12TH ICCRTS
"Adapting C2 to the 21st Century"

A human-centered approach for the optimization of human-system-interaction in future naval C2 systems

Suggested Topics:
C2 Technologies and Systems
C2 Concepts, Theory, and Policy
Cognitive and Social Issues

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Abstract

The quick and accurate identification of contacts of interest is essential for the successful fulfillment of nowadays naval missions. Especially in the littorals, there is a very high density of objects, entailing the possibility of various different asymmetrical threats. Modern sensors provide loads of data and information, based on which decisions have to be made in extremely limited time. When 21st century C2 software is being developed, these aspects must be particularly considered. The authors design and implement an exemplary system for surface warfare, yielding a demonstration facility and guidelines for future procurement specifications. In order to disencumber human decision makers, the main focus is on designing a graphical user interface that is as easy to use and as easy to learn as possible. To reach this objective, a highly user focused approach is chosen. Subject matter experts are asked frequently throughout all phases to examine the system and give feedback, based on which it can be optimized and enhanced. Furthermore, experimental tests with experienced officers are conducted under realistic service conditions. The acquired results are used for further optimization. The paper explains the methodology and presents results and lessons learned from an operational system developed following this approach.

1. Introduction

The participation in so-called “out of area” missions, e.g., to back a peace keeping mission or to enforce an embargo, is characteristic for nowadays naval vessels’ duties [BMVg, 2006]. In such missions, the tasks of situation recognition and assessment are characterized by eminently high complexity and uncertainty due to the simultaneous presence of neutral, friendly, and hostile objects. As opposed to the blue water scenarios of the cold war, the avoidance of collateral damage is mandatory now. Against this background the identification of unknown objects, the detection of the abilities and intentions of possibly threatening objects, the interpretation of rules of engagement, and the ultimate decision on whether or not to engage a particular object lead to exceedingly difficult decision making situations.

Besides the shift in mission objectives there has also been a lot of technological advancement in recent years. Range, speed, and accuracy of weapons have increased, and so did sensors and communication facilities. The growing amount of available data about the operational area and the increasing importance of communication, computers, intelligence, surveillance, and reconnaissance in C2 have given rise to the term C4ISR. Consequently human decision makers have less time remaining to ponder. This means high workload and stress for them and will possibly result in wrong decisions with serious consequences. Thus the importance of supporting decision makers to reduce workload and therewith improve planning, decision making, and operation safety increases significantly.

Reconnaissance is one of the most crucial tasks navies are facing. The quick classification and identification of unknown seagoing vessels is of the greatest importance, especially in the context of deployments like Operation Active Endeavor, where the mission is to conduct operations against suspected terrorist activities in the Mediterranean. Since the start of the operation in October 2001 nearly 79,000 merchant vessels have been monitored (as of 12 April 2006) by the forces of Active Endeavor [AFSOUTH, 2007]. Modern combat direction systems (CDS) make use of several different stationary and mobile image generating sensors that constantly deliver raw image material to be evaluated in a ship's combat information center (CIC). As environment, sight and weather conditions vary, so does this material concerning its quality. Infrared (IR) sensors, for instance, deliver a significantly inferior signal-to-noise (S/N) ratio and are responsive to environmental conditions such as temperature and humidity. Hence the analysis of contained details and information can become exceedingly difficult and time consuming, if accomplished solely by human operators on their own. But given the busyness of merchant waterways nowadays, time is a very limited asset. Consequently, an advanced support system is needed to guarantee a quick and reliable classification and identification of observed contacts of interest (COI).

The authors are creating a demonstration facility with two different workplaces. One of the workplaces contains the support system KEOD 2.0, which has been developed within an earlier project to support the classification of surface vessels based on electro-optical imagery, which is one particular aspect of situation recognition. This system has been tested extensively and will be officially deployed soon. At present, it is already deployed provisory to those vessels of the German navy that are currently involved in the UNIFIL (United Nations Interim Force In Lebanon) operation to secure the Lebanese coast and prevent arms smuggling. The other workplace will provide support for the overall tasks of C2, including situation recognition, the assessment of own and enemy abilities and possible courses of action, collaboration potential within the task group, engagement planning, and damage assessment. Unlike the first workplace, this one will be merely a demonstration facility. The intention is to use it as reference for future procurement specifications.

2. Some fundamentals for C2 support

The assistance to be included shall be deemed a cognitive amplifier, on no account shall human decision making be replaced by complete automation. Tactical decision making, due to its immanent complexity and high stakes, must be considered a naturalistic decision making process. Thus, all eight characteristic factors, as mentioned by Orasanu & Connolly [Orasanu & Conolly, 1993], are at quite difficult levels:

- Ill-structured problems: Significant preparatory work is necessary to obtain an understanding of what is happening and what responses might be appropriate. There is no single best way to proceed.
- Uncertain dynamic environments: Because of environmental and weather conditions as well as restrictions with the use of sensors, data about nearby tracks may be scarce or ambiguous. Furthermore, in the missile age settings are likely to change quickly.
- Shifting, ill-defined, or competing goals: Decision makers are driven by multiple competing aims, such as self-protection and the avoidance of collateral damage ("engagement blue-on-green"). It is unclear how things should be traded off against each other.
- Action/feedback loops: Own actions can lead to reactions of other involved parties. By this means additional information can be generated, but new problems might occur, too. An object might feel provoked, for instance, when being targeted by illumination radar.

- Time stress: The existence of time pressure is obvious, because anti-ship missiles can be fast and difficult to detect early. Hence decision makers do not have much time to ponder and are likely to experience stress.
- High stakes: Outcomes of real significance to the participants are involved, such as being hit by enemy fire, mistakenly killing civilians, loss of one's career or even of one's life.
- Multiple players: Although by definition the final decision is to the commanding officer (CO), there are several CIC team members involved in the decision making process, and the report of a single person can make the decisive difference.
- Organizational goals and norms: There are miscellaneous organizational settings relevant to the decision-making process. Therefore applied goals and values cannot simply be the personal preferences. Furthermore, the organization may respond to the decision makers' difficulties.

