PRECISE NAVIGATION WITH THE USE OF BUFFER ZONES

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Abstract
Taking analyses and evaluating navigational safety on restricted areas, both navigational dangers and navigating ships are treated as objects with deterministic dimensions and positions. On such areas there are usually used local navigational systems for estimating navigational safety relatively to particulars navigational dangers like: dangerous isobath, isolated rock, hydrotechnic construction etc. Also traditional paper charts with constant scale render difficult in proper and precise joining navigational information deriving from different sources (measured and archived – nautical publications). Such situation would be radically changed by combined use of the precise satellite navigational systems and ECDIS – navigational counterpart of GIS.

In accordance with recommendations of IMO (International Maritime Organization) navigation should be performed in unified, international reference system – WGS84. Both systems – GPS and ECDIS – fulfill this condition providing possibility for navigation with the use of global nautical information (GPS) and databases (ENC – Electronic Navigation Chart). Nowadays, we can evaluate spatial position of cartographic objects in ENC with certainly known accuracy connected with current ship’s position (Hsu, 1999). As safety zones can be formed buffer zones with the use of spatial accuracy. In presented article it is proposed the use of directional errors (Banachowicz, 2001) for creating buffer zones rounding navigational dangers (cartographic objects) and ships.

INTRODUCTION
Determining the position of the ship in fact the coordinates of one specific point are determined, the chosen point of the ship. It is usually the receiver antenna of the radio navigational system (satellite or ground) or ship’s centre of gravity while the ship’s position is determined for maneuvering purposes along the trajectory. In former times, when precision of position coordinates measurements was law – the error of position has often exceeded several times the largest ship dimensions, then in such case position of the antenna (centre of gravity) was identified with the ship. Nowadays navigational measurement techniques enable to take measurements with high precision (position error ordered to meters) which causes that dimensions of the ship and navigational obstructions can not be omitted.

Carrying out parallel shifting the position coordinates of the antenna (together with its accuracy) to the each external point of the ship, it let us obtain her coordinates in global reference system (with assessment of accuracy). The ship’s dilution is created in this way (Banachowicz and Uriasz, 2003). It is shown on Figure 1. It is trust area covering whole silhouette of the ship. It enables the assessment of ship position with consideration of navigational dangers, when we don’t have at disposal direct measurements of relative
position (radar, sonar) or when those measurements have several times smaller accuracy then position coordinates achieved from navigational positioning system.

Unfortunately such obtained trust area has statistical character and doesn’t provide the proper safety level in relation to the navigational obstructions, while ship is making the way through the water. In this case it is much more appropriate to use the buffer zones of the ship and navigational obstructions.

**PRECISE NAVIGATION**

The term of precise navigation has different meaning and interpretation. Firstly it refers to the navigation process (manoeuvring) in close distances to the navigational obstructions, which are mainly hydrotechnic constructions (berths, quays, dolphins etc), canal boundaries, invisible edges of dredged fairways etc. It also means the navigation performed with high precision for instance with the use of precise satellite navigational systems, lasers etc. It refers as well to the determination of position coordinates for hydrographical surveys, geophysical surveys, exploration of sea bottom. Nowadays meaning of precise navigation has application also in the comparing the positioning measurement information with databases information stored in navigational and hydrographical databases (HO-EDDB – Electronic Chart Data Base as supplied by a Hydrographic Office) (Hecht et al, 2002; Korte, 2000). The role of precise navigation has been raised due to possibilities of the use of nautical information stored in databases together with precise GPS position (Omerbashich, 2002).

**BUFFER ZONES**

As mentioned before, dilution of the ship comprises the accuracy of ship’s silhouette in every direction statically. While ship’s buffer zone is created as envelope of a family of directional errors of ship’s silhouette. The curve of directional errors is Booth’s lemniscate of the ecliptic type.

The canonical formula of Booth’s lemniscate has the following shape:

$$\left(x^2 + y^2\right)^3 - a^2 x^2 - b^2 y^2 = 0,$$  (1)
where:

\( a \) – major semi-axis of error ellipse,

\( b \) – minor semi-axis of error ellipse,

and the correlation is equal to zero.

In a general case it is obtained the following dependence:

\[
\left( x^2 + y^2 \right) - \sigma_x^2 x^2 - \sigma_y^2 y^2 - 2\sigma_{xy} xy = 0,
\]

(2)

where:

\( \sigma_x \) – disturbance of the vessel’s movement along \( x \) axis,

\( \sigma_y \) – disturbance of the vessel’s movement along \( y \) axis,

\( \sigma_{xy} \) – covariance.

Similarly to the buffer zone of the ship, buffer zones around navigational obstructions can be created, which geometrically are cartographical objects – points (for instance isolated point danger), lines (quays, isobaths etc) and polygons (prohibited areas etc). Parameters of those objects are stored in HO-ECDB. We assume in this case, that the ship is a solid stiff – her dimensions are constant, and in the case of cartographic objects their parameters are updated, i.e. sizes and positions are the same like in the database.

The buffer zone of the point is shown on Figure 2. The buffer zone of the line is created by parallel shifting of the curve of directional error (Booth’s lemniscate) along given line, which is shown on the next figure (Figure 3).
In the case of the polygon the Booth’s lemnistace is being shifted in parallel along its edge (corresponding curve or closed broken line). The situation is shown on Figure 4.

It can be observed that from geometric point of view, the ship is also a polygon but only moving relatively to the cartographic objects – navigational obstructions. Therefore the buffer zone of the ship is changeable in time and space. It’s dimensions and orientation is depended on precision of position coordinates, their correlation and ship’s heading.

The relations between buffer zone of the ship and navigational obstructions are shown on Figure 5. In this case the safety distance is calculated as a closest distance between buffer zone of the ship and buffer zones of the navigational dangers.
CONCLUSIONS

- Buffer zones can be created for different trust levels, however due to IMO standards of accuracy it should be the probability level $P=95\%$

- Buffer zones can be used in a precise navigation in narrow areas and while manoeuvring in port basins with the use of ECDIS

- Relation between buffer zones of navigational dangers and the ship depends on elements of covariance matrix of coordinates position of the ship and her heading

- The safety distance is calculated as a distance (closest) between buffer zone of the ship and buffer zones of the navigational obstructions (cartographic objects)

REFERENCES