EXTENSION OF SEA CHARTS FOR 3D VISUALIZATION

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ABSTRACT

This paper presents the extension of Electronic Navigational Charts (IHO-2) for sea charts for the usage of 3D visualizations. If 2D chart data is used to build up an interactive 3D scene, the change of the perspective leads to over-crowded displays and many occlusions. We developed a data management concept by defining a hierarchical topology and semantic groupings within the 2D chart data. The hierarchy can be stored permanently in the charts, and does not affect the standard. The structure can also be used in other 3D scenarios like city models if vector-based modelling in the 2D chart is available; application scenarios are reduction of the complexity, reduction of the scene to interesting regions and semantic clustering of objects.

1. INTRODUCTION

There is a broad interest to utilize video signals in real-time with additional data. The applications for this are widely spread. In (Yan, 2008) the authors describe the potential of augmented reality systems in architectural tasks in combination with GIS[1] data. The advantages are especially the enhancement of hidden structures and elements. A second new field of applications can be found in logistics. In modern logistic software systems the order picking and the staff education can be significantly improved by augmented information (Reif, 2008). The usage of a car as an augmentation device is the content of (Kolb, 2006). The main approach is the intuitive integration of the augmentation process into general tasks. The main fields of application are still the information supply and navigation, since the user needs additional information to be able to make decisions. Due to this task there are special requirements to solve. In (Kibria, 2009) requirement functionalities for urban planning are stated which can be adapted to other scenarios like navigation. Interaction and exploring skills are beside position information for example the ability to hide information, spatial queries and the selection of objects.

A navigational device which overlays 3D nautical information onto camera signals of the actual environment was developed (Koch, 2008). We use this as a wireless hand-held real-time device to display the 3D information over the image of the environment. The 3D data is prepared by a service point which is situated in the ships bridge and utilizes AIS[2] data. The user can look through the device and gets the sea charts data displayed in the context of the actual environment.

We describe how the standardized 2D chart data can be used to build up a 3D scene and how the data of a 3D scene can be restructured to get an interactive scene and new semantic queries. Scenarios for this advantage are the visualization of underground objects without the occlusion of overground objects, the visualization of objects only laying on especially labeled areas like urban districts or the reduction of the so called "Skin of the Earth"-surfaces. This can be used in every geospatial 3D scene to restructure the scene for dimension reduction, hide mechanism during visualization and new semantic object categorization based on object geometries.

The paper is structured by describing the general problem and the derivation of the concept based on the kind of data base. Then follows an introduction to the data base and the explanation of how the concept can be realized. At the end, we present results in the form of rendering results.

[1] Geographic Information System
[2] Automatic Identification System

1.1 Standards and Data Basics

The data is provided by an ECDIS[3] software system[4]. Electronic Navigational Charts are defined by the IHO (International Hydrographic Organization) in the Transfer Standard for Digital Hydrographic Data, Edition 3.1, Special Publication Number 57. For ECDIS systems and the usage of nautical charts there exists a Product Specification called ENC/PS on which the data also refers.

1.2 General Problem Definition

Standardized 2D chart data is optimized for the usage on a display which is situated perpendicular to the user. That means the user always stays in a top view perspective. The data can be displayed in scaling groups which have to be chosen before a chart is symbolized. This calls for the knowledge of the kind of provided objects in a scaling group. In the case of a 2D chart display the rendering process is fast and a switch between the scaling levels is possible. The change in the scaling means for a 3D scene that the complete set of data, often represented as a scene graph, has to be exchanged. This is not an adequate data handling for a real-time application. The second point is that instead of the top view perspective the user is situated within the objects and the rendering of the users viewing leads to occlusions and inseparable objects. Occlusions are semantically defined and their definition changes with the focus of interest. In the classical approach there is no clear interaction possible.

[3] The chart data is based on the product specification ENC of the IHO-S-57 standard, Version 3.1 (IHO-1)
[4] The software is provided by the SevenCs GmbH, which is a market-leading software company for e.g. Electronic Chart Display and Information Systems (ECDIS). It is owned by the United Kingdom Hydrographic Office (UKHO)

1.3 Display Concept

The scaling concept of the sea chart data implies that for a special region there exist several charts providing different data. Table 1 is a listing of several aspects of the same region of 5 nautical miles. The scene is represented by three scaling groups showing a different number of objects. The scaling Approach fits here as an overview whereas the scaling Berthing is a detail chart of a harbour. Even in the Approach mode there are 2622 objects, mainly situated crowded across the coastal line. To be able to support fast situation changes the user should be able to interactively chose the interesting topics of a scene. This means there is no possibility to use view filters or filters which define use cases. To handle the number of objects we build a hierarchy of the objects. This makes it possible to select the level of detail referred to the displayed information. Starting in an overview situation, the user can select the region of interest and guide the display management.
The display management concept is able to exchange object groups with higher level information. This scaling exchanges the scale groupings of the IHO. The number of displayed objects can be reduced to 1/3 without loss of information. This is done by defining a hierarchy between the objects based on their spatial relations. Each subtree in the hierarchy can be displayed independently. By utilizing attributes of the objects, semantic groups can be built. See Figure 1 for a scheme of the concept.

