM, the approximate position can be determined by constructing an isoazimuth (Benković et al., 1986). Given the fact that in astronomical navigation the objects at high altitudes (small zenith distances) are not sighted, this implies that the distance from the observer to the terrestrial projection point (GP) will be at very large distances so that, accordingly, it is not possible to determine the position by means of azimuths directly. If the deviation from the dead reckoning (or assumed) position was minimal from the actual one, the line of position could be approximately obtained as shown in the following example.

Example 1 (Nautičke tablice, 1984):
From the dead reckoning Lat=44.0°N; Long=19.0°W in the orthodromic azimuth ω_{GC}=066° we observe an object whose coordinates are Lat=48.5°N; Long=004.5°W.

Solution:
Correction c/2=5.1° is used from Nautical table 23 (Nautičke tablice, 1984).
Loxodromic azimuth $\omega_{RL}= \omega_{GC}+c/2=066°+5.1°=71.1°$.



Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 8: Orthodromic azimuth and calculated loxodromic azimuth (Example 1)

Figure 8 shows the relationship between the orthodromic azimuth and calculated loxodromic azimuth in the nautical tables: *"Correction to convert (radio) great circle bearing to Mercatorial bearing"*. The ECDIS system displays it as follows (Figure 8): the orthodromic azimuth is drawn by using the tool "Route planning" (as the course); correction (c/2) is calculated manually with the aid of nautical tables, while the loxodromic azimuth (LOP) is plotted by using the "Manually Fix Position" tool. The plotted LOP passes within one nautical mile from the dead reckoning (DR) that actually represents the true position as the correction c/2 has been calculated for it. Therefore, in the context of astronomical navigation this procedure will not be

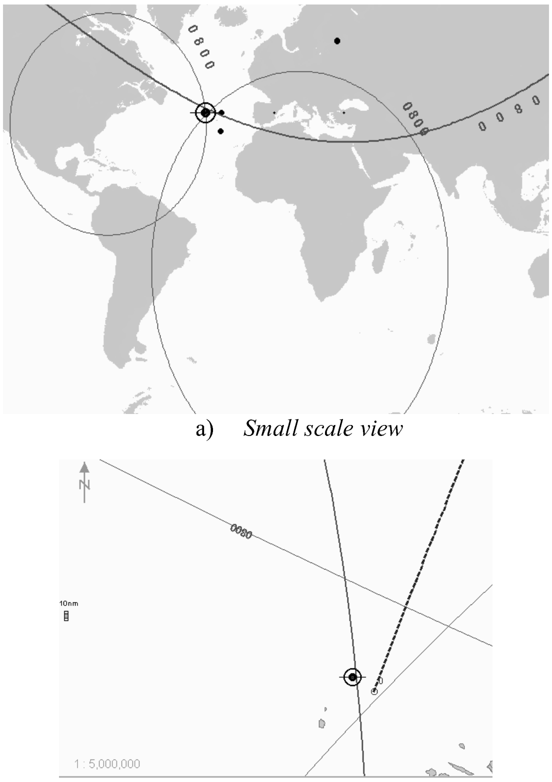
[3] For more details see (Lušić, 2018)

[4] In nautical tables this can be found under the name "Correction to convert (radio) great circle bearing to Mercatorial bearing" (Norie's Nautical Tables, 1991), (Nautičke tablice, 1984).

appropriate as the method itself cannot provide the transfer from the DR to the true position. This problem can be solved by constructing an isoazimuth, as described in Paragraph 5.

b) Use of the circle of position

If the ECDIS tool "Manually Fix Position" features the display of the circle as the line of position of unlimited radius, then the astronomical position can be easily fixed. The truth is that the line of position is defined by the zenith distance (90-Alt), i.e. the radius of circle of equal altitudes, where the circle's centre represents the ground position (GP). The GP coordinates are established as follows: latitude GP=declination of the body (Dec) and Longitude GP=Greenwich hour angle of the body (GHA).



a) *Small scale view*

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b) *Large scale view*

Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 9: Circles of equal altitudes on ECDIS display (Example 2 – Table 1)

Figure 9 shows the position obtained by using the tool "Manually Fix Position" (Transas ECDIS), in such a way that three distances are inserted for the same observation time. The distances are actually true zenith distances (90-Ho) from Example 2 – Table 1. Although the ECDIS in use features the possibility of plotting the line of position of unlimited radius, this LOP is not suitable for practical use due to errors in graphic display. Figure 9b (large scale view) indicates a considerable deviation of the inserted LOPs from the actual distances. For example: the first LOP-Kochab (in Figure 9b LOP perpendicular to the dashed line, deviates several dozen nautical miles from the real position – point "0"; the dashed line represents the true orthodromic azimuth for the same distance as the plotted circle of equal altitudes (Kochab), but calculated and displayed via the option "Route planning". This means that two functions within the ECDIS system (Transas ECDIS) display the distance in graphically different ways.

