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Numerical simulation for ship route planning

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Abstract. The need to identify an optimal route for the ship is the main objective of planning a voyage. The development of IT technologies helps to choose the optimal route, considering different factors that can influence an optimal routing of the ship's route. This study identifies and traces the route of a voyage using dedicated functions in the Matlab program with basic input data provided by the user. The output data provided by the developed application indicate both the actual tracing of the route on a real map and information on the course and distance for the chosen route.

Keywords: Ship route, Matlab Mapping toolbox, rhumb line, course, heading

1. Introduction

Optimizing the voyage of a ship is a major objective for shipping companies to make transport costs more efficient [5]. Until the advent of IT technologies, the planning of a ship's voyage was done traditionally, manually, using nautical charts, and information about weather forecasts and other current voyage data. The implementation of IT technologies in the maritime transport of the product or change in the way of planning the route of a ship's voyage. Thus, the additional computing power with more detailed weather forecasts made it possible to move from simply choosing a travel route to optimize the route about an established criterion. Currently, programs for optimizing a ship's voyage route are being developed, which consider the analysis of a single optimization criterion, treating the other criteria, which may influence the route of a ship, as limitations [4]. The main criterion in optimizing the voyage route of a ship is the identification of the shortest routes, with benefits on the reductions of the voyage time and implicitly of the fuel consumption, with an effect on the reductions of the air pollution. This article proposes the development of an optimal ship routing tool, using Matlab functions, based on the "shortest route" criterion, other criteria such as ship safety, optimization of fuel consumption in terms of resistance to ship advance, constraints geopolitical, etc., not being taken into account. This study draws the optimal route of the ship between two ports, with the aim of "the shortest distance," as well as to determine the distance of parks and the course of the ship. To exemplify the operation of the instrument developed in this study, the route Constanţa (Romania) - Cagliari (Italy) was chosen, a

complex route, in which the ship must be navigated through several seas and cross the Bosphorus Strait.

2. The method (Circle line vs. Rhumb line)

The shortest path between two points on the surface of the terrestrial sphere is called the orthodrome (circle line). Because the orthodrome does not intersect the meridians at a constant angle, it means that it cannot be used for navigation directly because in this case the helmsman should constantly change the ship's course.

There are several methods for solving orthodromic navigation problems, all of which result in a list of waypoints to be included in a roadmap for ocean navigation.

The successful execution of a crossing, both in terms of safety and economy, is one of the professional maturity exams of the navigator. The choice of the most favourable solution for the road to follow, the measures to be taken for the safety of navigation, etc., must consider the nautical qualities of the ship, the hydro-meteorological factors in the area, the type of cargo loaded on board, any precautions imposed by the stacking method, and mooring. Note that the recommended routes for the ocean crossing are invalid for all ships, even for the same ship they may differ depending on the loading conditions or certain particularities regarding its technical condition.

At sea, the shortest distance between the point of departure and the point of destination must be considered to allow the crossing in complete safety and in the shortest time, the risk possibly imposed by the particularities of the area or ship must be taken within reasonable limits, considering permanently by the primacy of the safety criterion.

Although the rhumb line is not the shortest way between two points from the surface of the Earth, however, navigation is possible only on rhumb line, a fact imposed by the way the ship is steered, which is done by maintaining a constant path with the help of the compass.

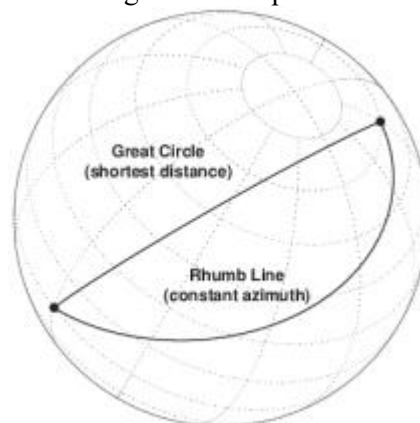


Figure 1. Circle line vs Rhumb line [3]

When the distance between the point of departure and arrival point is relatively reduced, for example in the case navigation in the Black Sea, the Sea Mediterranean or Red Sea, the difference between the rhumb line and the orthodromic distance is insignificant (Figure 1).

However, if the distance between the point of departure and the point of arrival is large and the points are at a great difference in longitude, as is the case ocean crossings, the difference between the rhumb line and the orthodromic distance may be considerable: in this case, if hydro-meteorological factors do not require otherwise, to reduce the distance traveled, navigate on short rhumb lines connecting intermediate points of the orthodrome; this way of navigating between two points at a great distance is called orthodromic navigation. Navigation along the orthodrome is not possible, because it would require a continuous change in the ship's course [1].