Sheridan [Sheridan, 1992] differentiates ten degrees of automation, as shown in Figure 1. Level 1 would mean not to provide any decision support at all. Levels 8-10 are not eligible for tactical decision making because in these approaches operators are completely dismissed from the loop. Level 7 can be regarded acceptable only for the initiation of so-called "last-chance" defenses against very critical threats, such as an inbound anti-ship missile. The support provided to operators should normally reside among levels 2 to 6 and adapt according to the complexity of the task at hand, the overall situation, and the operator state, as far as it is possible to assess it.

Degree of automation	System features
1	The computer offers no assistance, human must do it all.
2	The computer offers a complete set of action alternatives, and
3	narrows the selection down to a few, or
4	suggests one, and
5	executes that suggestion if the human approves, or
6	allows the human a restricted time to veto before automatic execution, or
7	executes automatically, then necessarily informs the human, or
8	**informs him after execution only if he asks, or**
9	**informs him after execution if it, the computer, decides to.**
10	**The computer decides everything and acts autonomously, ignoring the human.**

Figure 1: Scale of degrees of automation [Sheridan, 1992]

As pointed out in the introduction, operators onboard naval vessels have to make decisions based on a multitude of data and information. In current C2 systems these are predominantly presented in alphanumeric form. According to Card [Card et al., 1999] a user-centered presentation of complex data should feature the use of computer-supported, interactive, visual representations to amplify cognition by

- Increasing the memory and processing resources available to operators,
- Reducing the search for information,
- Using visual representations to enhance the detection of patterns,
- Enabling perceptual inference operations,
- Using perceptual attention mechanisms for monitoring, and

- ➢ Encoding information in a manipulable medium.

Some inferences can be drawn easily due to graphical visualization, whereas without it would be more difficult. By appropriately mapping information into visual form cognitive effort can be enhanced. The overall idea is to support thinking by visual perception.

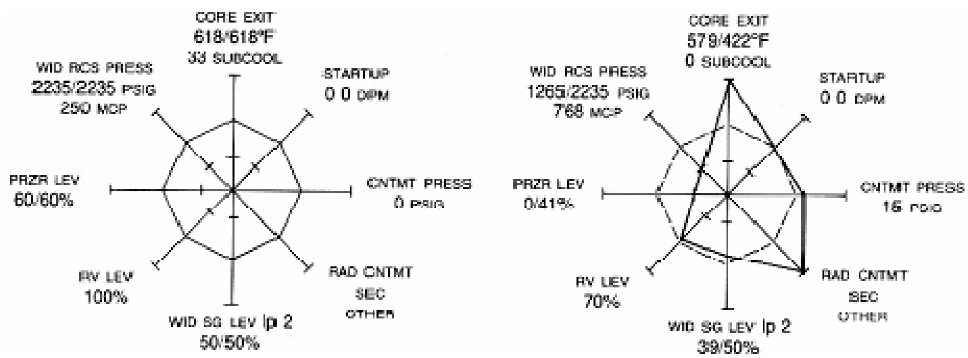

Figure 2: Polar display for nuclear power [Wickens, 1997], right one indicates parameter deviations

Figure 2 shows two states of a safety parameter monitoring display [Wickens, 1997] designed to support nuclear power plant operators. A polygon connects the values, indicated by the distance from the center, of eight parameters. As long as everything is all right a harmonic uniform polygon, as the one on the left, originates from the data. The right one indicates that there are parameters that deviate from normal. This visualization technique can be used to transform multiple different alphanumeric values into one graphical element.

3. Human-centered approach

The major goals of the authors’ work are to design ergonomic operating concepts and to realize prototypical user support systems. With the design of systems, in order to keep operators in the loop, the main focus is on an efficient handling of the tasks to do, an optimized graphical user interface, and clearly guided operating sequences [Schweingruber & Brütting, 2004]. Therefore, several discussions with experts as well as surveys of the procedures aboard take place.

It was decided to deploy on standard desktop PCs with flat screen display, mini keyboard and mouse. Experimentation with a test-bed for naval C2 components has shown that standard mice are highly accepted and well suited for support systems in naval environments [Grandt et al., 2003]. An argument often put forward in favor of roll balls is that they are relatively robust against ship movements, as compared to mice only loosely connected by a cable. However, by taking adequate measures undesirable mouse displacements can be prevented. Furthermore, most people are already trained with mice.

Both workplaces are implemented in the modern and reliable programming language Java. A graphical development environment is used that allows quick testing of the semi-manufactured product. GUIs that lack an understanding of the presumable operating procedures tend to be functionality-oriented and hence difficult to use and difficult to learn. According to the philosophy of rapid prototyping, subject matter experts, namely those operators in the ship’s CIC assigned to perform the tasks to be supported, are frequently asked to examine the systems and give feedback, based on which they can be optimized and enhanced. In the beginning, expert talks mostly take place ashore. Main partners are from Naval C2 Systems Command (KdoMFüSys) and the Federal Office of Defense Technology and Procurement (BWB).

Testing under realistic circumstances, as performed mainly in the next phase, is of course a part and parcel of human-centered development. Besides performance, reliability and stability of a system, acceptance and utilization by the navy personnel is of paramount importance. Experiments under realistic conditions are particularly valuable to find out about the two last mentioned.

The applied test procedure was designed based on navy specific requirements in consideration of tactical conditions. Limiting the group of test persons to seagoing personnel guarantees a homogenous collective with appropriate education and training as well as the most up to date experience. In experiments, navy personnel get a standardized personal introduction to systems and their functionality. Then operators observe an exemplary classification process run by the investigator before they have to work on realistic scenarios on their own.