	EC_ Harbour	EC_ Approach	EC_ Berthing
Cells	3	1	1
Total	8561	2622	532
P_Prim	3963	1259	401
A_Prim	2405	550	66
L_Prim	2077	630	61
S_Prim	116	183	4
Display Base	~25*	~10*	~7*
SkinOf-TheEarth	495	143	23
Our new Minimum	2597	783	37
named	539	280	46

Table1. Number of ENC objects (search radius 5 Nm) in different scaling levels (columns) differentiated by the kind of objects. P_Prim, A_Prim, L_Prim and S_Prim are point, area, line and sounding objects. Total means the sum of all 2D chart objects. The new minimum of the displayed objects in our 3D case is the sum of the display base, line objects and the minimum level in the new concept. (*dependent on the display filter)

1.4 Analysing ENC Data

We give a short introduction to the data structure of the standardized chart data of the S-57 standard. This is done to show that there are no usable relations to build a hierarchy or semantic groupings. We show how the data can be used to extract an object-to-object topology and semantic relations.

1.4.1 Object structure ENC/PS

The objects are defined by a separated storage of context and territorial information. This separation of the data is done to model the human object detection. Figure 2 shows a schematic overview of the structures. The feature object holds the information of the functionality and specific contextual data. This includes the information about the standardized object classes. These classes are defined in the S-57 object catalogue. The spatial object part stores the position and the display geometry. Until now, the geometrical modelling is defined for the 2D case. Possible representations are the vector, matrix and raster format. The ENC standard uses the vector-based modelling to describe the objects. In this case the spatial object is structured by a primitive and a segment type and uses line, point, area, point cluster, edge and node definitions. See Table 1 for an example of the usage of the components within the chart data.
Due to the demand of the ENC/PS to reuse the geometrical features (chain node structure) there can be built a vector topology which can be provided by the ECDIS system. As different geometries share several geometrical features, the relations provided by this solution are for example area-to-area or edge-to-area relations. They can describe if areas intersect, lie within or if nodes belong to areas.
Beside the single object definitions there are only two group definitions, G1 and G2. These groups of areas model the earth's surface and all others. All G2 objects are related to a G1 object, but within the G2 group there exits no structure.

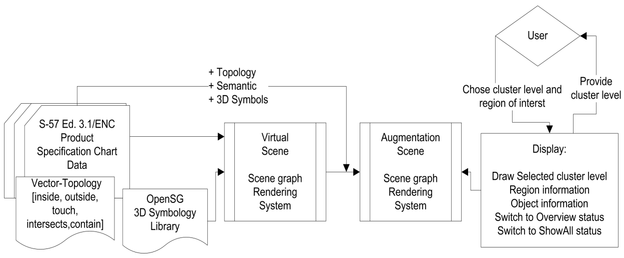

Figure 1. Data concept of the introduced display management

1.4.2 Module ECDIS_3D

The underlying ECDIS software provides a new 3D module. Laying upon the 2D data structure, the new module models all 2D chart data symbols as 3D objects for a fully virtual scene. This includes areas as water surfaces or water bodies. An example is given in Figure 6. The main point here is, that the data structure is the same as in the 2D case and that the modelling is not optimized for an augmentation scene which is characterized by a simultaneous display of video signals.

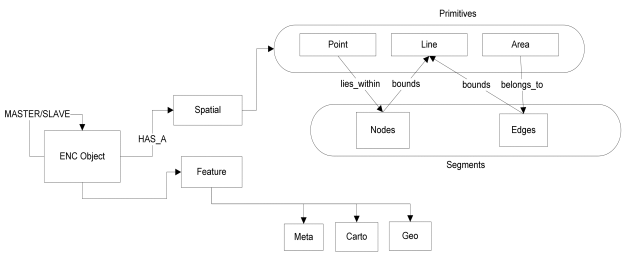

Figure 2. ENC data model. An ENC object is divided into the feature and the spatial object. Additional relations are rarely set between objects. Relations can be build in the geometrical definitions between the point, line, area, node and edge structures

This holds for many 3D scenarios where the data is generated from 2D charts.

2. APPROACH

2.1 Building Topology

The goal of the approach is to define a hierarchy between the chart data objects. As the standardized data structure does not provide an object-to-object topology we need to define relations between objects.

