# Better Situational Awareness by "Cognitive Integration": Qualitative Change in the Diagnosis of Conditions and Process Control through near Real-Time Calculation and Prediction Navigational Hazards of Large and Complex Data Sets by Means of Fuzzy Logic and Expert Knowledge

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## Abstract

Since the natural (biological) performance limit of man is near or can be extended only in very long periods, is alone in new, computer-aided methods and techniques of process analysis and assess-ment of the opportunity to increase the reliability of integrated systems. In the following paper, a method is presented which is able to calculate and predict navigational dangers. NTM, the NAUTICAL TASK MANGER was developed in about 15 years. There are extensive knowledge and experience which justify the accuracy of the mathematical solutions. The use of *fuzzy logic* to describe the quality (risk to the fulfillment of navigational tasks) is well suited for complex,dynamic and uncertain processes. The validity of the algorithms, the accuracy of rules and the precision of the expert knowledge were proved by means of practical tests. The NTM-assistant has acquired his knowledge of about 65000 calculations of practical cases and has proved the validity of his reviews as part of an usability study and practical tests (ship and simulator). It could be demonstrated that the grounding of the "Costa Concordia" could be predicted at least 10 minutes before the event. NTM calculates from the existing data sets of a conventional integrated navigation system, the current level of risk of partial processes of navigation, may indicate the hazard curve graphically, perform a trend calculation of the probable development, assess the reasons for the current states, give first recommendations and in a simulation status, the effects of recommended actions. The NTM delivers with this "diagnosis at a glance" a complex image of the real situation with the most important decision-making process variables that provide the conditions for intelligent process control in safety-critical situations. Regarding to ship navigation process means that : control of the "*movement*" (movement as a state change over time) of the vessel from the starting point to the destination port. It uses the set of principles, procedures and methods for receiving, processing, storage and disclosure of information between the needed elements for the process control in their way, appropriate selection and rational combination for process control. The control process has to satisfy under the environment and the function-related stresses and taking into account the technical characteristics of the equipment and the mental and physical factors influencing the manpower for a specified period of time and in a given space with the requirements of reliability (with the required qualities: efficiency and safety), and thus to preserve the stability of the system. In a process control by means of man-machine systems, which is characterized by information and communication as well as knowledge and experience, the research is not confined to academic institutions. The resulting obligation arises in particular from the causes of the grounding of the cruise ship "Costa Concordia". Such human errors can be reduced if weaknesses in human performance can be balanced with modern information processing solutions.

## 1. Introduction

Who at first creates the transition from the functional-technical presentation of the information on their valuation, that is able to implement the semantic aspect of information processing into methods and procedures for diagnosis and control of dynamic processes, determines the future for a long time.
In the traditional sense COGNITION is the "***ability to perceive and targeted interpretation of the life-world.***"

"The cognitive processes relate to the information recording of man by the perception, the assessment of what is perceived, the storage of what is perceived in the memory and the interconnection of these memory contents to a **system of knowledge.**" (Source : http://wirtschaftslexikon.gabler.de/Definition/kognition.html#definition)

This system of knowledge is a prerequisite for the **design of the "life world"**; this is the design of the **"marine life world"**, in particular the design of ship management / navigation processes. Since the natural (biological) performance limit of man is near or can be extended only in very long periods, is alone in new, computer-aided methods and techniques of process analysis and assessment of the opportunity to increase the reliability of integrated systems.

In the following paper, a method is presented which is able to **calculate and predict navigational dangers**.

