Design and Evaluation of an Image Analysis Tool supporting Naval Reconnaissance

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C2 Experimentation / C2 Assessment Tools & Metrics

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Abstract

Reconnaissance is one of the primary tasks of the German Navy and will also be one of the main tasks of the future weapon system Corvette K130. The drone „Marinedrohne" with it's two image generating optical and radar sensors is intended to fulfil this specific task as an essential system of the Corvette K130.

The goal was the design of an image analysis tool for the operators in the ship's command and control center supporting naval reconnaissance, assigned to analyze the drone's optical reconnaissance results. The support was realized in assisting the classification and identification of objects detected on images received by the drone's sensors.

Specific graphical user interfaces were realized and implemented in a simulation system with the required task oriented presentation of significant information. Experimental tests were conducted to evaluate the system and the acquired results were used for an optimization. The final system provides substantial support for image analysis, object classification and identification and allows an efficient handling of the tasks, supported by a generic concept, optimized graphical user interfaces as well as clear and guided operating sequences.

Introduction

The main task of the future weapon system Corvette K130 of the German Navy will be naval reconnaissance in cooperation with different units of the German Navy as well as with units of allied nations. The drone „Marinedrohne" will be an essential system of the Corvette K130 to fulfill this important task. It will be a platform independent, remotely controlled, and up to 6000 ft height variable deployable 1-ton helicopter reconnaissance system. The drone will be equipped with two major sensors. One sensor will be an Electric-Optical sensor (EO) and the other one an Inverse Synthetic Aperture Radar sensor (ISAR). The combination of both sensors shall ensure the definite identification of objects beyond the horizon of the ship based sensors, even during bad optical conditions.

First of all the optical results of reconnaissance by the drone will be available as raw material like pictures or sequences of pictures and their substantial parts of information will have to be extracted by the operators to ensure the definite identification of the object. These will be information, which can be identified as details on the images and have to be detected and classified by the operator using supporting tools. Afterwards it has to be transferred into the digital structure of the combat direction system (CDS) of the Corvette K130 to make it available for all operators in the command and control center. This process should happen without a loss of time or content, or falsification of content (BMVg, 1998). At present it does not seem to be possible to design this process fully automatically. Therefore the task related support of the operator for his relief as well as the increase of safety for planning, decision, and action is of great importance. The basis for the support are operator related operating concepts and optimized ergonomic user interfaces under consideration of the specific operating sequences.

Design of the Image Analysis Tool

The design of the image analysis tool supporting naval reconnaissance reflects the analyzed influencing variables listed below:

- Specifications concerning the drone „Marinedrohne“ and Corvette K130
- Available technologies for drones and Unmanned Aerial Vehicles (UAVs)
- Realized concepts of support systems for optical reconnaissance
- Opportunities for these specific tasks

On the basis of this influencing variables and the following general conditions:

- the „Marinedrohne“ as a helicopter drone provides images from fixed and moving positions,
- drone possesses two reconnaissance sensors (EO and ISAR),
- availability of algorithms for contour and mark or attribute comparison as supporting tools,
- and workplace design limited to a one display unit as user interface,

the design and realization of the support system happened by structuring the identification process and support system for the illustration of navy specific operating sequences during task processing.

During image and data analysis the operator has to bear relation to the drone controller concerning planning and execution of the mission as well as to the decision making command team concerning data transfer to the combat direction system (CDS) of the platform (Fig. 1).