Within the geometrical definitions of an object exists an implicit vector-topology. We utilize the relations which provide an unambiguous hierarchy. Figure 3 describes the process. A general chart is interpreted as sectional model. The areas define layers by their territorial characteristics. Primitives are situated above the areas. Starting with the most important area we can build up the base hierarchy given directly by the standardized chart data, evaluating the relations 'inside' and 'contains'. The drawback of this top down method is, that we can only process area objects. Due to the lack of information which point object refers to which area; the second step is a bottom up approach starting at the point primitives. Each of them refers at minimum to one area, as all chart cells are assumed to be surveyed. Calling all areas on which a point primitive is situated leads to a number of unordered area primitives, except of the relations to the G1 or G2 groups.

To order the remaining areas we use the surface area, as we mainly want to relate objects due to their geographic context. This approach is similar to the base of the vector-topology, but in this way we can manage all objects of the chart data, including point primitives. After these estimations, each point primitive refers to a group of ordered areas. An example of the hierarchy is given in Figure 4.

Excluded of this approach are the safety ("Display Base") information since they have to be displayed always and line objects which mainly do not refer to a single geographic region.

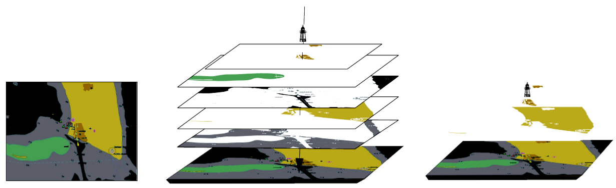

Figure 3. Main concept of the hierarchy building approach. On the left a detail of a general chart in classical view is shown. The middle shows the interpretation of areas as sectional model. Objects are therefore situated on several area objects. On the right, you see the cleared hierarchy.

2.2 Building Semantics

In Figure 5, right, we show the resulting object-to-object hierarchy. As the data has a realistic instance we can interpret the objects within the hierarchy. To use this information in the display management, the generation of additional semantic groupings is done by utilizing the S-57 object attributes. Sub trees in the hierarchy referring to a labelled node are used to define a semantic group. As the Figure 5 shows, semantic groups can have a topology itself. To show the number of possible semantical groupings, see Table 1 for the evaluation of the attributes ObjectName (OBJNAM) and NationalObjectName (NOBJNM).

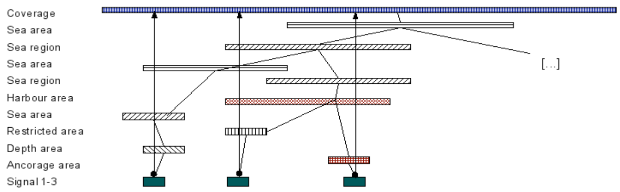

Figure 4. Schema description of the hierarchy. On top the main areas and on the bottom the primitives. The real object names are given for a better explanation. The arrows shown here have the same meaning as in the Figure 3, whereas the lines between the areas show the relationships which build the new hierarchy

2.3 Standard conformity

The ECDIS software system models relations between objects, which are normally not filled. These relations are used to store the generated hierarchy into the 2D chart data. As only the value of the relation is changed, whether the size of the data nor the standardized structure is affected. The approach can be used as a preprocessing, done only once. The charts can then be used for all visualizations by evaluating the relations.

This can not be done for the semantic information we built. The solution here is to use an exchange format to store the generated information permanently until its usage in a scene rendering system. For this purpose a format is needed which can hold not only the semantical grouping but also the standardized 2D chart data. Since the new Version 4.0 of the Standard S57 will use a defined GML (Geographic Markup Language) Scheme (called S57/GML) as exchange format the International Standard CityGML of the OGC (Open Geospatial Consortium) fits the requirements very well. CityGML is a representation scheme for 3D scenes and can hold the 2D data by using only a few extensions of the CityGML standard. The paper (Koch, 2010) shows an explanation of the storage of the generated data into the CityGML format by defining an application domain extension.