To evaluate the effectiveness of a system, an extensive questionnaire was designed that subjects have to fill in directly subsequent to an experiment. The questionnaire consists of rating scales and questions. Test persons are asked to rate certain qualities of a system by means of the 2-level rating scale (see Figure 3) called ZEIS [Pitrella, 1989]. On the first level, a relatively raw decision has to be made among poor, medium and good. On the second level, a finer differentiation takes place on an 11 point scale with adequate descriptions.

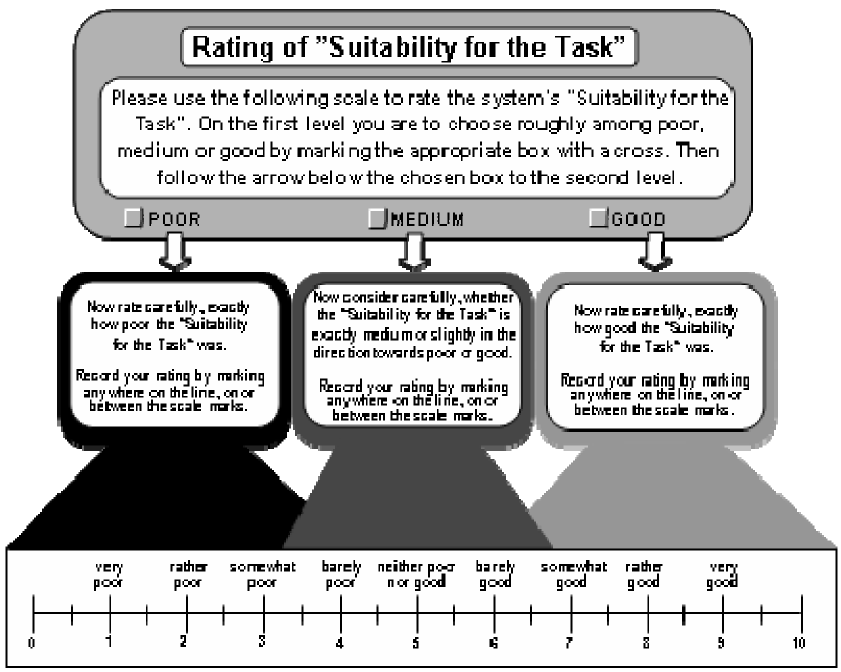

Figure 3: ZEIS rating scale for suitability for the task

The main advantages of subjective rating scales are that they are well accepted by test persons, highly valid and provide hints for system development [Pfendler, 2000]. The rating scale is used to review a system in regard to the five criteria suitability for the task, self-descriptiveness, controllability, conformity with user expectations, and error tolerance.

These ergonomic criteria are defined in international standard DIN EN ISO 9241, part 10 [DIN EN ISO 9241-10, 1996], as follows:

- Suitability for the task: A dialogue is suitable for a task when it supports the user in the effective and efficient completion of the task.
- Self-descriptiveness: A dialogue is self-descriptive when each dialogue step is immediately comprehensible through feedback from the system or is explained to the user on request.
- Controllability: A dialogue is controllable when the user is able to initiate and control the direction and pace of the interaction until the point at which the goal has been met.
- Conformity with user expectations: A dialogue conforms with user expectations when it is consistent and corresponds to the user characteristics, such as task knowledge, education and experience, and to commonly accepted conventions.
- Error tolerance: A dialogue is error-tolerant if, despite evident errors in input, the intended result may be achieved with either no or minimal corrective action by the user.

Although these criteria are analysis oriented and do not contain any advice on how to deal with design conflicts, they provide an accredited assessment framework. Augmenting this norm that specifically applies to dialogue design, comments on the standards [DATech, 2006] give advice for whole systems. In addition to filling the rating scales, subjects have to answer questions on what in particular displeases them and what appeals to them, so that system designers not only know where deficits are but also get hints on how to address them.

4. Support system for classification based on electro-optical data

One of the workplaces in the demonstration facility will be filled with a support system for surface vessel classification based on electro-optical imagery. This system is based on two algorithms [Günther et al., 1996] that were developed at the Helmut Schmidt University of the Federal Armed Forces in Hamburg (HSU-HH). One performs investigations of object contours (contour classifier), whereas the other investigates relative locations of visible marks (marks classifier). Both deliver result lists containing those ship classes that have most in common with the analyzed data. The algorithms have been tested extensively at the Bundeswehr Technical Centre for Ships and Naval Weapons (WTD 71) in Eckernförde and both proved to be reliable and accurate [Römer, 2001].

The original GUI was created for testing purposes by HSU-HH and extended by WTD 71. The focus was on proving the validity of the algorithms, usability aspects were not taken into account. The support system with this GUI carries the name KEOD 1.0 (classification using electro-optical data) according to the navy project within which the deployment is organized. The goal of the successfully completed UNbiS (user support concept for the application of optical sensor imagery for the classification and identification during surface reconnaissance) study was to create and realize an ergonomically optimized GUI. The resulting support system is called KEOD 2.0. The follow-up study UKIDuO (support for classification, identification and data acquisition of civilian and unconventional objects) aims to enhance the system, so that it can deal with non-conventional objects and will finally result in a KEOD 3.0.

4.1 Classifiers

The contour classifier needs the outer contour of the object to be classified (OTBC) and the information whether it has its bow left or right on the image as input. It compares the OTBC with reference silhouettes of all known ship classes in the database. These silhouettes are supplied binary and were derived from 3D models picturing representative role, pitch, and position angles. Bow and stern positions in the contour of the OTBC are fitted into the binary reference matrix so that the silhouette's length is standardized. To assign the data at hand to the most probable reference objects, an average-free normalized cross-correlation function is used, whereupon movements in x and y directions are performed until a maximum correlation coefficient is found. Sections where lines are close-by but not exactly one upon the other are accounted for devalued. In the final step, the result list is sorted according to the correlation coefficients so that the ship with the most similar contour heads the result list.