**NTM, the NAUTICAL TASK MANGER was developed in about 15 years.** There are **extensive knowledge** and experience which justify the accuracy of the mathematical solutions. The use of ***fuzzy logic*** to describe the quality (risk to the fulfillment of navigational tasks) is well suited for complex, dynamic and uncertain processes. Their disadvantage is that the validity of the algorithms, the accuracy of rules and the precision of the expert knowledge can only be proved by means of practical tests. The NTM was undergone this test. The NTM-assistant has acquired his knowledge of about 65000 calculations of practical cases and has proved the validity of his reviews as part of an usability study and practical tests (ship and Simulator) / 1 / Fig.1). It was always implemented without any problems in the existing hardware on board or in a simulator (Integrated Systems)

**It could be demonstrated that the grounding of the "Costa Concordia" could be predicted at least 10 minutes before the event** (with the help of process-typical mathematical methods (fuzzy logic) and expert knowledge).

NTM calculates from the existing data sets of a conventional integrated navigation system, the current level of risk of partial processes of navigation, may indicate the hazard curve graphically, perform a trend calculation of the probable development, assess the reasons for the current states, give first recommendations and in a simulation status, the effects of recommended actions. App- lications for use on board, the competence determination on the simulator and the evaluation of the situation in a Fleet Operation Center are available as simple software programs.

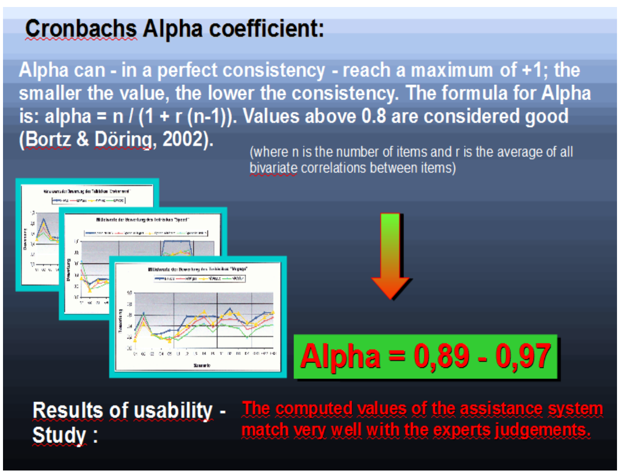


Figure 1 : Test results of the usability study (2008)

## 2. Solution approach and example "Costa Concordia"

*"The technology is great when it works,"* writes Lützhöft 2004 in her dissertation "Maritime Technology and Human Integration on the Ship's Bridge" and criticized continued: *"Even in most ostensibly integrated systems, human **operators still must perform integration work**. ... In short, technology alone cannot solve the problems that technology created."*

That's not the problem with the grounding of the "**Costa Concordia**". Here the captain has obviously seen too long from the bridge window. In fact, the integrated navigation system contained the necessary output data in order to make a reliable diagnosis situation. **The installed software with their manner of presentation but did not allow this and so got the ship and its passengers in the disaster.** The subsequent reconstruction of the data and their possible pre-processing and evaluation were as shown in the further, can detect and prevent the accident in time. To take such assistance systems on board or to test a trial basis in simulators **until today unfortunately rejected.**

Navigators can before beginning a chain of events neither their origin nor the current state, nor its anticipated further assess reality accurately enough. Data / information will be included on their own terms. They must seem to him only sufficiently familiar, confirm his experience and fit into the individual model concepts. For the selection and evaluation process time is required. Could you shorten the time for viewing (and operation) of displays, the situation "at a glance" record (ie including their evaluation), would the pronounced and entitled by Paul Morgan / Carnival Corporation & plc criticism "*... he needs to look out of the window more and spend less time looking at the equipment. ...* "already be obsolete.

In the application of methods of investigation of the causes of the grounding, which focus on the **determination of the lack of information and their regulating effects of actions**, leads to preven-tion-oriented insights / 2 /. The accident actually very easy to avoid was not caused by an oversupply of information, but by the **absence of a regulatory action situation assessment** (with calculation of the height of current and anticipated danger).

This conclusion can be reached in many other marine casualties. In case of serious disturbances in the ship's command must be sought primarily for the causes of the **interaction or communication failures of the man-machine system**.

