

# Electronic Navigational Chart in aid of generation of multi-dimensional radar display

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*Abstract:* - The main aim of the research presented in the article was to develop a new multidimensional presentation for navigation radar. The presentation, which in the aspects of technology, meets the standards, referring to three-dimensional visualization of space data; it also improves safety of navigation through providing navigators with more accurate radar information in a form much easier for interpreting. Initially it was assumed that the new presentation would increase a possibility of detecting echoes of small signal amplitude.

*Key-Words:* - Radar, 3D Visualization, ENC

## 1 Introduction

In working out the multidimensional (three-dimensional) radar presentation, which is to be visualized in the standard format of navigational electronic charts, integration of radar observations with electronic navigational charts is enforced. In this case, the radar observation has to be understood as digital recording of the radar visual signal, achieved at a radar receiver level. It enables acquisition of a value of visual signal voltage level, necessary for building of three-dimensional visualization. According to the nomenclature applied in the Report, an expression "multi-dimensional" radar display is used to distinguish it from a typical three-dimensional image, characterized with three dimensions of a specific object (width, length and height or depth).

The work-stand, where producing multi-dimensional radar display is to be performed, requires working out special electronic navigational chart in a standard which enables a combined presentation of information (map and radar) in the integrated operator's interface. It would be useful to have a possibility of searching in ENC cells automatically the data on navigational signs, which can be presented in the radar image. For appropriate

identification of objects traced by radar, it is necessary to acquire the "map" information about the observed echoes. An indicated area is defined by the position observed (geographic coordinates  $\varphi$ ,  $\lambda$ ) and actual range of radar operation as a radius of a circle. A process of searching binary blocks, describing punctual objects in ENC and conversion of the above data to a simple test form, are presented below. There are also presented the principles of searching out spatial objects and rules of generating an image of the spatial objects included in ENC.

## 2 Electronic Navigational Chart

Requirements referring to the principles of ENC radar presentation in the Electronic Chart Presentation and information Systems were identified by the International Hydrographic Organization in specifications of S-52 series - „Specifications of the map contents and aspects of its presentation in ECDIS”. ECDIS create ENC presentations basing on patterns of punctual, linear and superficial graphic symbols, defined by IHO. The patterns are spread in digital form in a file named "Presentations Library". The following sections are the file contents:

- Five Tables of Colours (each one contains 64 colours),
- Library of Symbols, including:
  - Definition of traditional punctual graphic symbols (applied on paper maps M-4) and simplified (applied on WECDIS presentation only),
  - Definition of surface and linear graphic symbols,
- five Look-Up Tables with instructions concerning presentation of ENC objects on radar display.

Tables of Colours are used for calibration of monitors. Calibration is necessary to enable rendering precisely the colours applied in ENC presentations.

Library of Symbols contains graphic punctual, linear and surface signs defined in vectors form.

Look-Up Tables state precisely what way the classes of objects included in ENC have to be presented in ECDIS systems.

In Fig. 1. there is presented the algorithm of map/chart image generation in ECDIS systems suggested by IHO.

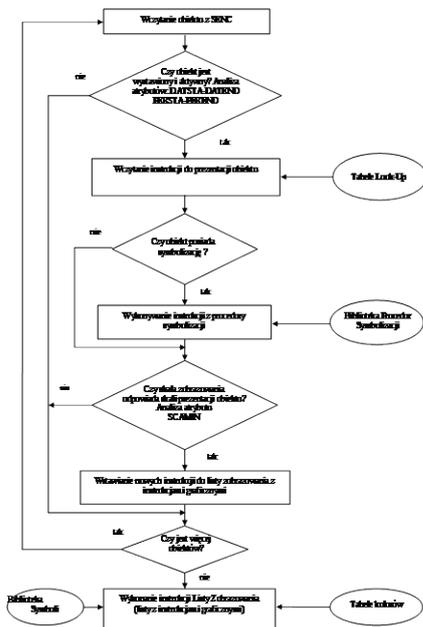


Fig. 1. Algorithm of generating the map image in ECDIS [5]

The algorithm's run starts from reading in a class of the object with its attributes and values of the attributes. Next, in the conditional block the following attributes are analyzed:

- DATSTA – date of exposition of the object (e.g. a buoy),
- DATEND - date of removal of the object,

- PERSTA – date of starting activity of the object exposed temporary,
- PEREND – date of finishing activity of the object temporary exposed.