This study succeeds in obtaining a navigation route using one of the two methods with the help of a very well known software used in engineering.

3. Matlab implementation

In order for a better calculation of both rhumb and circle line we choose to use the Matlab dedicated built-in Mapping toolbox functions.

3.1 Display a chart in Matlab

Using the function “geoshow” (Figure 2) to display map latitude and longitude data, in this study to display a chart of the Mediterranean Sea (Figure 3)

```
load coastlines
axesm('mercator', 'MapLatLimit',[28 47], 'MapLonLimit',[-10 37],...
'Grid','on', 'Frame','on', 'MeridianLabel','on', 'ParallellLabel','on')
geoshow(coastlat,coastlon, 'DisplayType','line', 'color','b')
```

Figure 2. Geoshow function

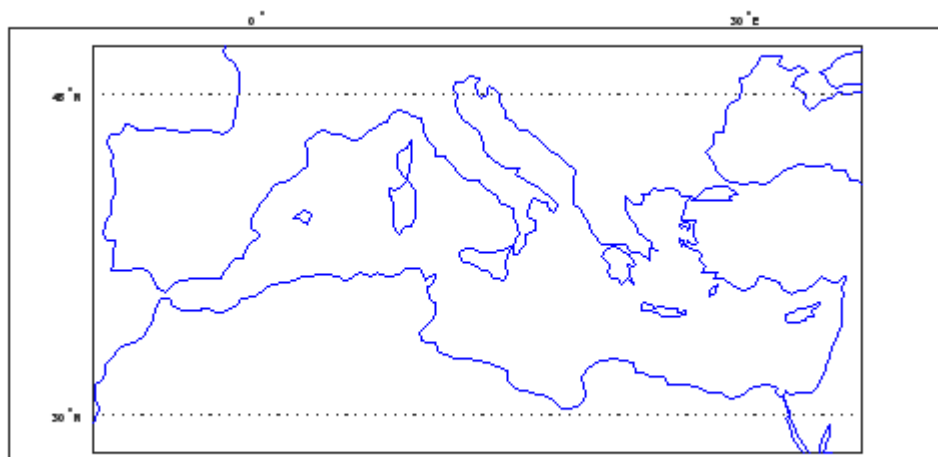


Figure 3. A chart of the Mediterranean Sea

3.2 Configure the waypoints coordinates

In this study, it is supposed that the ship route starts from Constanta port (Black Sea) and ends at Cagliari port (Mediterranean Sea). In consequence, it is needed to read the waypoints coordinates (latitude and longitude) from the Excel file (Figure 4). It is critical to mention that we can achieve any route we want, everything we need is a set of coordinates as large as possible. In most situations, the best possible accuracy the coordinates should be extracted from a navigation simulator where our ship is supposed that sail with a 6 knots speed.

```
A=readcell('fisier.xlsx')
B=cell2mat(A(:,1));
C=cell2mat(A(:,2));
```

```

latitude=str2num(B)
longitude=str2num(C)
lat=[latitude]
lon=[longitude]
x=dm2degrees(lat)
y=dm2degrees(lon)
waypoints=cat(2,x,y)

```

Figure 4. Waypoints coordinates

3.3 Route mapping

After preparing the input data, the actual route will be realized with the help of the function “track” using “rh” - rhumb line main parameter (Figure 5).

```

[ltrk,ltrk] = track('rh',waypoints,'degrees');
geoshow(ltrk,ltrk,'DisplayType','line','color','r')
constanta=[ 44.1565,28.6622]
caliagri=[39,9];
geoshow(constanta(1),constanta(2),'DisplayType','point',...
        'markeredgecolor','k','markerfacecolor','k','marker','o')

geoshow(caliagri(1),caliagri(2),'DisplayType','point',...
        'markeredgecolor','k','markerfacecolor','k','marker','o')

```

Figure 5. Ship route using Matlab „rh”-Rhumb line method

The expected route is depicted in figure 6.