The marks classifier needs horizontal and vertical positions of visible marks on the image at hand as well as the rotation angle around the vertical axis. The support system's database contains the same data for all known ship classes. The classifier compares the data of the OTBC with that in the database. This is achieved by accumulating scaled Euclidean distances between OTBC and presumably corresponding database mark positions. The visibility of the individual ship parts with different position angles is considered, so that erroneous assignments of hidden ship parts are impossible. The operator's statement that a particular mark can be seen at a certain position is dealt with in a fault-tolerant way. Each pair of ship parts is allocated a confusion probability, from which a coefficient for the respective Euclidean distance is derived. The database ship classes are listed according to their total distance to the OTBC, so that the ship class with the most similar marks heads the result list.

4.2 GUI design

Beginning with sensor imagery at the one side and the two reliable algorithms described above on the other side, an ergonomically optimized GUI had to be designed.

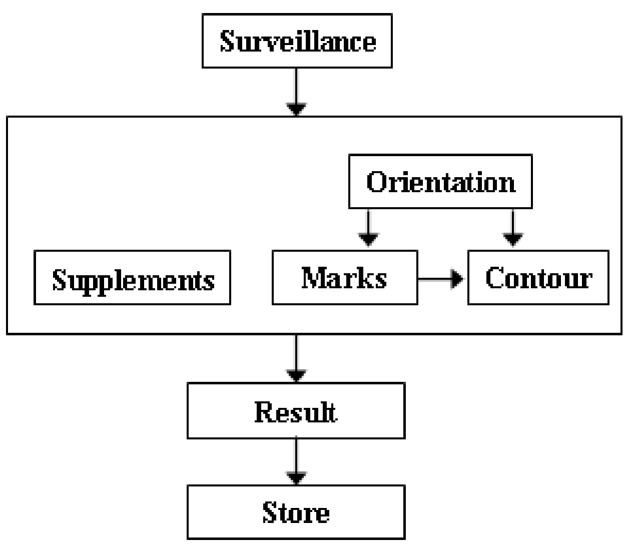

Figure 4: Process states in support concept

To guide users through the steps necessary to feed the algorithms with data and to interpret the results, a sequence of clear cut process states (see Figure 4) has been developed in cooperation with subject matter experts. In every process state, only information that is needed to fulfill the particular subtask is displayed [Mooshage & Schweingruber, 2005].

To make it easy for operators to find required information and functionality, throughout all process states the overall layout is constant. The GUI is subdivided into four quadrants (see Figure 5) that stand for different subject areas [Schweingruber & Mooshage, 2005].

The 1st quadrant always contains imagery originating from the attached sensor. Depending on the process state currently performed, different manipulations can be made within this image.

The 2nd quadrant is reserved for controls belonging to certain tasks. Contents of this area change according to the process state that is selected.

In the 3rd quadrant, the overall controls can be found. This area consists of buttons to go to another process state, to load, save and store classification results, as well as to change the language used by the system, to change the colors between day-light and darkness mode, and to shut down the system.

In the 4th quadrant, there is a database viewer in which all known ship classes can be browsed through. It is possible here to look at reference pictures, outline drawings, VRML models, as well as facts and data of all ship classes in the database. The sub-database choice function, which allows reducing the search space to a dedicated selection of ships, is also located in this quadrant.

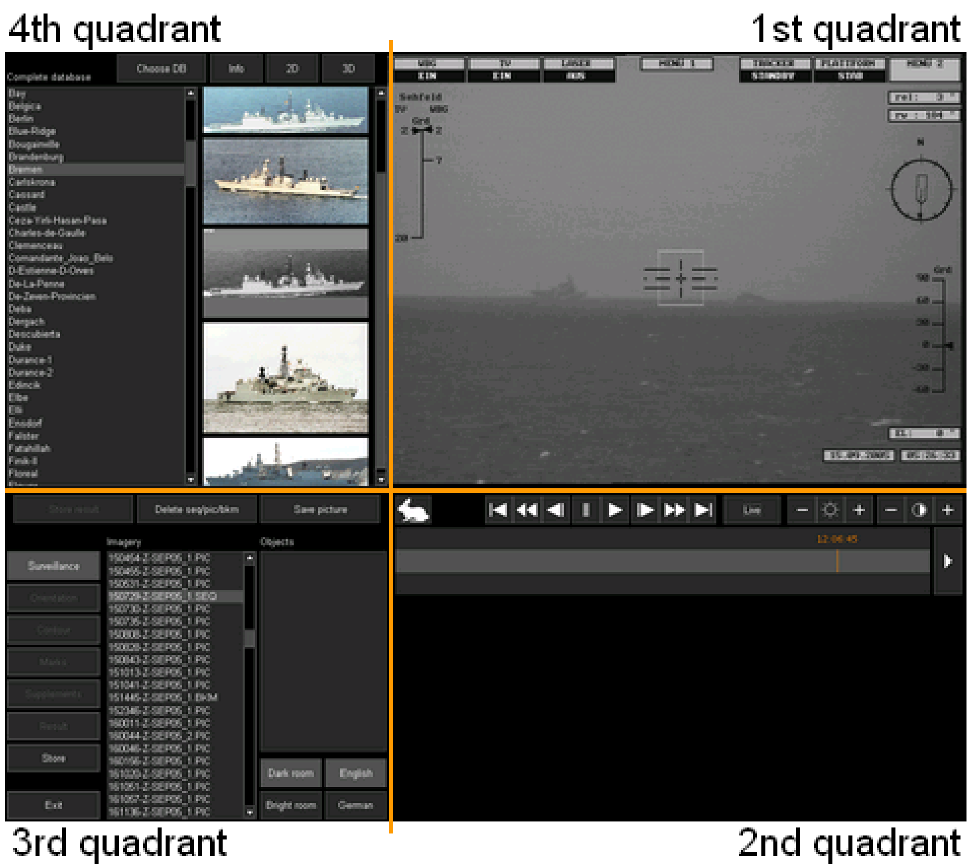

Figure 5: The four quadrants of the GUI

In process state Surveillance, the operator's task is to choose appropriate imagery from the available material. A time-bar allows reviewing what has been recorded within the past few minutes. Through buttons that are similar to fast backward, fast forward, single image back, single image ahead etc. on typical remote controls or simply by clicking at any position in the time-bar it is possible to navigate the available imagery easily. Images can be further optimized by zooming and manipulating brightness and contrast. Once the operator has decided which image to take, the next process state can be selected.