**Always undergoes the right decision formative *cognitive process*** (cognition "ability to perceive and purposeful interpretation of the life-world"), **a four-time error** :

1. MALFUNCTION at the **realistic figure**
2. MALFUNCTION by **faulty interpretation of reality**
3. MALFUNCTION regarding **individual objective** and
4. MALFUNCTION by **defective formation of differences** between desired and actual as the **triggering action regulating pulse** for the nature and timing of the decision.

Due to the limitations of human perception only a part of the presented is received. The image of the situation, the mental model formation, has its limits. The selection and evaluation of signals / data / information contributes subjective character and is one of the backgrounds for human behavior and actions.

Actuality, clarity, structure, situation specificity, task-centeredness, simplicity, informative value, accuracy and quality requirements form requirements for the quality of the image of the mirrored situation in the user's brain (inner model). Accuracy and speed of comparison operations between the depicted situation and the planned objectives of a partial task of navigation form basis of action regulation. By means of evaluation of the signals / data / information system-immanent objective process parameters change in subjective, qualitative state action regulating parameters of individual processes. The focusing of human attention to only one part of reality, usually selected by navigator , further reduced the presented region.

**Man alone is not able to reflect complex, dynamic, random and exponential processes realistically, and above all to predict.** He "worked out" as his decision background images of reality that correspond to his wishes and hopes, his expectations and his knowledge. This is an inherent human weakness and shows up at wrong action causes noticeable in a distinct manner.

Result of the **STATE DIAGNOSTICS** is the **identification and evaluation** of deviations between SETPOINT and IS, ie the estimation of the **HEIGHT OF DANGER** for the achievement of planned (set) GOALS. In case of differences between subjective and objective evaluations, the result of the diagnosis is always a STATEMENT about the current quality of task performance.

Early, foresighted identification of possible dangers with action-regulating effect of control measu-res decisively determine the qualitative condition (quality) of a process and as a result the **compe-tence** of the actor. **DANGER** is a characteristic of a process or sequence that has the potential to cause a loss in itself. The **height of danger** in a process determines the **quality.**

The experience-based and anticipation-based assessment generate meanings of system states that have lasting effects for **situation awareness**. Ratings are made on the basis of target-performance comparisons. Their differen-ces regulate the actions. If the system states recognized only incompletely in its meaning, the man insists nonetheless on its expected rating. Meeting information, do not support the initial diagnosis, the diagnosis is not corrected usually, but the information is discarded. It takes a long time or happens not often that image / model and reality the same. Human and ma-chine form the reality from different. A third dimension is added when the current subjective model of reality is compared with their own ideas about safety and risk. This comparison, the magnitude of the difference between planned state and target position and timeliness are responsible for decision-making and action regulation, for the type, size and time of process control measures to adequately process intervention points.

The most realistic "internal model" of a situation or a situation sequence determines the nature and timing of actions (action regulation process interventions). Incomplete, inaccurate or false models arise as a result of deficiencies in information processing. Lens not existing, false or incorrect information processed lead to wrong actions. Improper action are not adapted to the situation, time and place inappropriate behaviors with which the predeter-mined and desired operational objective contrary to the intention can not be achieved. The inap-propriate behavior is the user at the moment of execution unaware. Not into the model matching conditions remain intentionally disregarded. The user is not willing to change his plan of action quickly, even if the rules would require it.

The attribution of errors to personnel or equipment in the form of so-called human or mechanical error "*... is based on a false perception of the structure of man-machine systems."* The *"... transformation of the process via the process control system to the mental model of the operator "is" characterized by a plurality of deformations in the multi-level image". ...* "*In many computer-based process control systems "exist in addition to many levels of action and action regulation processes, which have by inadequate interaction design variety of inconsistencies between mental model, system model of the process control system and process model."* / 3 /

In connection with the investigation of the causes of the grounding of the Italian cruise ship "Costa Concordia" is encountered in the official investigation report on the attestation, „*... that Costa Concordia resulted in full compliance with all the SOLAS applicable regulations, matching therefore all the related requirements once she left the Civitavecchia Port on the evening of the 13 January 2012.*" / 4 /