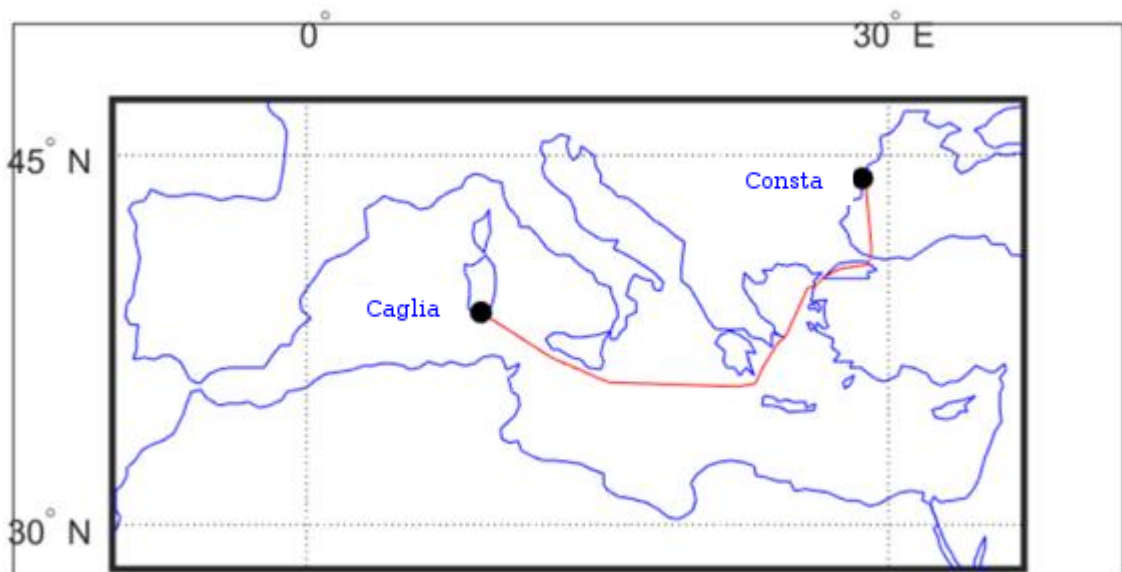


Figure 6. Constanta-Cagliari route

3.4 Course and distance

After tracing a route, we can use the same data set to determine the voyage course and distance (Figure 7). For this study the total distance is summing 1354 Nm. Moreover, for each two intermediate coordinates, we can extract the course (e.g. for a latitude 44.1565 degrees and a longitude 28.6622 degrees our course is 145.5656 degrees).

```
[course distnm] = legs(x,y,'rh');  
round(sum(distnm))
```

Figure 7. Course and distance

4. Discussions

This developed software tool is the first stage in optimizing the ship's route. The creation of a user interface was not considered relevant at this stage of the study. The next stage of the study development is to introduce in the optimization analysis and other optimization criteria, such as optimizing fuel consumption according to stochastic data about weather conditions (height, direction, and frequency of waves, wind speed, and direction) and safety of the ship (wave height). From these weather data, the additional resistance due to the dominant wave height, the dominant wave direction, and the dominant wave frequency can affect the parameters of the ship's route optimization, regardless of the ship's speed, influencing the fuel consumption of the propulsion engine. [4,7].

Therefore, in the multi-criteria analysis of optimal ship routing, in addition to the "shortest distance" criterion and the fuel and safety optimization criterion of the ship, it is possible to introduce statistical data on waves during the period of the year and the areas in which the ship will sail.

Different methods of analysis can be used to perform this multi-criteria analysis.

Into to the formulation of the ship weather routing optimization problem, different methods are used to solve it, ranging from Dijkstra's algorithm, dynamic programming and optimal control methods to isochrone and isopone, methods or iterative approaches for solving non-linear optimization problems.

The choice of the appropriate method depends on the specific requirements concerning optimization objectives, control variables and constraints as well as the implementation these. [4,5].

5. Conclusions

The article developed an optimized routing tool for a ship based on the criterion of the shortest distance between two ports, using Matlab functions. The Matlab framework provides an optimized route, as well as the calculation of the route distance and the determination of the ship's course, for a constant speed suggested throughout the voyage and based on intermediate coordinates to follow.

To validate the developed optimization tool, a computer simulation was performed for a ship departing from the port of Constanța bound for the port of Cagliari. The data entered into the program are the speed of the ship of 6 Nd and 58 intermediate coordinates that the ship must reach during the voyage.

The results of the simulation were tracing the route on the map, calculating the optimized route distance of 1354 Nm and the course of the ship at different points along the route (e.g. for a latitude 44.1565 degrees and a longitude 28.6622 degrees our course is 145.5656 degrees).

In conclusion, this optimized routing tool developed in the study can estimate the ship's route, which can be used in the process of planning a voyage between two ports. This optimization

tool can also be improved by adding other optimization criteria to the analysis. Another research challenge would be to compare the estimated route through this optimization tool with the actual route of the ship, resulting from the influence of different real navigation conditions.

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