Process state Orientation provides graphical support for the ascertainment of the rotation angles on all three axes, because both classifiers need information about the object's spatial orientation on the chosen image. In the 2nd quadrant, a model ship can be rotated to the appropriate position. It is possible to choose among three different ship types, so that the model is somewhat similar to the OTBC seen above. However, it is not intended to have more ship types for choice, lest operators waste too much time for choosing.

In process state Contour, the object's shape is supplied. The operator is asked to do that within the sensor image area in the 1st quadrant. It can be performed by inputting points that are connected by a polygon, by completely painting, or any combination of both. A preview line between the last clicked point and the current mouse position always indicates how it would look if clicked now. By clicking the right button of the input device, points can be removed. Painting can be removed by holding that button and moving the device, whereat the motion speed determines how fast painted sections are taken away. The 2nd quadrant provides undo and reset buttons as well as a button to close the polygon, so that it is not necessary to exactly hit the starting point again. In experiments, many subjects are of the opinion that it is possible to automate this task, but according to experts from the authors' organization's sister institute, the Research Institute for Optronics and Pattern Recognition in Ettlingen, there is no accurate algorithm for this job as of today. Especially the multitude of different image qualities prevents the successful application of a single algorithm to deal with all of them reliably.

Within process state Marks, the operator is asked to input the identifiable marks. If process state Contour has not been completed before, it is necessary to highlight the frame of the OTBC first, otherwise it is derived form the silhouette. In the 2nd quadrant, a list of all position dependant marks such as bridge, turrets, masts etc. can be found. After a mark has been chosen, its position must be clicked at on the image at the 1st quadrant. An erroneously entered mark can be removed by placing the cursor nearby and clicking the right button. Therefore the temporarily nearest mark is always highlighted by a circle. Furthermore, an undo button allows removing the mark entered last, a remove button to remove all of a kind and a reset button to forget about all of them. It is not necessary to always move the cursor to the menu below the image to change to another kind of mark. By clicking the left or right button outside the frame, the next or previous line of the marks list is selected. The marks are sorted as they typically appear from bow to stern.

Process state Supplements can be used to incorporate any almost definite information into the classification process. If, for instance, the length of the OTBC can be estimated quite exactly, ships that are significantly shorter or longer can be neglected. Other criteria are any kinds of marks, nation, form of bow and stern, part of hull number, and ship grouping. Supplements can be used in addition to the algorithms or as stand-alone means for classification.

Finally, process state Result presents a list containing the most probable ship classes as figured out by algorithms and supplements function, and offers several opportunities to compare the material at hand with reference imagery, outline drawings, 3D models, and data records. The database viewer at the 4th quadrant changes its appearance, so that 3D model, outline drawing and the reference image with the most similar rotation angle of an entry selected in the result list can be seen in maximum size directly alongside the chosen original sensor image. It is important that the operator performs a visual comparison, because the scope covered by the algorithms is limited and humans have different skills as to pattern recognition. Once the operator has found the entry within the result list that seems to equate the OTBC, the decision can be saved. It is possible to add comments in written and spoken form, so that another operator investigating the material can be told the circumstances of the classification, e.g. why there was a particular interest in that special object.

Process state Store is not directly connected to the classification sequence. The amount of stored classifications is likely to increase quickly when vessels are, for instance, deployed to sea area monitoring operations. To ease the handling of such material, this process state provides a concise table that is sortable according to many different criteria. The content of the store can be burned on DVD to enable the crew to send it to naval command for further analyses.

4.3 Evaluation and enhancement

This support system has been tested extensively during development. Initial tests took place onboard German fast patrol boat S71 Gepard (P 6121) in the Baltic Sea in November 2004 as well as onboard German frigate Lübeck (F 214) on the passage from Reykjavik/Iceland to Wilhelmshaven in December 2004. Many subjects mentioned potential details to augment and enhance the system in their questionnaires as well as in personal discussions with the investigator. Ideas were discussed with experts from KdoMFüSys, and the reasonable ones were realized.

The enhanced support system was evaluated again during SEF (standard mission training task group fleet), which is the most important annual exercise of the German navy. It took place in the Baltic Sea in September 2005. Besides the German participants, Scandinavian and East European navies as well as NATO task group SNMG1 (Standing NATO response force Maritime Group 1) were involved. The exercise was based on a complex geo-political scenario and consisted of a phase with guided exercises and a free-play phase.

Tests took place onboard several German vessels, namely tender Donau (A 511), fast patrol boats S71 Gepard (P 6121), S76 Frettchen (P 6126), S73 Hermelin (P 6123), frigate Hamburg (F 220), and frigate Köln (F 211). Crew onboard S71 Gepard had changed considerably since November 2004, so that no operators participated a second time; thus these experiments could be assumed independent from the earlier ones. Again many subjects mentioned potential details to augment and enhance the user support system in their questionnaires as well as in personal discussions with the investigator.

Changes and augmentations to the support system were realized until March 2006, the deadline for version KEOD 2.0. Afterwards a number of documents had to be written in order to prepare the necessary official testing by the responsible entities. Detailed reports about the two above mentioned experimentation campaigns can be found in earlier publications [Schweingruber & Mooshage, 2005; Mooshage & Schweingruber, 2006]. This paper will report a third experimentation campaign that focused on the online help.

5. Online help for the support system

Although the support system described in the chapter above can be operated intuitively, classification based on optical imagery remains a complex task, featuring diverse special cases and subtleties. As it can not be guaranteed that all operators who will work with the support system will have had adequate lectures before, it was decided to develop an online help system to be included with the next release, KEOD 3.0. Although there is a printed user manual, this solution is probably suboptimal because the system is used in CICs which are mostly rather dark. This circumstance hinders the use of paper-based documentation. Therefore, a special ergonomically designed online help system has been implemented and an empirical evaluation of both the online help and the printed manual under realistic circumstances took place before inclusion of the online help was finally recommended. The experimentation campaign also provided hints on optimization potential.