In case the analysis result is negative, passing to the block checking a number of the objects in SENC is effected; in case it is positive, then from the Look-Up Tables there are taken out the lines of instructions for presentation of the object. The next step is verification is the given object provided with symbolization procedures. In case the result is positive, the instructions of the selected object' symbolization procedure are performed. In the subsequent conditional block there is analyzed SCAMIN attribute, standing for the minimal value of the nominative of the presentation scale in which the object may be presented.

In case the analysis result is positive, the new graphic instructions are inserted to the Presentation List. The Presentation List is a track of graphic commands recorded in the system operational memory. Execution of instructions, included in the Presentation List, is a last step of the algorithm. This step consists in building of digital map/chart image applying graphic signs included in the Library of Symbols, drawn using colours taken from the colour palette currently selected by the operator [5].

## 2 ENC – searching for spatial objects

In accordance to the accepted model of spatial representations of characterizations of the real world unitary fragments, the features' objects, provided with geometric representations, are linked through indexes with the spatial objects carrying over the fragments of their geometry. To simplify the model, the two-dimensional, flat picture of the real world was assumed. Consequently, the spatial objects of vector type may be of zero, one or two dimensions, which are implemented respectively as nodes, edges and faces. The third dimension is expressed as the object's attribute. In addition, according to the Product ENC Specification, the spatial objects defined in ENC are to be coded using topology of "chain – node" type. Topology of "chain – node" type is a set of nodes and edges. Every edge has to be referred to the linked node as to its beginning and its end (which can be the same node). Geometry of the node, referring to the edge, is not a part of the edge. However the vector objects can be co-divided, they cannot be duplicated. The punctual representations are coded as nodes (insulated or connected). The linear representations are coded as series of the edges and connected nodes. The area

representations are coded as closable loops of edges, which start and end at the common connected node.

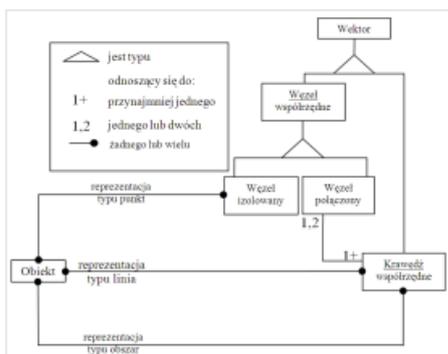


Fig. 2. "Chain - node" type topology

ENC files are based on logical records ISO/IEC 8211. The basic element of ISO/IEC 8211 file is a Logical Record - LR. The first LR of ISO/IEC 8211 file name is "Data Descriptive Record - DDR) and it contains description of the logical structure of real data in the file. All the remaining records ISO /IEC 8211 are named the "Data records" and they include the real data assigned for replacement/exchange. The basic structure of ENC file is presented in Fig. 3.

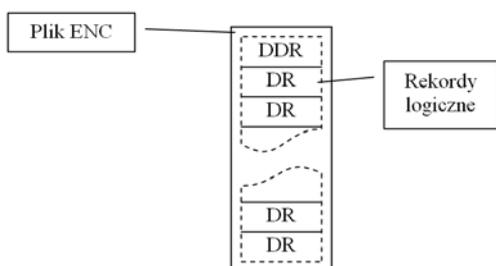


Fig. 3. Structure of ENC file

Every logical record is composed of the following items:

- heading,
- catalogue,
- fields area.

To manage identification of records contained in ENC file, a record identifier is used; it is defined using the four following signs "0001". The record identifier is preceded with its heading. According to ISO/IEC 8211 the heading structure has to be of the form as follows.