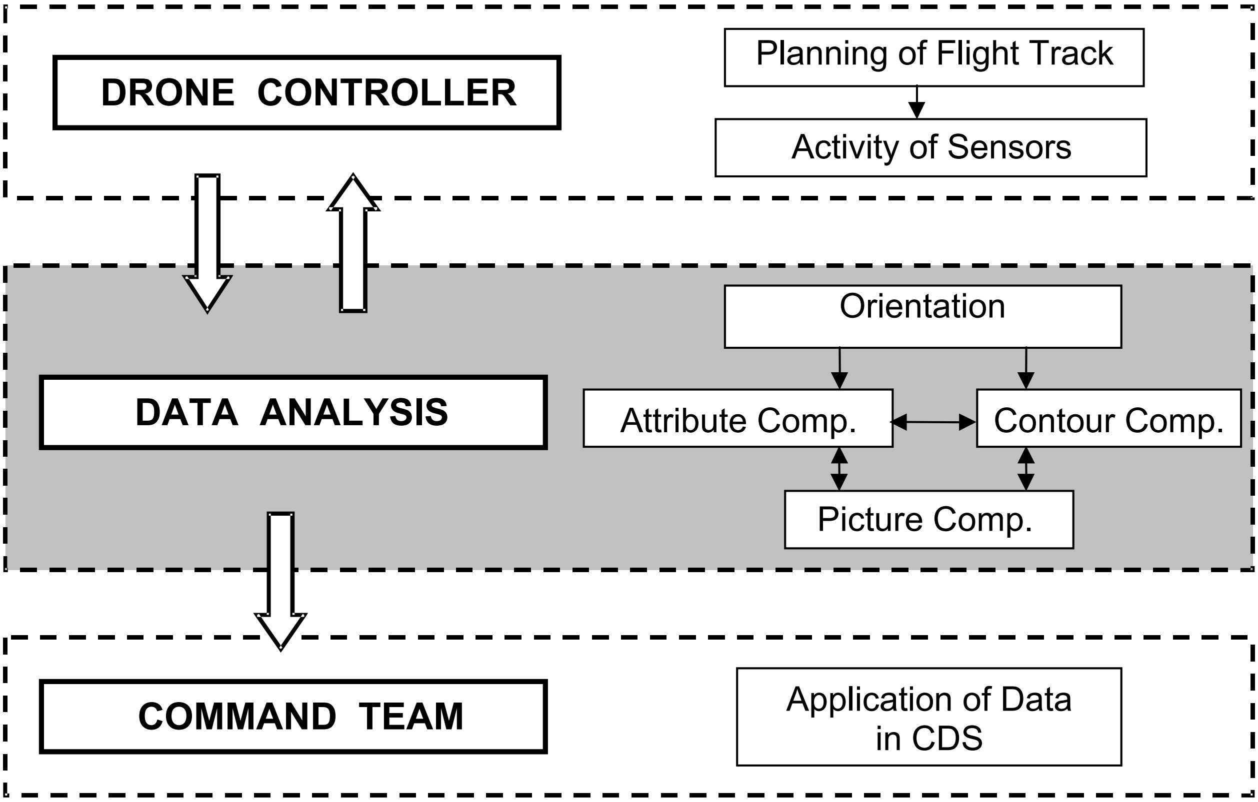

Fig. 1: Process Environment

The relation to the drone controller results from the instant data analysis being transmitted from the drone during a mission. On the one hand results of instant data analysis can affect the actual mission execution as well as the mission planning. On the other hand the retrospective data analysis of already conducted missions may affect the planning of future missions and the actual or future tactical use of the drone or the platform. The relation to the drone controller may necessitate a second display unit for surveillance of secondary information e.g. tactical situation display, general task survey and status readouts.

The reflection of the process environment (Fig. 1) leads to the process structure of Figure 2. The operator may select an actual or already conducted mission (MISSION SELECTION) out of the complete number of archived drone missions (DRONE MISSIONS). From this mission the operator selects the best qualified picture of the two sensors for the identification of an object and edits its brightness and contrast (PICTURE SELECTION and PROCESSING) for a better perceptibility. If the operator wants to use the support of the system, which are in detail algorithms of mark-, attribute-, and contour comparison, he first has to determine the spatial (3-D) orientation of the object (ORIENTATION). Afterwards the operator may select marks and/or attributes from a list and assign them to the object (MARK and ATTRIBUTE DETERMINATION) and/or mark the contour of the object as a polygon on the display (CONTOUR DETERMINATION) in any sequence. These inputs will be analyzed concerning the spatial relation of the assigned marks and attributes and the spatial coordinates of the contour with regard to the perspective of the object. The results are then compared with the data of known objects of an internal data base in consideration of the objects determined orientation.