The assignment of an erroneous behavior of nautical personnel is the result:

*„It is worth to summarize that the human element is the root cause in the Costa Concordia casualty, both for the first phase of it, which means the unconventional action which caused the contact with the rocks, and for the general emergency management. It should be also noted that the Costa Concordia is, first of all, a tragedy, and that the 32 dead people and the 157 injured, depended only by the above mentioned human element, which shows poor proficiency by key crewmembers. ....*"/ 4/

Without doubt in this case, people have failed: in the first place, the captain and the officers. And second ? Surely the developers of technical systems. It seems so simple, to pass the island very close and to avoid the contact of a rock. And why is it still happening? Because no one, no officer, no technique has drawn attention to the state of the growing danger.

**There was nothing that has sent a action regulating impulse in any way. How can this happen at the high range of potentially available data?**

**People will continue to make errors** that occur because people just working with their properties: because they believe, hope, expect, modify, select, ....

If you look at the first of the mentioned shortcomings in this context, **interference in the realistic figure**, so this refers to the FIGURE of the DANGER of the controlled sub-processes: here keeping the height of the dangers of grounding and keeping the planned track, the fact hinds the Navigator to fulfill his task in the nautical set **"standards or quality measure of good seamanship."**
The second of the mentioned disorders, the **erroneous interpretation of the traditional image of situations** is derived from the first, and can only occur when the selection and interpretation of signals, data, information will remain in humans characterized by its performance characteristics and evaluations. With an objective calculation of the hazard and its optical presentation and retrievable causes an erroneous interpretation is largely excluded.
The third fault, the **quality of the individual objectives**, is influenced from two points of view: first, the quality of vision depends on the knowledge and experience of the individual from himself. There are very complex opportunities for positive influence on the quality. The simulation of desired situations of varying complexity, dynamics and randomness with targeted training effects is just one of them. An improvement in the quality of objective can of course also be achieved through the extraction of expert knowledge and its use in assistance systems. The collection, processing and use of data will become part of the most important tasks of a modern process control in practice and simulation.
The fourth fault is caused by the preceding disorders and leads to **defects in the formation of differences between desired and actual**. It forms the background of the decisive action regulation and can be reduced so that the objectives quantified by expert knowledge and the reality largely objectively shown (the level of risk) (here **fuzzy algorithms**) are compared by means of specific mathematical techniques.

New solutions must have the same decision behavior like the user (expert), if a **new quality** of pro-cess control shall be achieved. They do not aim to describe the controlled system as realistically as possible. They have to work according ***"Detect - Rate - Decide"*** - model behavior of experts in danger diagnosis. Classic "sharp" mathematical method can not solve the problems.
The aim is to depict the chain links **RECOGNIZE and EVALUATE** mathematically and to represent the result of comparison operations graphically. Requirements are, inter alia, sufficient process knowledge, establishing criteria for "good seamanship" (expert knowledge), process adequate mathematical solutions and effective graphs for "diagnosis" of the current, operational process risks.
Risk must be understood as an opportunity and as a design factor of good seamanship. However, this requires the specification of qualitative task goals and the accurate and timely diagnosis of process states (with the representation of the level of danger for the fulfillment of tasks). To produce the desired non-linear behavior of the effects of the input variables and to implement the escalation of the time and pressure action mathematically corresponding inference strategies had to be developed.

The solution was named "***difference quotient of the membership functions of two fuzzy sets***":

$$\text{Danger (G)} = \frac{\text{State of maximum danger - state of allowed danger (good sms)}}{\text{State of maximum danger - state of current danger}}$$

Since the physically determined events of different dimension and importance (nm, min, degree / min, etc.) the states of maximum, of allowed and of actual danger must be defined in their "human interpretation" (eg "more or less dangerous") and to processed for a qualitative statement (in the form of language).