Tab. 1. Structure of data record heading

Bite number	Length [bite]	Field name	Sub-field contents and specification
0	5	Record length	number of bites in record
5	1	Replacement level	SPACE

6	1	Heading identifier	„D”
7	1	Integrated code expansion index	SPACE
8	1	Number of version	SPACE
9	1	Application index	SPACE
10	2	Field indicator length	2 SPACES
12	5	Field area base address	Field area base address (number of bites in heading and in catalogues)
17	3	Replaced signs set index	3 SPACES
20	1	Field length area size	1 – 9 variable (defined by a coding person)
21	1	Field position area size	1 – 9 variable (defined by a coding person)
22	1	Reserved	„0”
23	1	Field discriminant area size	„4”

The exemplary heading with record identifier is presented below (sign „□” represents space):

**00160□D□□□□□00095□□□55040001**

The logical record catalogue contains parameters necessary for identification and location of every field in the fields' area. The catalogue is composed of iterative fields containing the field discriminant, field length and field position. Field positions are specified in reference to the beginning of the fields' area. A position of the first field following the catalogue is 0. The exemplary catalogue of the features' record is presented below:

**0000300000FRID0001300003FOID0000900016A  
 TTF0003100025FSPT0000900056**

A structure of the features record field is to be as follows:

- |--FRID (7) – Field of "Features' record identifier"
- FOID (3) – Field of "Features' object identifier"
- <R>--ATTF (\*2) – Field of "Features' record attribute"
- <R>--NATF (\*2) – Field of "Features record national attribute"
- FFPC (3) – Field of "Features record to/for features object index control"
- <R>--FFPT (\*3) – Field: „Index of features record to features object"
- FSPC (3) – Field: "Features record to spatial record indicator's control"
- <R>--FSPT (\*4) – Field: „features record to spatial record indicator"

R is to mark out that the given field may be repeated, whereas a volume in bracket to specify a number of sub-fields in the field.

Tab. 2. Features record attribute field structure (ATTF)

Sub-field name	Label	Format	Specification and contents of sub-field
Label/attribute code	ATTL	b12	Proper label/attribute code
Attribute value	ATVL		Sequence containing proper value for domain determined by attribute code in ATTL

To define a type of geometric primitive representing the features' object it is necessary to analyze sub-field PRIM in FRID field.

Tab. 3. Features' record identifier (FRID)

Sub-field name	Label	Format	Specification and contents of sub-field
Record name	RCNM	b11	„FE” {100}
Record identification number	RCID	b14	range: 1 to $2^{32} - 2$
Geometric primitive of the object	PRIM	b11	„P” {1}point „L” {2}line „A” {3}area „N” {255}object does not indicate directly any spatial object
Group	GRUP	b11	range: 1 to 254, 255 – lack of group
Label / object code	OBJL	b12	Label / object code
Record version	RVER	b12	RVER contains consecutive number of record edition
Record updating instruction	RUIIN	b11	„I” {1}insert „D” {2}remove „M” {3}modify

The tree structure, describing the spatial record, is of the following form:

|--VRID (4) – Field of "spatial record identifier"

|--<R>--ATTV (\*2) – Field of "spatial record attribute"

|--VRPC (3) – Field of "spatial record index control"

|--<R>--VRPT (\*5) – Field of "spatial record index"

|--SGCC (3) – Field of "coordinates control"

| alternative methods of presentation of the coordinates

\*--<R>--SG2D (\*2) – Field of "2-D coordinates"

\*--<R>--SG3D (\*3) – Field of "3-D coordinates" (sounding matrix)

\*--<R>--ARCC (\*5) – Field of "arc/curve definition"

| alternative definitions of arc /curve

\*--<R>--AR2D (3\*2) – Field of "arc coordinates"

\*--<R>--EL2D (3\*2) – Field of "ellipse coordinates"

\*--<R>--CT2D (3\*2) – Field of "curve coordinates"

According to the specification for ENC product, it is not admissible to apply arcs and curves, therefore the fields ARCC, AR2D, EL2D and CT2D in spatial records would not appear.

