USING CONTEXT KNOWLEDGE FOR MARITIME SITUATION ASSESSMENT

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Abstract: *In maritime surveillance applications, the aim is to enhance the situation awareness of decision makers located in a central operations centre. Based on the maritime operational picture of the current situation at sea, a decision maker has to decide for specific actions, e.g., for sending out a coast guard boat to counter possible pirate attacks. In order to enable detailed situation awareness in the maritime domain it is necessary to support decision makers with automatic means for in time decisions.*
Automatic situation assessment (SA) services try to interpret the vessel's behaviour and can be employed as means of enhancing situation awareness. Such SA services have been developed on the basis of an object-oriented world model (OOWM), which is able to fuse object observations from different sensors and to keep the resulting estimated track data in a short-term memory. For enhancing the performance of the SA services, we propose the combination of static context knowledge with the dynamic data of the OOWM. Static context knowledge consists of either approved data or a priori domain knowledge modelled by experts (e.g., maritime territorial boundaries) and is persisted in a long-term storage like the Coalition Shared Data (CSD) server.
In this article we provide a description of each system and highlight the benefits and drawbacks of each. Furthermore, a combination of dynamic OOWM data with context knowledge stored in the CSD server is suggested as we state that combining OOWM and CSD data will improve SA services and context knowledge likewise.

Keywords: *Context knowledge; situation assessment; object-oriented world model; Coalition Shared Data server.*

1. INTRODUCTION

Maritime surveillance applications can be of use for many different tasks, like the protection of property and equipment in harbours or bays, the surveillance of maritime borders, or within operations to counter piracy. In such tasks, heterogeneous sensor systems ranging from radar sensors to electro-optical or infra-red imaging and video sensors can be employed to collect data on a monitored environment. Furthermore, systems like the automatic identification system (AIS) or geographic information systems (GIS) can provide additional information.

In order to enhance the situation awareness of decision makers, collected data have to be made available and integrated into an operational picture of the maritime environment being monitored. To share and store surveillance information and sensor data relevant for decision making, the approved CSD server architecture described in Section 2 is used. Section 3 illustrates the integration of dynamically acquired sensor data by means of an OOWM and the enhancement of situation awareness, based on OOWM data, with SA services. Since CSD server and OOWM/SA operate on different levels of information topicality and have differing but compatible objectives, Section 4 proposes a combination of both systems which aims at improving SA services as well as context knowledge.

2. COALITION SHARED DATA

The concept of Coalition Shared Data (CSD) has been developed on requirements from the military surveillance and reconnaissance community.

In combined operations it was not possible to share surveillance data (like images, videos, reports) in time due to restrictions in operational processes and technical interoperability problems. Each sensor produced proprietary data and common dissemination techniques and interfaces were not defined. To overcome this problem operational processes have been adapted and along them technical standards (Standardization Agreements – STANAGS) have been developed.

Within the CSD concept, systems internally can use proprietary data formats. When sharing (sensor) data, the proprietary data formats are converted into standardized ones, so that inquirers do not have to know the type of source the information is coming from, but can focus on the information itself. Since the CSD concept is realized as client-server architecture [4], the standardized data is transferred to a local CSD server responsible for data storage and dissemination. The interfaces as well as the metadata that describes the products stored in the server are standardized too. Within the metadata all relevant aspects of the products are defined and query able. Additionally, products can be linked to each other by creating associations.

Connected to the same network, exploitation systems or situational awareness systems can query their local CSD server. They can generate additional information (e.g. reports) that is also stored on the CSD server(s). An important aspect of the CSD concept is the ability to synchronize data over wide area networks. Here a server A connects to another server B and performs a subscription on the metadata. By this, awareness about all data is established in the full network. The CSD concept has up to now been tested by different nations and stakeholders in exercises and military operations (e.g. **Error! Reference source not found.**, [2], [3]). It is summarized in Fig. 1.

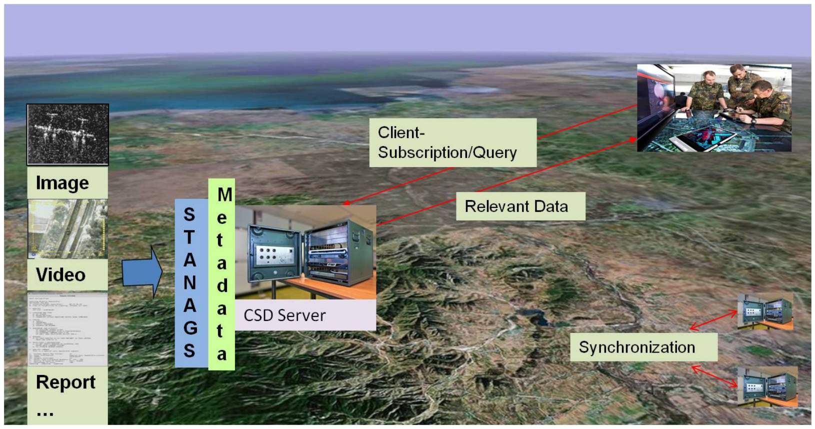

Fig. 1: Information sharing with the CSD concept

The CSD concept has proved itself to be useful in terms of data that has been approved and does not need to be updated (at least not on regular bases). Data consistency within this concept is secured by not being able to change product data once it has been stored on a server. The metadata can be changed on the system that owns the product, but not on systems the data is synchronized to. The main idea of the CSD is to share data in a bigger community, which means the information disseminated must be of relevance for the community. Thus it is not the ideal storage mechanism for products that have not been filtered before.