4.2 Use of *Maps or Manual Correction Function*

Given the fact that the ECDIS system features the possibility of manual drawing of lines, circles, symbols etc. the latter can be used for the display of LOPs, i.e. positions. The obtained positions will not be recognised by the system automatically, but this does not make this function less important in any way. It is exactly owing to this function that the user of ECDIS can also perform operations that have not been systematically defined and embedded as the final ready-to-use options. The basic features of the functions "Maps" and "Man Corr" have been described earlier in Paragraph 3 and now the study will show how to use these functions for obtaining the line of position (LOP), i.e. the position in astronomical navigation. For the purpose of exemplification, the tool that has been most commonly used in recent practice will be used: the intercept method where the final portion of the problem is solved on the navigation chart, i.e. on a sheet of plain paper. It is assumed that the numerical or tabular calculation of the basic elements is performed manually in the form of tables or with the aid of other program solutions. Therefore, only the final stage of the LOP graphic plotting will be carried out using ECDIS. In our example, the elements defining the LOP (GP, ΔH and Azc- from Table 1) need to be drawn in ECDIS system.

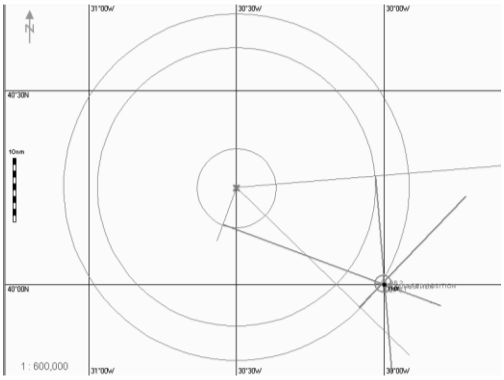
Example 2.
On September 01, 2015 at UT 08 00 00, at DR Position Lat=40°15.0'N and Long=030°30.0'W three bodies (Kochab, Spica and Pollux) are observed.

The measured altitudes (Ho), true azimuths Az, calculated altitudes and azimuths (Hc and Azc), and Ho-Hc are shown in Table 1.

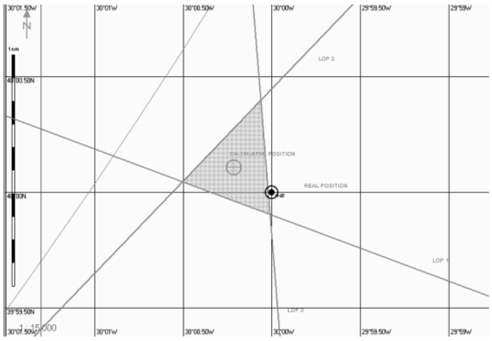
Table 1: Example of the intercept method

Kochab		Spica		Pollux	
GHA327°43.5' Dec74°04.9N	GP Long032°16.5'E Lat74°04.9N	GHA348°50.5' Dec11°15.0S	GP Long011°09.5'E Lat11°15.0S	GHA073°46.0' Dec27°57.7N	GP Long073°46.0'W Lat27°57.7N
Ho 45°42.9'	Hc 45°49.0	Ho 26°07.2'	Hc 25°40.3'	Ho52°11.8'	Hc52°33.3'
Az 20.3°	Azc 20.5°	Az 134.0°	Azc 133.7°	Az 265.3°	Azc 264.6°
ΔH=Ho-Hc=-6.1'		ΔH=Ho-Hc=+26.8'		ΔH=Ho-Hc=-21.5'	

The results[1] from Table 1 are used to perform the intercept method's last step using the ECDIS system (Figure 10).



a) Small scale view



b) Large scale view

Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 10: Position obtained by intercept method

Figures 10a and 10b clearly show that the triangle resulting from the LOPs has been sufficiently small for fixing the reliable position. This is the screenshot of ECDIS (Transas ECDIS) where all lines and symbols were inserted via the "Maps" function".

5 USE OF AZIMUTHS AND ISOAZIMUTHS FOR POSITIONING

Azimuth-only direct positioning in astronomical navigation is typically avoided for a number of reasons. Two of them are rather serious. The first reason, described earlier in the paper, refers to the fact that the observed azimuths are orthodromic azimuths and do not represent lines in the Mercator navigation chart. Also, the sighted orthodromic azimuth cannot represent a line of position because the same value of this orthodromic azimuth can be obtained by observers at various positions. Another reason, not less important, is the fact that azimuths cannot be accurately measured. It is very hard, sometimes even impossible, to achieve the accuracy better than +/-1° (Xu et al., 2014), and a minor azimuth error results in major move (error) of the LOP. For instance, an azimuth error of 1° to the object situated 3,000 NM results in the move of the LOP of about 51 NM[2]. For practical use of azimuths in direct plotting of LOPs, it would be necessary to achieve the minimum precision of +/-0.1°, which is presently feasible only in static conditions. Assuming that, nevertheless, it is possible to achieve the azimuth precision of at least +/-0.1°, ECDIS tools can be very useful for quick and simple solving the issue of fixing the vessel's position with the aid of celestial bodies. The following paragraphs will explain how to use the ECDIS system for the construction and display of isoazimuths as lines of position and for direct fixing of the position in astronomical navigation by using only the available azimuths of celestial bodies.