Fields VRID, SG2D and VRPT have to be analyzed using from the spatial record. The first is to enable determining a type of geometry. The second allows arranging a table of points for drawing the geometric primitive. The third enables to define a sequence of points of the table.

Tab. 4. Spatial record identifier (VRID)

Sub-field name	Label	Format	Specification and contents of sub-field
Record name	RCNM	b11	„VI” {110}insulated node „VC” {120}connected node „VE” {130}edge „VF” {140}surface
Record identification number	RCID	b14	Range: 1 do $2^{32} - 2$
Record version	RVER	b12	RVER contains the subsequent record edition number
Record updating instruction	RUIIN	b11	„I” {1}insert „D” {2}remove „M” {3}modify

Tab. 5. 2-D coordinates (SG2D)

Sub-field name	Label	Format	Specification and contents of sub-field

Coordinate along Y axis	*YCOO	b24	Y coordinate
Coordinate along X axis	XCOO	b24	X coordinate

Tab. 6. Spatial record index (VRPT)

Sub-field name	Label	Format	Specification and contents of sub-field
Name	*NAME	B(40)	Foreign index
Orientation	ORNT	b11	„F” {1} ahead „R” {2} astern „N” {255} NULL
Use index	USAG	b11	„E” {1} outside „I” {2} inside „C” {3} outside boundary cut off by data limitation „N” {255} NULL
Topology index	TOPI	b11	„B” {1} initial node „E” {2} final node „S” {3} left surface „D” {4} right surface „F” {5} containing area
Masking index	MASK	b11	„M” {1} mask „S” {2} show „N” {255} NULL

Tab. 7. Features’ description object identifier (FOID)

Sub-field name	Label	Format	Specification and contents of sub-field
Production agency	AGEN	b12	Agency code
Identification number of features’ description object	FIDN	b14	range: 1 do $2^{32} - 2$
Identification division of features’ description object	FIDS	b12	range: 1 do $2^{16} - 2$

Selected attributes of the searched out features’ object record contained in sub-fields **RCNM+RCID**, **PRIM**, **OBJL** of **FRID** field and sub-fields **AGEN**, **FIDN**, **FIDS** of **FOID** field are subject to the special analysis.

#### 4 Principles of generation of spatial objects images contained in ENC

According to ENC Product Specification, coordinates of points stored in ENC have to be referred to the selected reference ellipsoid. It is recommended to apply WGS-84 reference system, but it is necessary to remember about the fact that in S-57 standard there were defined 228 of them and each of them may be applied. Information about the

applied reference system are coded in DSPM field of data set’s geographic reference record. The parameters transferred in this field are presented in Table 8.

Tab. 8. Data set parameters, DSPM

Sub-field name	Label	Format	Specification and contents of sub-field
Record name	RCNM	b11	„DP” {20}
Record identification number	RCID	b14	range: 1 do $2^{32} - 2$
Horizontal geodesic reference system	HDAT	b11	HORDAT attribute value
Vertical reference system	VDAT	b11	VERDAT attribute value
Sounding reference system	SDAT	b11	VERDAT attribute value
Data compilation scale	CSCL	b14	Compilation scale denominator; e.g. scale 1:25000 is coded as 25000
Units of depth measurement	DUNI	b11	DUNITS attribute value
Units of height measurement	HUNI	b11	HUNITS attribute value
Units of positioning accuracy	PUNI	b11	PUNITS attribute value
Coordinates units	COUN	b11	Units of coordinates measurement „LL” {1} width / length „EN” {2} flat coordinates „UC” {3} units on map
Coordinates multiplication coefficient	COMF	b14	Multiplication coefficient for calculation of the floating-point values to integral numbers and conversely, for coordinates’ values
3-D multiplication coefficient (sounding)	SOMF	b14	Multiplication coefficient, for calculation of the floating-point values to integral numbers and conversely, for 3-D values (sounding)
Comment	COMT		Sequence of signs