5.1 Functionality of the online help

The online help allows accessing all help topics without leaving the support system. The support system, its process states and all necessary operation procedures are illustrated. Topics can be chosen within the context of the current process state, so that information is presented matching the actual work step. In order to prevent users from getting lost in the hypertext environment of the online help, a clear navigation concept has been designed, featuring a clearly arranged overview of topics, position-fixing and possible next steps visualization. Because the online help must satisfy the needs of users with different levels of experience, access to desired information is possible in multiple ways, allowing each operator to choose a preferred way of his own. One of the ways is a search function.

Tool tips are minimal invasive. They provide short help texts close to the positions of functionalities, invoked automatically when the mouse pointer remains over a component for a predefined amount of time. Their advantage is that they can appear without significant change to the GUI. Target audience is inexperienced users and users who use the system merely sporadically. Tool tips are system initiated and their appearance is independent from being needed. Because experienced operators might find them annoying, it is possible to disable them.

The main help component consists of detailed help texts and illustrations. It can be invoked in different ways. The F1 key, as in many other programs, opens the help function. It can be closed using the F1 key, too, to allow quick switching. The F2 key opens the online help taking into account process state and mouse position and directly jumps to the corresponding page. In addition, there is a button for invoking the help function. The main help component features a GUI with two columns (see Figure 6). In the left column, there are different means for navigation; the right column contains the actual content.

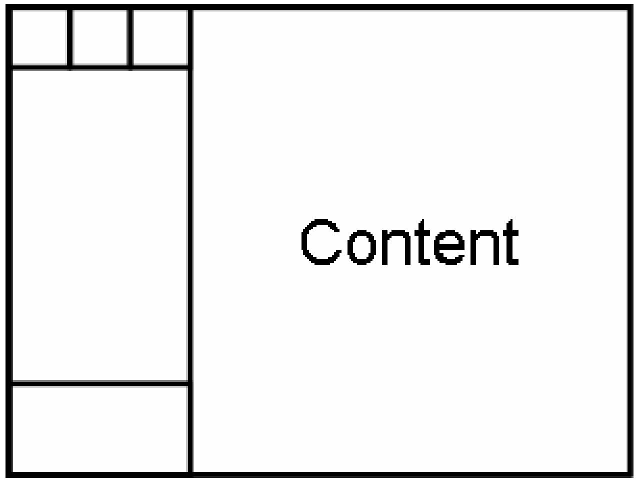

Figure 6: GUI layout of the online help

Access and navigation components are placed in the upper left. It can be chosen among a table of contents, a keyword index and a search function. The content below changes in accordance. If the table of contents is chosen, a tree view appears. A currently shown page is highlighted within the tree to ease orientation. Operators get an overview and can assess the extent of the help. The keyword index presents a listing of typical keywords in alphabetical order and allows directly invoking help pages with the keyword being highlighted in the content. The search function results in a list of hits with links to corresponding help pages to choose from. In the lower left browser like navigation is possible with back and ahead buttons.

In addition to the regular help pages, there are some special pages. After the first invocation of the online help, a page giving a scarce overview and explaining the specifics of this particular online help system appears. Another special page for quick introduction scarcely explains functionality and organization of the support system, addressing those operators who did not use it for quite a while. Another special page deals with the special features of the online help.

5.2 Evaluation of the online help

The experimentation campaign took place under realistic circumstances onboard German frigate Bremen (F 207) in the North Sea in April 2006. Test persons were divided into two groups who worked with the support system for eight consecutive days. Group 1 had access solely to the online help, whereas group 2 had access solely to the printed manual. It was tried to get two homogenous groups in order to prevent bias due to test persons who have significantly different levels of experience in optical classification. Both groups got an introduction to the support system together to make sure they get the same standard of knowledge. Afterwards subjects worked individually in order to get to know the system and its complete functionality. In the following days, they got tasks every day, where they had to classify targets using the support system. Subsequent to each session, test persons filled questionnaires. The second part with text questions was only asked for on the first and on the last day. On the days in between only the ZEIS scale had to be filled. In addition to the questionnaire, there was a discussion with the experimenter to find out if there were conspicuities. The intention of this course of action was to find out whether there were any differences in how subjects worked and got along with the system.