Query and subscription in the CSD is based on metadata that describes products. Object based query is only possible in a very limited way (i.e. if the metadata describes the content of a product) but it has not been designed for it. A semantic layer that would be solving this problem is missing at current state.

3. WORLD MODEL AND SITUATION ASSESSMENT

The object-oriented world model (OOWM) is a data fusion architecture based on the JDL (Joint Directors of Laboratories) data fusion process model [5]. In [6], the existing OOWM was applied to the maritime domain and a simulation tool to generate test data has been developed. The object-oriented world model serves as a standardized interface between lower level fusion methods, e.g., signal processing, and higher level fusion methods, e.g., situation assessments, see Fig. 2. The essential feature of the OOWM is the capability of using different fusion methods, which have to combine the observations coming from different sensors. The main challenge is to estimate the positions of the observed objects (e.g. vessels), which can be done by various tracking methods. The instantiated objects with their current and past states are represented in the OOWM and can be visualized in a dynamic situation map. This map can be interpreted as a consistent representation of the real world and its dynamic objects, which is known as maritime picture in the maritime domain. As visualized in Fig. 2, the OOWM also serves as an information pool for higher level fusion methods, such as the so-called situation assessment (SA) services.

The aim of SA services in the maritime domain is a task-oriented interpretation of the current situation at sea. To support this challenge automatically, the SA service has to differentiate between relevant and irrelevant situations at sea or detect and localize suspicious vessels, e.g., by probabilistic methods like Bayesian networks [7]. In [8], a dynamic Bayesian network for the calculation of the probability that an observed vessel is carrying refugees on board is presented in detail.

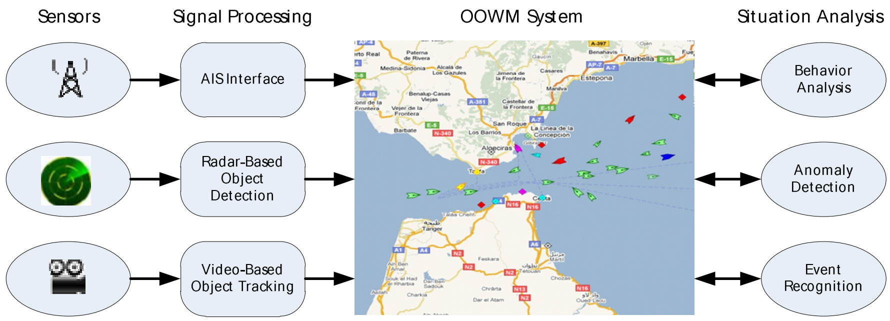

Fig. 2: OOWM serves as a standardized interface between sensor deployment with signal processing modules and situation assessment services

One essential benefit of the OOWM system is, that it provides standardized interfaces for object observations on the one hand, and for SA services on the other hand. Fusion and tracking of objects, which is based on incoming observations from different sensors, is done in an object-oriented way. Furthermore, the tracking, fusion and SA algorithms are encapsulated as modules and can therefore be exchanged easily. Thus, the OOWM system allows an easy integration of new sensors or new services.

One drawback of the OOWM system is that it is acting like a short-term memory, because the current and past object states are only buffered in the working memory. Thus, tracks of observed vessels are only stored in a time window and are deleted when outside the window. Also, the knowledge about situations that happened outside the time window is getting lost and cannot be recalculated. Furthermore, the context knowledge about an area of interest, e.g., shipping lanes, is implicitly modelled in the SA services. However, it is more useful to have a central storage for context knowledge. Then, different SA services can make use of the same context knowledge, without defining them separately.

4. SYSTEM COMBINATION

In order to overcome the previously presented drawbacks, this paper proposes a combination of CSD server, OOWM and SA services as illustrated in *Fig. 3: Combination of OOWM and CSD*Fig. 3. As can be seen, sensor systems provide their data to both CSD server and OOWM. Using the example of track data, manually chosen relevant track data along with exploitation information get stored in the CSD server, while raw track data is forwarded to the OOWM for integration and subsequent analysis by SA services. As the first step of system integration described in Section 4.1, the CSD server shall serve as a persistent storage for SA information. For the next step, Section 4.2 illustrates how context knowledge stored within a CSD server can be integrated into the OOWM and used to improve SA services.