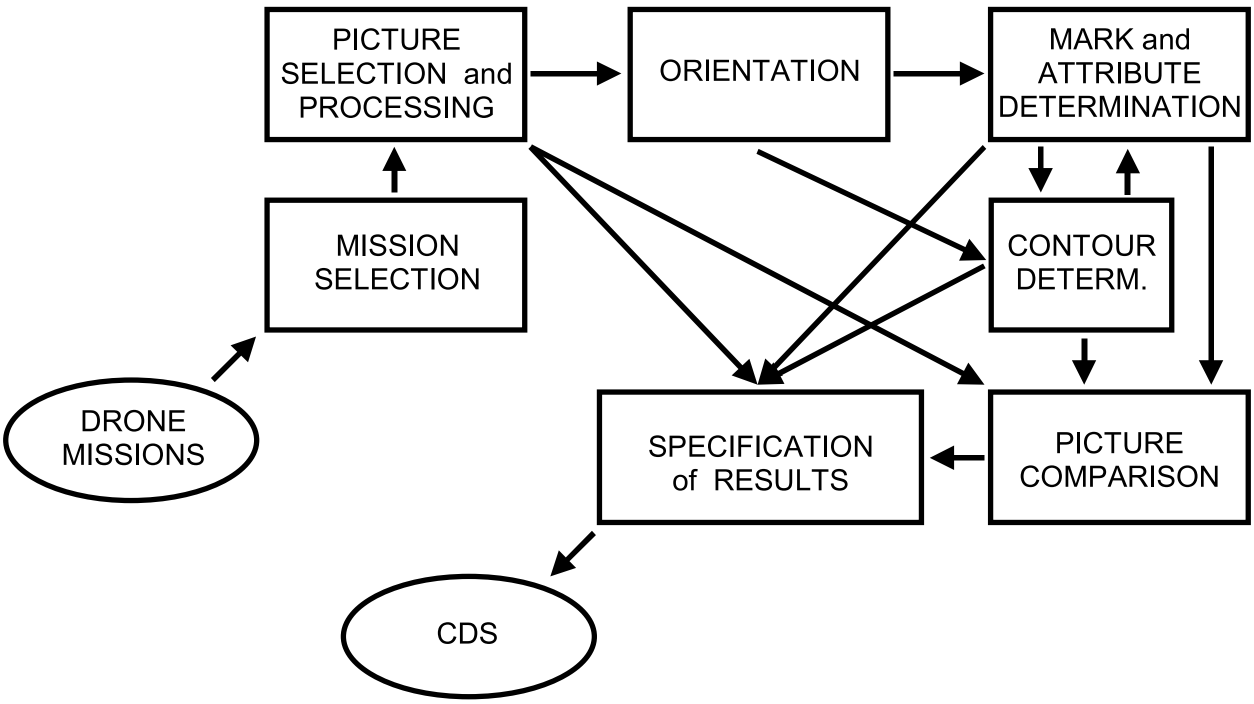

Fig. 2: Process Structure

The system will then list matching candidates in a readout, depending on the accordance concerning marks/ attributes and contour and the operator has the opportunity to conduct a visual comparison between available reference pictures of the candidates out of the data base and the object on the selected image (PICTURE COMPARISON). This enables the operator to exclude candidates of the readout or allocate a reference picture of a candidate to the object on the selected image for definite identification (SPECIFICATION of RESULTS). These results of reconnaissance can be analyzed and sent to the Combat Direction System (CDS) to make them available for all operators in the command and control center.

Realization of the Image Analysis Tool

The realization of a structured user support system with its graphical user interfaces resulted from the illustrated process structure (Fig. 2) by generating 5 definite process conditions and regarding process transitions (Fig. 3). The following list shows the functionality of the process conditions (Fig. 3) on the left side according to the functions of the described process structure (Fig. 2) on the right side.

Mission	Drone Missions
	Mission Selection
	Picture Selection and Processing
Orientate	Orientation
Marks	Marks and Attribute Determination
Contour	Contour Determination
Identity	Picture Comparison
	Specification of Results
	CDS

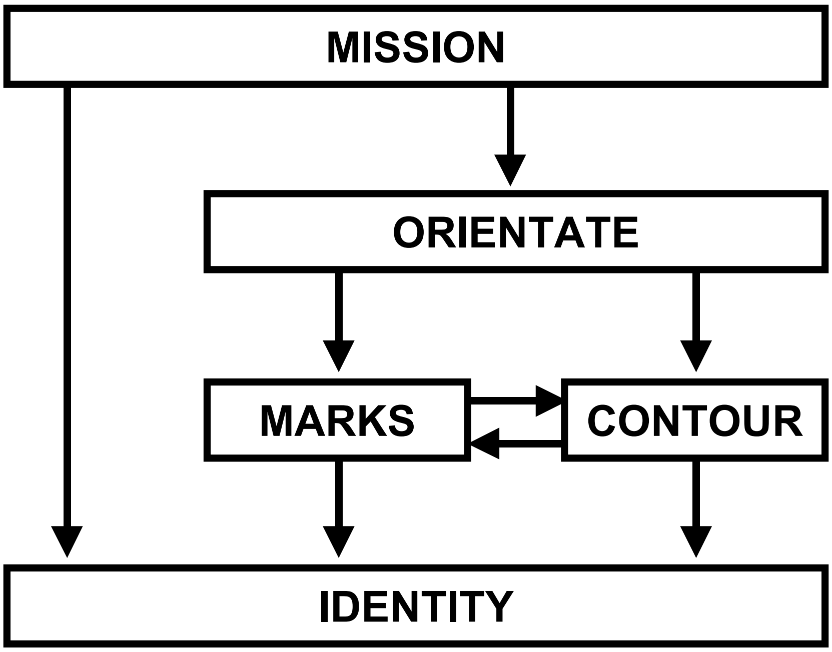

Fig. 3: Process conditions and transitions

The realised graphical user interfaces for the 5 listed process conditions include 4 functional main areas (Fig. 4). The control and status area over the whole width at the bottom of the display to control the user interface, display status values, and select sensor images. The data base area at the left side of the display is designed for navigation in the data base and to get access to the reference pictures. The picture area in the right half of the display represents up to two sensor pictures or a sensor picture and a reference picture from the data base. The disposal area between the data base sector and the picture sector is intended for free display of small reference pictures or input sections during individual process conditions (not used in Fig. 4). The functionality of these main areas are consistent during all 5 process conditions, except the function to search and select sensor images which is only possible and reasonable during the process condition MISSION.