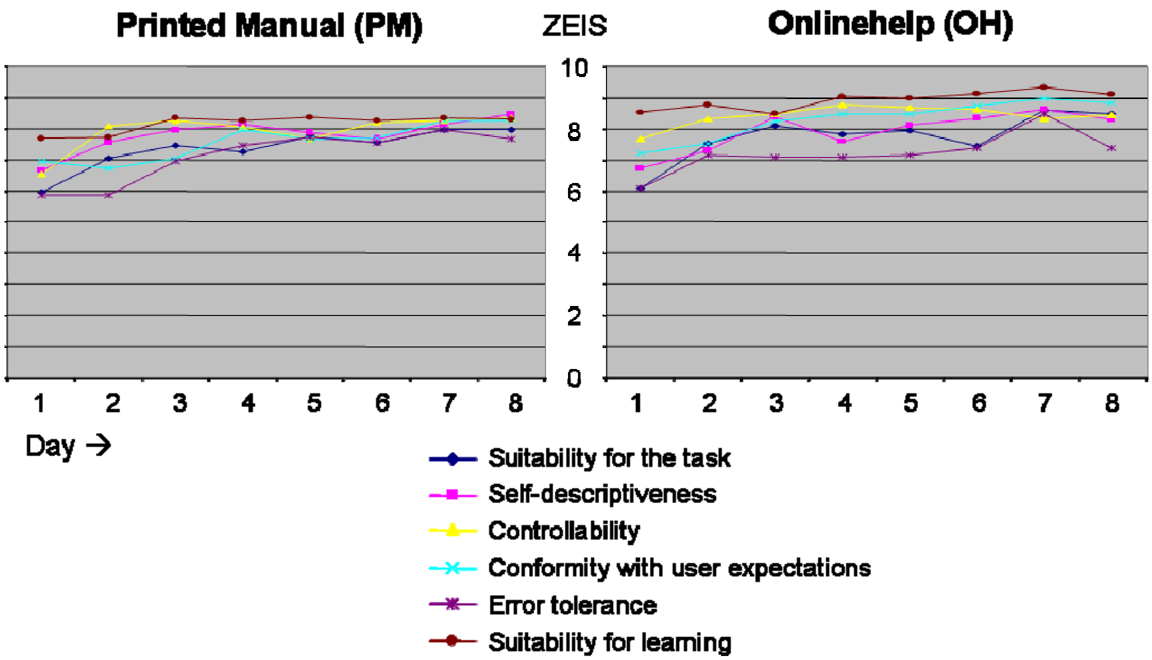

Figure 7: Arithmetic means of the two groups

Arithmetic means were calculated for the two groups for all rated criteria over the eight consecutive days. Figure 7 shows time on the x-axis and arithmetic means on the y-axis. Learning curves arise from all considered criteria. Thereby absolute numbers are not important and not meaningful, due to the very limited number of subjects. Because the experiments took place under realistic circumstances in the midst of maneuvers, only five subjects per group could participate over the whole experimentation period. Although statistics would benefit from more participants, realistic circumstances were considered way more important. However, valuations can be derived from the graphics. Values climbed in the first days and then remained at a relatively constant level. The group using the online help rated the criteria predominantly somewhat more positive.

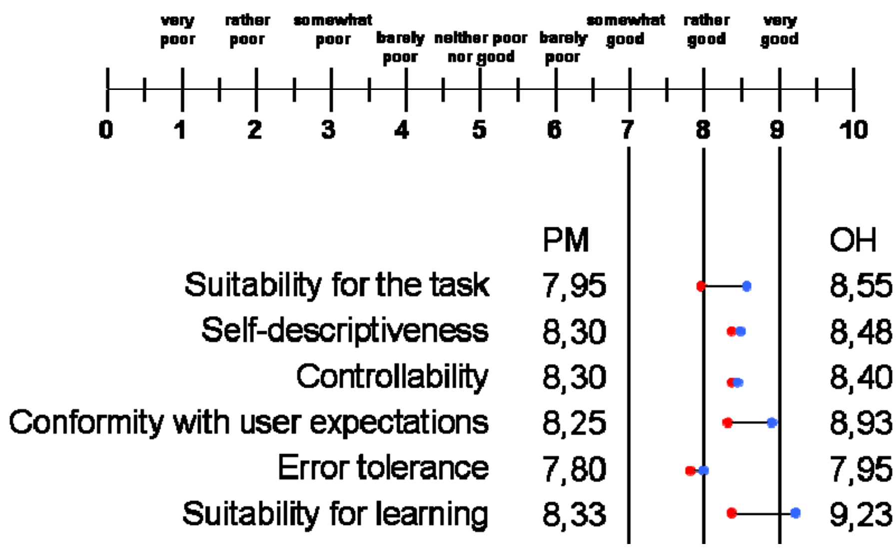

Figure 8: Arithmetic means of last two runs

Figure 8 shows the ZEIS scale in the upper part and the arithmetic means in the lower part. The red points represent the group using printed manuals and the blue points represent the group using the online help. Again precise values are not of importance, because merely tendencies shall be deduced. In general it can be stated that all subjects were satisfied with the system, because all of them chose rather good and better. The values for both groups do not differ significantly. Concerning suitability for the task, conformity with user expectations and suitability for learning the group with the online help rated slightly better with the other criteria nearly identical.

The results of linear regression are presented in Figure 9. It is clearly cognizable that all lines have positive gradients. This means, both groups were successfully learning over the experimentation period. The group with online help was partly somewhat more successful.

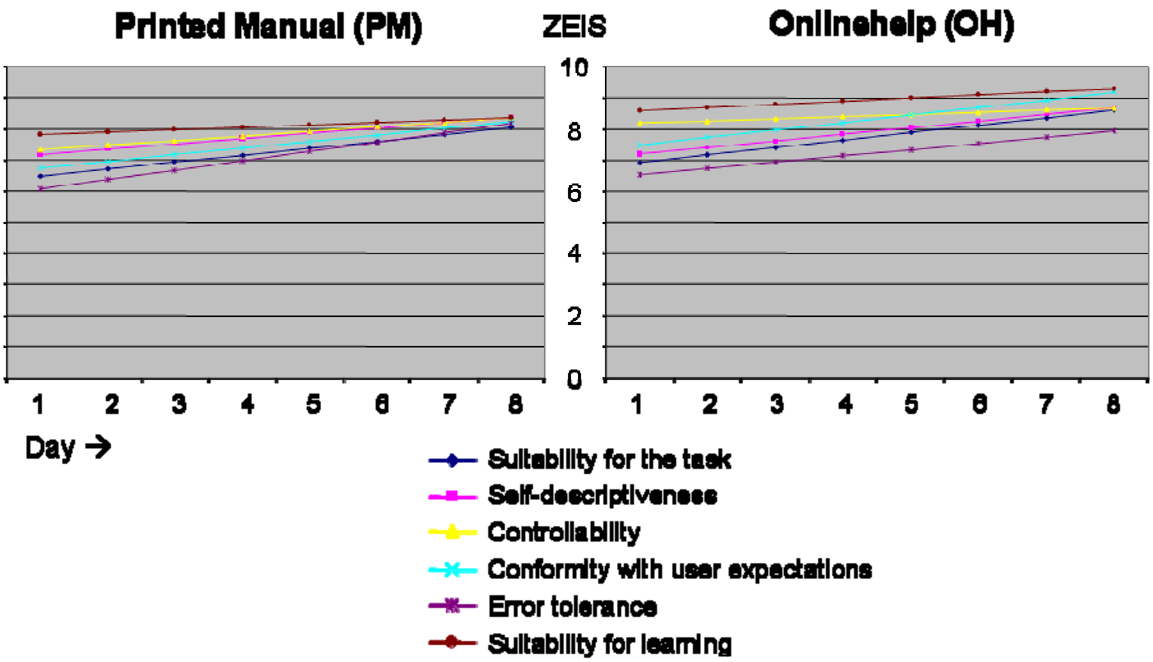

Figure 9: Linear regression of arithmetic means

When combining these results with the arguments brought forward in favor of the online help above, it can be concluded that the support system would in fact benefit from adding the online help. Consequently it will be part of the next release.