5.1 Isoazimuths

Isoazimuths can be graphically constructed[3] by taking into consideration the function "Correction to convert (radio) great circle bearing to Mercatorial bearing" (Norie's Nautical Tables, 1991). However, when there is a large distance between the position and the observed object (distance from Pos to GP – Figure 7), the method of calculating two points in the immediate proximity of the dead reckoning (assumed) position represents a better solution.

Example 3 (input data from Example 2 – Paragraph 4.2)
Suppose we know the true azimuths (Az) and equatorial coordinates (Dec and GHA). The DR is also known. Altitudes remain unknown. The starting assumption is that the dead reckoning (DR) position is not correct so that, accordingly, two selected latitudes (or longitudes) are shifted by 15' N/S, i.e. 15' E/W from DR. The task can be completed by calculating two longitudes for the two selected latitudes, or vice-versa. In this particular case, the latitude is selected for the first and third body, longitude is calculated, while the procedure is opposite for the second celestial body. This selection is performed in order to make the obtained points as close to DR as possible.

The obtained coordinates of the reference positions are:

First body (Kochab)

- selected long 1: 030° 45.0'W, calculated lat 39° 40.3'N
- selected long 2: 030° 15.0'W, calculated lat 39° 40.3'N

Second body (Spica)

- selected lat 1: 40° 30.0'N, calculated long 030° 13.9'W
- selected lat 2: 40° 00.0'N, calculated long 030° 02.3'W

Third body (Pollux)

- selected long 1: 030° 45.0'W, calculated lat 39° 33.5'N
- selected long 2: 030° 15.0'W, calculated lat 39° 50.1'N

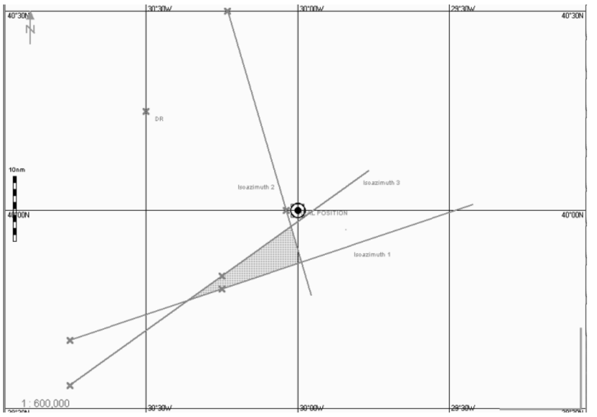
[1] Results (calculated azimuths Azc and calculated altitudes Hc) provided through Skymate software.

[2] Based on the expression d(error)=0.017 D (D-distance to object) (Benković et al., 1986).

[3] More details about the method in (Benković et al., 1986).

Joining of the obtained coordinates results in a straight line that can serve, relatively well, as an isoazimuth so that it can represent a line of position. Its accuracy relies on the accuracy of the azimuth, DR error, but also on the reference (selected) positions in relation to the true position. The LOP is more accurate when the true position takes place between reference positions (closer to the centre), which is not the case in the described example.

Figure 11 shows the intersection of the three obtained isoazimuths (actually, three lines of position). Each of the lines is defined by two reference positions (marks "x" in Figure 11). The position error is relatively large, however yet smaller than the DR error. Figure 11 is a screenshot of the ECDIS (Transas ECDIS) display and all visible lines and symbols have been inserted via the "Maps" function.



Source: (Transas Navi-Sailor 4000 ECDIS)