Fig 4: Graphical User Interface during process condition MISSION

Evaluation of the Image Analysis Tool

The user support system with its graphical user interfaces was evaluated within experimental tests and optimized on the basis of the acquired results. For this reason a specific test procedure and an according questionnaire with a list of questions and a 2-level rating scale called ZEIS (Pitrella, 1989) following DIN EN ISO 9241 was conceptualized (DATech, 2001; DIN 66234, 1988; DIN EN ISO 9142-10, 1996). Regarding navy specific requirements experimental tests to evaluate the performance of the system as well as acceptance and utilization of the system by the operators were conducted with 10 subjects handling a specific navy scenario. In fact, all participants got a personal and standardized introduction to the system with its functions and supporting tools and observed an exemplary identification of an unknown object run by the investigator. Afterwards the navy officers had to work on a fictive but realistic scenario on their own. The results of these experimental tests indicated very good ratings from the subjects because of the definite process structure with its process conditions and operating sequences in combination with the supporting functionality of the system and the clear graphical user interfaces (Schweingruber & Brütting, 2003).

The ratings of the subjects on the first level of the 2-level rating scales concerning the criteria suitability for the task, self-descriptiveness, controllability, conformity with user expectations, and error tolerance with the descriptors „low“, „adequate“, and „high“ were made by the subjects as follows:

Suitability for the task	low	0	adequate	0	high	10
Self-descriptiveness	low	0	adequate	2	high	8
Controllability	low	0	adequate	0	high	10
Conformity with user expectations	low	0	adequate	0	high	10
Error tolerance	low	0	adequate	0	high	10

Tab.1: Ratingscale Results

Analyzing these results the support system and the user interfaces were evaluated by the subjects after task processing concerning the 5 criteria in general with „high“ apart from two ratings „adequate“ for self-descriptiveness. These results are to be judged before the background of a short introduction to the system of approximately half an hour, which is another hint to the simple appliance of the designed system and graphical user interfaces. Furthermore the subjects mentioned some potential details in the questionnaire to optimize the user support system in detail.

Fig. 5: Optimized graphical user interface during process condition IDENTITY

Analyzing the subjects inputs and implementing all reasonable improvements resulted in the realization of a suitable user support system with ergonomically optimized user interfaces and handling sequences enabling the operator to carry out a certain and quick identification of unknown objects in sensor pictures (Fig. 5).

Conclusion

The application of such a user support system on boats or ships of the German Navy during difficult missions can make it much easier to make that information and reconnaissance results available to the CDS which are essential to judge the tactical situation and support the tactical decision making (Schweingruber & Grandt, 2002).

This will increase capability and performance, especially in cooperation with other units of the German Navy as well as with units of allied nations. Furthermore the user support system has not been realized for a specific sensor or platform, which makes it also usable as a support tool for the identification of unknown objects in combination with any other sensor or any graphical material of an object, e.g. picture, photograph or facsimile. Therefrom the system can be used at any platform for any service.

References

BMVg (1998): *Taktisch-Technische Forderung (TTF) Marinedrohne, bordgestützt*. Bundesministerium der Verteidigung. Fü M II 4. Bonn.

DATech (2001): *Prüfhandbuch Gebrauchstauglichkeit - Leitfaden für die software-ergonomische Evaluierung von Software auf Grundlage von DIN EN ISO 9241*. Teil 10 und Teil 11. Version 3.0. DATech Deutsche Akkreditierungsstelle Technik e.V. Frankfurt a. M.

DIN 66234 (1988): *Teil 8 - Bildschirmarbeitsplätze, Grundsätze ergonomischer Dialoggestaltung*. Deutsches Institut für Normung e.V. Berlin.

DIN EN ISO 9142-10 (1996): *Ergonomic requirements for office work with visual display terminals (VDT's) – Part 10: Dialogue principles*. International Organization for Standardization. Genf.

Pitrella, F.D. (1989): *A Cognitive Model of the Internal Rating Process*. Forschungsinstitut für Anthropotechnik. FAT-Bericht Nr. 82. Wachtberg.

Schweingruber, J.; Grandt, M. (2002): *Human-Machine Interface for CCIS*. TTCP HUM TP-9. Human Factors Integration for Naval Systems. Annual Meeting & Workshop. Portsmouth/UK.

Schweingruber, J.; Brütting, M. (2003): *Ergonomisches Bedienkonzept für die Objektidentifizierung mit bildgebenden Sensoren*. FKIE-Bericht Nr. 58. Forschungsgesellschaft für Angewandte Naturwissenschaften e.V. (FGAN). FKIE. EFS. Wachtberg.