6. UNIFIL NAVOPS

The United Nations Interim Force in Lebanon, or UNIFIL, was created by the United Nations in 1978. Following the cease-fire ending the 2006 hostilities, the mission was enlarged in accordance with United Nations Security Council Resolution 1701 [UNSCR 1701, 2006], including a naval component to assist the Lebanese navy in securing the Lebanese coast and prevent arms smuggling.

The German navy provides a total of eight vessels to this naval operation, seven of them dispose of electro-optical sensors. In order to ease the recognition of unknown surface objects and to collect imagery to be used for database updates, it was decided to equip these vessels provisionally with KEOD 2.0 support systems. The deployment was declared a test, so the authors had the chance to distribute questionnaires with the system to get more feedback about how it is used. So far, returned questionnaires arrived from task group tender Frankfurt am Main (A 1412), fast patrol boats S74 Nerz (P 6124), S77 Dachs (P 6127), S78 Ozelot (P 6128), and S80 Hyäne (P 6130), as well as frigate Mecklenburg-Vorpommern (F 218), which already returned to its home port at Wilhelmshaven. Mecklenburg-Vorpommern's support system was transferred to succeeding frigate Brandenburg (F 215). Brandenburg and frigate Karlsruhe (F 212) did not send any feedback yet. Altogether, 23 questionnaires have been returned so far.

According to the written and verbal reports received so far, it was easy for operators to learn how to use the system and get results of good quality with it. The responsible officers reported that the system, despite partially used without any briefing, was very helpful and that they look forward to getting it permanently. Unfortunately, some of the subjects found the two-level rating scale in the questionnaires not as easy. For security reasons, it was impossible to have an experimenter aboard. That is why merely from the text questions in the second part of the questionnaire results could be analyzed. Some of the most important outcomes are as follows:

- 65% of the subjects were of the opinion that the system includes all necessary functionality. The most mentioned point of criticism was that contours are not deduced automatically. This value is usually a lot better, when an experimenter has the chance to explain that contour deduction is too complex for automation given the abundance of different image qualities.
- 57% of the subjects were of the opinion that they did not have to perform any unnecessary steps. Many subjects stated that they find manually drawing the contour unnecessary.
- 62% of the subjects were of the opinion that the amount of work invested is appropriate for the results gained. Again it was criticized that contours have to be drawn manually.
- 87% of the subjects were of the opinion that they did not have to perform tasks that the system should do instead.
- 77% of the subjects stated that they did not have to input anything that the system should already know.
- 67% of the subjects were of the opinion that no workarounds and tricks were necessary to achieve desired results. Interpreting this value one should bear in mind that due to incomplete briefings not all functions of the system were familiar to all subjects.
- 87% of the subjects were of the opinion that all necessary information is available well arranged on the GUI.
- 87% of the subjects stated that they could always easily spot what to do next.
- 90% of the subjects were of the opinion that messages from the system were always comprehensible.
- 82% of the subjects stated that they never needed the help of colleagues or the manual to find out how to go on.
- 86% of the subjects were of the opinion that all steps are arranged in a suggestive sequence.
- All subjects stated that they could continue interrupted actions without any problems at any later time.
- All subjects stated that they could undo steps whenever necessary.
- 61% of the subjects stated that they did not notice any longer waiting times.

- All subjects were of the opinion that functions und menu items are always at the appropriate / expected position.
- 80% of the subjects were always sure that the system is still running when they had to wait for a moment.
- 70% of the subjects stated that they were never surprised by a reaction of the system. It is to keep in mind that not all subjects got an adequate briefing.
- 86% of the subjects were of the opinion that they could always repair the consequences of incorrect inputs with slight effort.
- 86% of the subjects stated that all necessary functions are available whenever needed.
- All subjects had the impression that they could explore the system by trial and error without any risk.

As indicated before, briefings were scarce due to tough time constraints. The online help described above is not part of the deployed version KEOD 2.0, because it was finished after the deadline for that version. The predominantly positive feedback, despite these circumstances, confirms once again, that the human-centered approach in fact leads to systems with adequate functionality and intuitive handling that are highly accepted and appreciated by operators.

7. Conclusion and outlook

Because of new types of missions accompanied by more sophisticated actors and sensors the work human decision makers have to perform onboard naval vessels is becoming significantly more demanding. Hence providing operators with adequate support is an essential requirement for 21st century naval C2 systems. Full automation is impossible because many of the tasks to be done feature eminently high complexity. Critical steps and final decisions must always be performed by human operators. But disencumbering them and appropriately helping them to create a correct understanding of the situation can make the difference between a catastrophe and doing exactly the right thing. According to the authors' approach relief can be achieved by improving the visualization of complex dynamic information and easing human system interaction.

While the workplace meant to support the overall tasks of naval C2 is still in the design phase, the support system for classification of surface targets based on electro-optical imagery has reached a deployable status. It will be officially deployed as soon as all bureaucratic hurdles are overcome. Provisionally deployed systems have proved that the system is of great benefit within the scope of UNIFIL naval operations. Version KEOD 3.0, that is currently being realized, will include new features, such as the online help, capability to classify non-military and unconventional vessels, as well as an operator library.

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