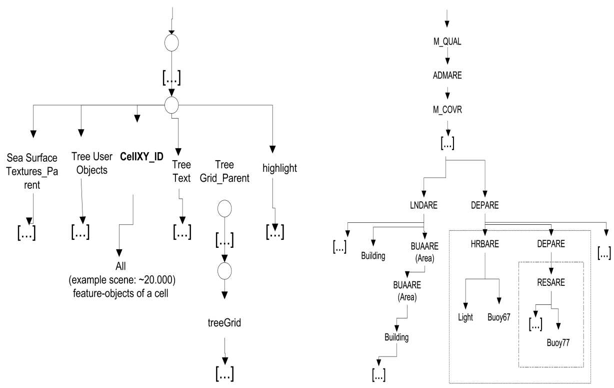

Figure 5. Scene graphs generated by the virtual and augmentation scene. On the left: the data used is the original 2D chart data. This resolves in one scene node which holds all objects (here about 20.000) without any structure. The advantages of a scene graph system can not be fully used here. On the right: the new data structure is represented by a scene graph. All sub trees can be activated or deactivated. The important areas are situated in the upper and the point objects like sea signs and signal stations can be found at the bottom. The dotted lines represent semantic groups, which define the selectable sub trees for the user

3. RESULTS

The 3D visualization is now levelled by the given hierarchy. This hierarchy can be handed to a scene graph rendering system. The user can decide if land or water areas are relevant. The changes are handled in real-time. Reduced data is marked and the underlying objects can be displayed by selecting the group. Figure 6 shows 3 example scenes. In the top row sea signs (a building and a tower) occlude interesting signs in the background. The top left image shows the reduced scene without the occluding sea signs. The areas in the near of the user are suppressed. The second row shows another scene where the user selects the focus. Left to right: fully rendered, only "Skin of the earth"-surfaces, single land area and the shoreline construction of a harbour. In the bottom row is again a classical top view scene as in the 2D cases, but only to show the behaviour of the areas. On the left the scene with only water areas shown and on the right only one selected build up area; only objects to which the area refers to and display base objects are rendered. The results show that new object classifications are possible since they are now stored in labelled groups.

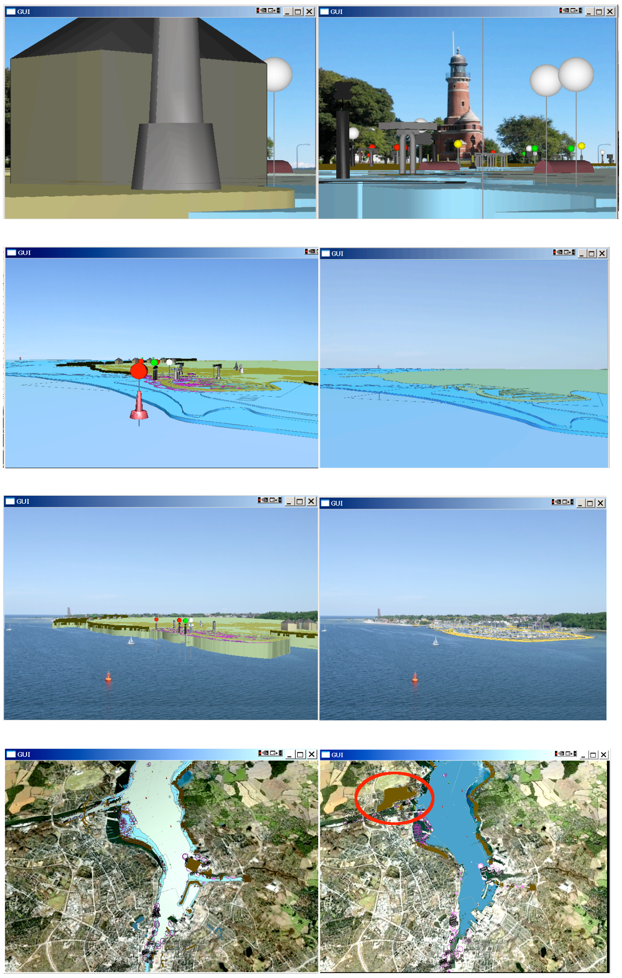

Figure 6. Top row: Overloaded display situation: original, fully rendered and without the land area in front; Middle row: fully rendered scene, reduced scene to "Skin of the earth"-surfaces, selected land region and selected shoreline; Bottom row: Fully rendered example scene from a higher viewpoint to show the areas, left fully rendered, only water areas with all features and a selected build up area (always left to right)

4. CONCLUSION

This paper describes the usage of standardized 2D charts for an interactive 3D scene. A simple modelling of 2D chart data as 3D models lead to crowded displays and in the case of sea charts to an inadequate scaling concept. To solve this, we build a hierarchy by an evaluation of the vector based topology within the geometrical object definitions and enhance the data with the generation of semantic groups. The result is a 3D visualization of a 2D chart which suits the requirements of a real-time augmentation application. The approach relates objects of the chart data by their geospatial characteristics. All point objects are related to area objects. The reduction in the display is done by selecting sub trees in the hierarchy which are interesting in the actual use case. Due to stay standardized, the topology can be stored in the given data structure whereas for the semantic groups a solution for an exchange format is provided. The structure of the 3D scene is not dependent on sea charts and can be widely used to enhance chart data by new object categorizations which help to clean up scenes or fasten up the rendering process.

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