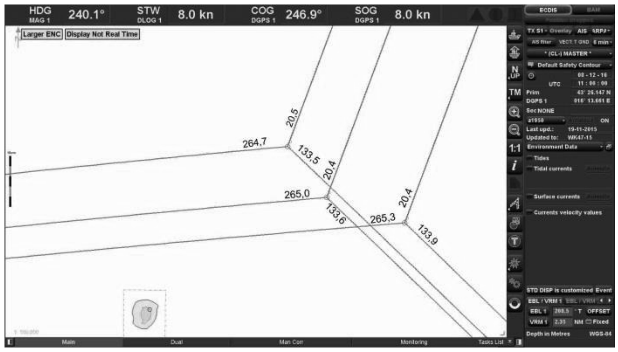
Figure 11: Position by isoazimuths

5.2 Direct plotting of the azimuth

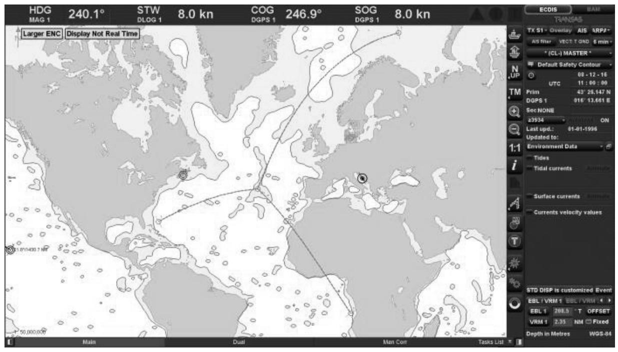
The estimation of the position based on the direct plotting of the azimuths can be performed by using the tool "Route planning". The procedure is as follows (Figure 12):

- plot the GP as per known Greenwich hour angle and declination;
- draw the GC bearing, i.e. orthodromic azimuth, (or course) between the DR (or assumed) position and GP for the first body. The procedure is repeated for other bodies, after which the obtained azimuths (courses) are compared;
- If the azimuth are not good, the DR is shifted, as estimated, by a certain value (Figure 12: 10' south and 10' east) and the calculation of the azimuths (courses) is repeated;
- The procedure is repeated as long as the obtained results approximately correspond to the sighted values of the azimuths (Figure 12: the third position shifted from the first one by 15'S and 30' E).

Solving the problem in the above described way is a relatively long procedure because the ECDIS system does not feature the direct plotting of the orthodromic azimuths so that the latter are simulated by orthodromic courses with the aid of "Route planning" tool (Transas ECDIS). The procedure would be considerably easier if the ECDIS had the capacity of plotting a number of orthodromic azimuths and if these azimuths could be automatically shifted, following the shift of the DR (assumed) position.



a) *Large scale view*



b) *Small scale view*

Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 12: Direct position by three azimuths

(a – large scale view, b – small scale view)

Figure 12 is a screenshot of the ECDIS (Transas ECDIS) display where all visible lines have been inserted via the "Route planning" function. Textual values of azimuths (Figure 12a) have been subsequently inserted using special graphic design software for the purpose of simple explanation of the problem solution.

6 CONCLUSION

The Electronic Chart Display and Information System (ECDIS) is an electronic device primarily designed for safe passage planning and sea voyage supervision. It has become increasingly mandatory onboard a variety of vessels and has been gradually displacing navigation paper charts from use, thus affecting the traditional ways of performing navigation. ECDIS has become a synonym for modern navigation, the groundwork for building or designing future solutions. On the other hand, astronomical navigation is a synonym for classical navigation, which many modern mariners now consider to be history.

However, astronomical navigation has an essential feature that makes it a valuable navigation asset that is likely to survive, in some form, a number of years to come. Unlike other systems, mainly electronical, astronomical navigation is the only autonomous system that is available as long as the observable celestial bodies exist. If the mariners and watch-keeping officers are allowed to use electronic almanacs and associated software tools for dealing with the elements of astronomical navigation, it seems legitimate to wonder why these elements are not integrated into ECDIS systems. With the exemption of the nautical almanac, which may or may not be fitted into a future ECDIS system, other elements necessary for plotting astronomical lines of position should be definitely incorporated into basic ECDIS functional tools. Even though modern ECDIS systems allow drawing of lines, circles, symbols and other items used for performing any task in paper charts, this feature is not suitable for astronomical navigation, nor does it comply with the basic ECDIS concept of making the navigation at sea simpler and more efficient and reliable. Of all tools for plotting the lines of position (LOP) in astronomical navigation by means of ECDIS, it is important to emphasise the importance of direct drawing of the circles of equal altitudes and GC (orthodromic) azimuths. If ECDIS systems were able to draw the circles of equal altitudes, this would mean that the problem of fixing the position in astronomical navigation could be reduced to measuring altitudes by means of the sextant and direct plotting of the zenith distance in ECDIS whose centre is the Ground Position (GP), just like the circle as an LOP is drawn by using the "Manually fix position" tool. Then the elements of the intercept method would not be needed at all. Moreover, if ECDIS systems could directly plot the GC (orthodromic azimuth) from the selected point towards an object, or if isoazimuths could be calculated, the position fixing would be possible just with the help of azimuths. One of these days, when classic astronomical navigation does become history, i.e. when the sextant disappears from vessels, the suggested improvements could remain as the available back-up option for the mariners. This alternative does not require a comprehensive knowledge of astronomy, or classic astronomical navigation, and would be as simple as the plotting of azimuths and circles (LOPs) within the existing ECDIS function "Manually Fix position".

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