For transformation of ellipsoidal coordinates to flat ones of all the points which describe geometry, it is necessary to take use of parameters of **HDAT** and **COMF** sub-fields. The sub-field **HDAT** is to determine the horizontal coordinates’ reference

system, whereas COMF – it's a coefficient which is to be used to multiply these coordinates. In case the Mercator map projection is applied, such transformation is realized in two stages. At the first stage there are determined flat coordinates of all the points in Mercator's projection for the structural parallel, located on the equator and the scale equal to unity according to the relations:

$$e = \sqrt{\frac{a^2 - b^2}{a^2}}, \quad (1)$$

$$\text{arc}1' = \frac{2\pi}{21600}, \quad (2)$$

$$x' = \lambda \cdot 60 / \text{COMF}, \quad (3)$$

$$y' = \frac{1}{\text{arc}1'} \ln \text{tg} \left( 45^\circ + \frac{\varphi / \text{COMF}}{2} \right) \cdot \left( \frac{1 - e \cdot \sin(\varphi / \text{COMF})}{1 + e \cdot \sin(\varphi / \text{COMF})} \right)^{e/2}, \quad (4)$$

where:

COMF - coefficient for replacement of an integral number to a floating-point value,

$\lambda$  - longitude coded in XCOO sub-field of SG2D field,

$\varphi$  - latitude coded in \*YCOO sub-field of SG2D field,

$e$  - first eccentric of the reference ellipsoid defined in HDAT sub-field of DSPM field,

$a$  - length of semimajor axis of the reference ellipsoid specified in millimetres, determined in HDAT sub-field of DSPM field,

$b$  - length of semiminor axis of the reference ellipsoid specified in millimetres, determined in HDAT sub-field of DSPM field,

arc1' - angular value 1' specified in radians.

At the second stage, values of scaling factors for the selected scale and structural parallel of map presentation are to be determined:

$$s_x = \frac{\text{arc}1' \cdot a \cdot \cos \varphi_o \cdot r_x}{m \cdot (1 - e^2 \cdot \sin^2 \varphi_o)^{1/2}}, \quad (5)$$

$$s_y = \frac{\text{arc}1' \cdot a \cdot \cos \varphi_o \cdot r_y}{m \cdot (1 - e^2 \cdot \sin^2 \varphi_o)^{1/2}}, \quad (6)$$

where:

$r_x$  - horizontal resolution of the presentation system (e.g. printer) expressed in pixels per millimetre,

$r_y$  - vertical resolution of the presentation system (e.g. printer) expressed in pixels per millimetre,

$m$  - denominator of the presentation' primary scale,

$\varphi_o$  - structural parallel latitude of the presented map specified in degrees.

The first stage is performed within a time of loading ENC data set. The data are then converted to the internal data base of the system. At the time of conversion the program is to compose geometry of spatial objects, to determine flat coordinates of the points which describe this geometry and to record this way processed data to the memory.

The second stage is performed instead at the time of generating the map image; then the scaling factors determined before, are substituted at the respective fields of the composite matrix of geometric transformations; coordinates of all the points contained in the internal system's data base are then multiplied thereby.

A product of the composite geometric transformation matrix and the column vector with flat coordinates of points of the internal system's data base  $x'$  and  $y'$ :

$$\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} Sm \cdot \cos K_k & -Sm \cdot \sin K_k & Sm \cdot (\cos K_k \cdot dx - \sin K_k \cdot dy) + x \cdot (1 - Sm) \\ Sm \cdot \sin K_k & Sm \cdot \cos K_k & Sm \cdot (\sin K_k \cdot dx + \cos K_k \cdot dy) + y \cdot (1 - Sm) \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix}, \quad (7)$$

where:

Sm - primary scale of ENC presentation,

dx - value of ENC presentation displacement along the monitor screen rectangular coordinates of Y-axis, expressed in pixels,

dy - value of map image representation displacement along the monitor screen rectangular coordinates of X-axis, expressed in pixels,

$K_k$  - turning angle of ENC presentation in sinistrorse Cartesian system expressed in degrees,

X, Y - coordinates of the calculated ENC presentation's point in Cartesian system of rectangular coordinates of monitor screen, expressed in pixels, is to enable to realize geometric transformations, i.e. scaling, rotation (e.g. for presenting ENC presentation in relation to a course) and translation of ENC presentation (e.g. for presentation of other region apart from the currently

presented one). This stage is the final one for map presentation display.