4.1. Using Situation Assessment for Selection of Relevant CSD Data

As the user may want to have access to results of the SA services outside the time window of the OOWM, it is a logical consequence to store the results in a database. This is done by saving the results of the SA services in the CSD server. The SA services are able to detect relevant data, e.g., tracks of interest, and also to generate some sort of metadata, e.g., a track of an illegal immigration vessel or tracks of a piracy attack. This metadata can be interpreted as a proposition for a situational description.

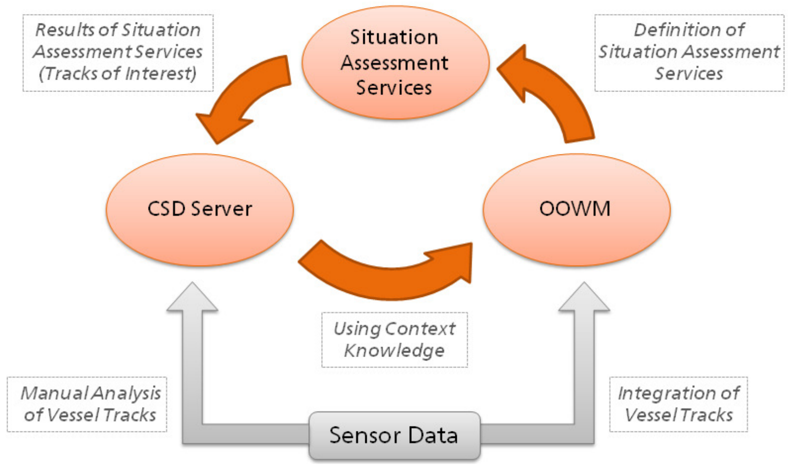

Fig. 3: Combination of OOWM and CSD

As the final decision of storing relevant tracks is done by a human interpreter, he is manually checking the results of the SA service. If the human interpreter decides that these results should be classified as relevant data, he is able to extend or change the situational description before saving the results into the CSD server. Doing this way, it is guaranteed that only correctly interpreted data is stored and that the consistency of the CSD is kept.

If some recognized situational descriptions are tagged as non-relevant by the human interpreter, the false detections by the SA service can be collected. When enough false detections have been collected, they can be analysed and used for enhancing the quality of the SA service, e.g., an adjustment of the parameters in a dynamic Bayesian network. By this analysing process, the false detections in future can be reduced.

Thus, the SA service is able to provide a human interpreter with the information that is most relevant to be stored. By using the automatically analysed data, which is originally coming from the OOWM, existing knowledge in the CSD server can be extended easily.

4.2. Using CSD Context Knowledge for Situation Assessment

Within a CSD server, selected products from intelligence, surveillance and reconnaissance (ISR) tasks are stored due to their relevance. These products constitute information of assured quality on longer-term discoveries and relevant facts for a considered area of interest. Yet, the stored products are not well-suited to describe the situation in an area at a (near) real-time scale. To describe an up-to-date operational picture, current sensor data (e.g., tracks) would have to be integrated with approved surveillance information (e.g., the whereabouts of a pirate outpost) and static context knowledge (e.g., maps of depth of sea or maritime boundaries). This can be achieved by extending and adapting the OOWM to support this kind of information integration.

Such an extension to the OOWM has to be designed to allow modelling the domain of ISR information. Thus, it has to be equipped with context knowledge describing the contents of CSD products (e.g., the features of surveillance objects, object-based taxonomies) as well as general information on a monitored geographic area (e.g., geospatial data on boundaries, points of interest, depth of sea, etc.) As input to this OOWM extension, CSD products containing structured symbolic information can be used, such as exploitation reports, in order to establish a context-enhanced static knowledge for a monitored area.

By using CSD information within an extended OOWM, not only static and dynamic information are integrated, but also object-based queries are enabled and SA services can access a broader base of information. In addition, the OOWM can derive new information suited as context knowledge for SA services by considering static and dynamic information together. In a maritime piracy scenario, for example, the existence of potentially dangerous areas could be derived from a combination of track data on recent pirate attacks, information on the whereabouts of pirate outpost and geospatial background information.

5. CONCLUSION AND OUTLOOK

For enhancing the situation awareness of decision makers in maritime surveillance tasks like property protection, border surveillance or counter-piracy operations, we propose to combine approved static data and background information residing on CSD servers with the dynamic data used in SA services. This combination is believed to prove advantageous for both systems. On the one hand, SA services support the automated selection of dynamic surveillance information, e.g., annotated track data, which consequently can be persisted on a CSD server acting as a central long-term storage. On the other hand, context knowledge stored in CSD servers can be integrated with current sensor data, in order to serve as a basis for establishing an operational picture of the current situation at sea and form an extended information base for SA services.

In future work, the details of the system combination shall be further elaborated, and a demo scenario shall be implemented.

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