## 5. Description of the multi-dimensional radar display modelling program

The computer application with implemented model of three-dimensional radar display was worked out as an ECDIS prototype. In Chapter 3 of the Report there is presented description of the model of creating three-dimensional radar display in ENC. Hereafter there is presented the technical description of the worked out in laboratory ECDIS prototype with the implemented, newly worked out, heuristic model for three-dimensional radar presentation. Efforts were made to present in it an essence focused on presentations of tools provided for the application for modelling the newly elaborated multi-dimensional radar display. Every issue included in the description is illustrated with pictures of the application tool windows.



Fig. 4. Information about the program for 3D radar display visualization

### 5.1. General characterization of the application

The laboratory – worked out ECDIS prototype was based on the computer application with the implemented model of creating multi-dimensional visual signal coming from navigational radar (description of this model is presented in Chapter 2), generated on the grounds of ENC data. The application was worked out in the integrated development environment of C++ Builder 6.0 application. It operates under Windows NT i XP operational system control, using program interface of the graphic library OpenGL [3] [4].

The process of generating three-dimensional radar display of sea bottom, realized by the application, is performed at four sub-processes:

- modelling geometric multi-dimensional radar display,
- modelling the material properties,
- modelling the illumination,
- monitor screen presentation of the modelled out, three-dimensional area of multi-

dimensional radar image display in dynamic perspective map projection.

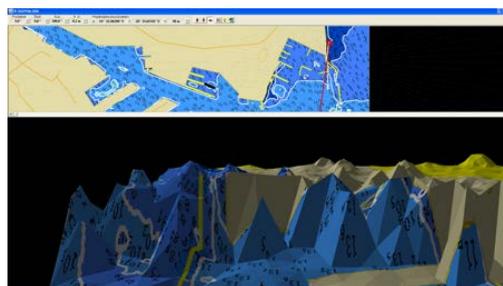


Fig. 5. Main window of ECDIS prototype application for visualization of multi-dimensional radar display

### 5.2. Geometric modelling of multi-dimensional radar display

Three-dimensional radar display is generated basing on data, acquired from recording real radar visual signals. Measurement data are stored in text files in a form of vectors, described with geographic coordinates of each measurement point and visual signal voltage value. The files are stored in directories, wherein the cells of electronic chart, used in the application, are found.

Basing on the data, there are determined the spatial locations of node points in the ellipsoidal squares' grid, describing a numerical model of "radar image display area". Principal parameters of each node of this grid, necessary to determine its spatial location are ellipsoidal coordinates and visual signal value. A value of radar signal amplification in the node is determined in a result of interpolation (in the prototype there was applied interpolation performed with the inverse distances method) of amplification value (voltage) of visual, determined at a node point or nearby the point.

In Fig. 6. the dialog box for inserting values of interpolation parameters is presented.



Fig. 6. Dialog box for inserting values of interpolation parameters

The following are parameters adjustable by operators:

- resolution; accountable for a size of grid "mesh",
- scale of parameter; accountable for amplification of visual signal at the grid node
- parameter of the method and level of smoothing rate; coefficients adjustable in the applied interpolation method of reverse distance,
- number of points for interpolation; it defines a maximal number of the closest points taken for interpolation.

At the following stage of the ellipsoidal squares grid processing, the ellipsoidal nodes coordinates and interpolated out in it values of visual radar signal are transformed to geocentric reference system. This way prepared geometric model is used directly in a time of visualization.

**5.3. Modelling of properties of the material**

Modelling properties of the radar display area material consists in determination of a type of texture covering the area and its properties [1] [2] [4] [6] [7]: reflective when referred to light sources, properties of the own light emission properties and ratio of gloss.

In ECDIS prototype the radar image area was covered with classic texture of "flat" sea navigational chart. The decision about the above was undertaken for two reasons. The first is that the worked out application is not capable to acquire radar display from the navigational radar's indicator. On carrying out the research, first of all the primary (original) visual signal recording was performed. Recording the radar display would force working out a method of associating those signals with raster radar image, recorded at a level of the indicator. It is suggested to apply specialized PC RadarKit cards (see chapter 2). While the research, the raster radar image was recorded. It was applied for rough detection of differences in visualization of radar information. The records were not synchronized. The next reason for placing map texture on the radar image is its possible comparison with the map. It is of special importance if the coastal zone is considered. There are visible on-shore elements, which should generate a strong radar echo. Such a way of presenting the radar image "shape" enables easier identification of the coastal zone objects. At the open sea the texture is of no great importance. It is to be expected that at places of hills, the radar image displays an object which generates the radar echo.

Determining the material properties were to indicate the one capable to emit its proper light and in case of ambient light and diffused light – to reflect mainly the blue light, also to absorb the whole specular reflection light and under no condition became shining. In Table 9. the settled parameters of modelling the material properties are presented.

Tab. 9. Properties of material covering the sea bottom surface

Property of material	Components of 32-bite colour		
	Red	Gree n	Blue
Ambient light reflection	130	241	255
Falling light diffusion	130	241	255
Emitted light intensiveness	0	44	90
Specular reflection light intensiveness	0	0	0
Gloss degree	0	0	0

**5.4. Modelling of lighting**

Modelling of lighting consists in determination of three different types of light [1][2][4][6]:

- ambient light, falling equally on all surfaces from all directions,
- diffused light of rays propagate equally from one point toward all directions,
- specular reflection light, reflecting from surface in specular reflection way.

In Fig. 7. a dialog window for inserting values of the modelled lighting parameters is presented.

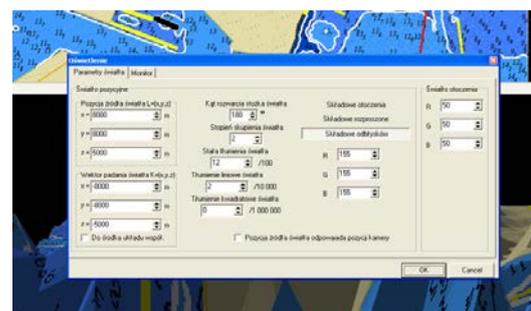


Fig. 7. Dialog window for insertion of modelled lighting parameters values

Properties of global ambient light are determined defining its intensiveness with RGB colour components. Whereas the diffused light properties are settled with specifying parameters of the accepted in the model, singular position light. The parameters are as follows:

- coordinates of light source position,

- light falling vector,
- position light properties (i.e. intensiveness, concentration ratio, attenuation constant, linear and square attenuation volume).

### 5.5. Multi-dimensional radar image presentation performance

Monitor screen presentation of modelled three-dimensional radar image surface, more precisely – of the surface representing radar visual signal voltages, in dynamic perspective map projection/representation are realized with consideration of the defined parameters of projection and parameters of camera movement. The following are the parameters:

- observer's position (camera) in relation to geocentric reference system, described with orthocartesian coordinates,
- camera orientation, described with angles of spatial orientation: heel, inclination and rake,
- speed and course of the camera in motion.

In Fig. 8. there are distinguished the edition windows for insertion of projection parameters.



Fig. 8. Edition window for inserting parameters of projection and speed of camera in motion

An advantage of such presentation is potentiality of turning the display optionally to any directions. The camera is capable to approach closely to any of radar display elements and to analyze it from an optional observation point. It is necessary then to take use of inclination angles, turning angle and an altitude (height) of camera above sea level.

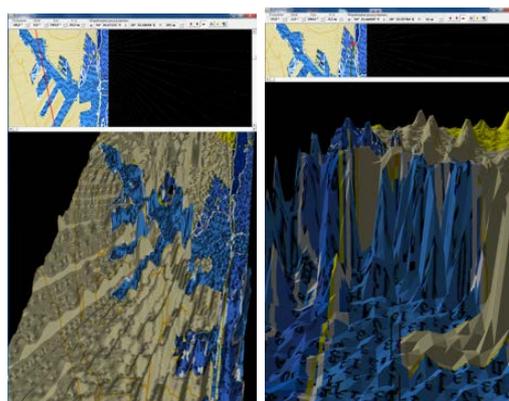


Fig. 9. Exemplary multi-dimensional visualizations of radar image presentation

All the efforts presented above resulted in creation of a tool which is capable to perform a series of analyses and comparisons of 3D radar image quality and the identical one, displayed in the radar indicator. While choosing interpolation parameters upon reading in a presentation to the system, the operator may adjust the image to have it displayed more detailed; he is also able to mitigate an influence of disturbances on signal values at the grid nodes.

Low resolution and an optimal number of points for surface interpolation make the radar presentation more detailed. It is presented in the figure below. Then searching out characteristic radar echoes of signal becomes easier.

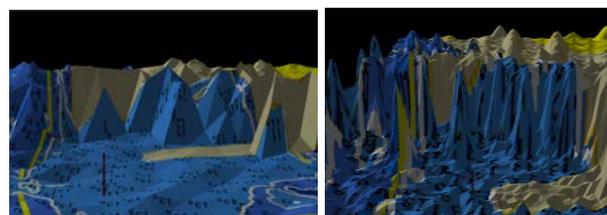


Fig. 10. Modifications of multi-dimensional radar presentation

Implementation of the newly worked out model of three-dimensional radar presentation into the program and presenting it in conformity with the presentation creation standards in ENC, is extremely complicated operation. For reasons of geometric modelling it requires working out very complicated functions, which transform geometric and description data, coded in accordance with S-57 standard, to a form of matrix, represented with the ellipsoidal squares grid and a texture of the "flat" navigational chart in Mercator's representation. It was necessary to create the tool functions for modelling properties of the material and illumination of three-dimensional radar image model, which optimally use the graphic OpenGL

library. It also required application of geometric transformations in 3D to enable determination of location and spatial orientation of so-called camera and in a time of visualization of the modelled presentation, in dynamic perspective representation /projection (carried out in the logical and physical monitor screen).

## 6 Conclusion

Application of radars on sea-going ships and vessels is essential for safety of navigation, especially in poor visibility and bad weather conditions. Radars are used in navigation for fixing positions and for detection and identification of vessels, objects and other targets. A process of carrying out navigation basing on automated anti-collision systems ARPA is till now characterized with comparatively low accuracy. The reasons thereof are not only, difficult to eliminate, radio waves interferences and technical constraints in presentation of radar echo on the screen, but also misidentification of radar echo, as well as random and deterministic disturbances of radar observations.

The main aim of the research presented in the article was to develop a new multidimensional presentation for navigation radar. The presentation, which in the aspects of technology, meets the standards, referring to three-dimensional visualization of space data; it also improves safety of navigation through providing navigators with more accurate radar information in a form much easier for interpreting. Initially it was assumed that the new presentation would increase a possibility of detecting echoes of small signal amplitude. Radar echoes may come from vessels and targets, characterized with lowered qualities of microwaves reflection, as, for example, objects constructed applying stealth technology. The research proved that the three-dimensional representation of the original visual signal improves detection of small signal amplitude echoes. Application of the digital signal's filtration methods may provide navigators with information about the objects which remain invisible on the contemporary radars' indicators. It does happen, as their echo is at a level (or below) of noise and interferences occurring within the radar presentation. When the original visual signal is examined in navigational radar's receiving block and the advanced technology used to produce multi-dimensional visualization, the radar image can be presented applying representation, increasing probability of detecting those objects. Apart from the fact, that in IMO Regulations the requirements referring to radar indicators and detecting

capabilities of deck radiolocation equipment are explicitly defined; it is purposeful to search for new solutions in this subject, having in mind increasing safety of sailing.

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