This was achieved by the combination of "fuzzy" mathematical solution methods and expertise.

Putting the membership function of the state of maximum risk (eg cpa <= 0.1 nm), with $\mu = 1.0$ and the "good seamanship" (eg cpa = 0.8 nm) with $\mu = 0.5$ (is total security unavailable in shipping) , you can set all current membership functions depending on the size of the measured / calculated cpa in an "input grid" between $\mu = 0.0$ and 1.0. In this manner, e.g. for the encounter parameters you get appropriate calculation methods, providing comparable "risk statements" (eg the passing distance is dangerously close, the target passes soon, the distance is quite low).
The mathematical model processes each parameter according to the rules of good seamanship by the known gravity method followed by a defuzzification to an aggregated hazard statement: eg "**HIGH DANGER**" and labels this condition diagnosis with a "therapeutic" part eg "***Last minute maneuver***", which was derived from the Collision Avoidance Regulations : For the difference quotient of the membership functions of the fuzzy sets "**passing distance**" is obtained:

$$\mathbf{gef_{cpa}} = \frac{1-\mu_{gs}}{1-\mu_{ac}} * wf_{cpa}$$

($wf_{cpa}$ is a parameter weighting factor )

By aggregating of the calculated parameter statements can be obtained between "***no risk***" and "***high-risk***" of the current situation of the encounter:

$$\mathbf{gef_{targ\ act}} = wf_{targ} * (gef_{cpa} + geft_{tcpa} + gef_{dis}) / (wf_{cpa} + wf_{tcpa} + wf_{dis})$$

$$0 <= gef_{targ\ act} <= 1$$

Each "sharp" state of the variables can be transformed into "fuzzy" states. The physically accurate measurement of the parameters and their mathematical treatment according to "classical" mathematical method as well as the application "fuzzy", based on expert knowledge of mathema-tical methods allow human-oriented presen-tation of information.
A quick, task-oriented, informative modeling and non-

linear behavior is possible. A detailed mathematical and physical description eg the hydrodynamic processes of optionally large dynamic complexity and randomness is not required for this part of the diagnosis situation. Linguistic expressions simplify understanding, eg for the description of the causes of different input parameters.

An adaptation to other conditions is achieved by changes of membership functions, input grid modifications and weighting factors. For the calculation of the height of danger for the fulfillment of nautical tasks the advantages of fuzzy logic can be used extensively in conjunction with expert knowledge and within the meaning of the cognitive processes occurring in the head of the navigator.

### 3. Assistance system NTM (Nautical Task Manager)

In addition, a solution will be presented on the basis of the accident of the "CC", which relies exclusively on the information present in the INS or this preprocessed. For the period from 21:30 to 21:45 (time of grounding) a state analysis should be performed based on the following **requirements and characteristics of the assistance system NTM** :

1. The state analysis must be task-oriented, ie the analysis must be able to rely on a task-oriented structure of the navigational process.
2. There must be process state indicators, with which the process can be mapped largely real and described mathematically.
3. The process indicators must to be merged into a statement about the quality of the performance of a partial task.
4. The causes of a partial process state must be presented and evaluated.
5. The future development of partial processes must be able to be predicted (ability to foresight / good seamanship).
6. First recommendations according to the partial task structure and their states must be given.
7. The complexity and the degree of control of partial processes must be specified.
8. It must be possible a comparison between the current process states and the quality of good seamanship.
9. All measurement results must be graphically displayed and stimulate the regulation of actions.
10. The relevant current process states must be classified and displayed in operating areas depending on the level of risk for the fulfillment of tasks.

**The critical lack of current systems came to light when answering the following questions!**

QUESTION 1: In what quality I fulfill my duties at the time and does exist some risk in the sub-processes and if so, how much is it ?
QUESTION 2: How do the risks have actually developed in the last few minutes?
QUESTION 3: How will it go in the next few minutes, if I do nothing?
QUESTION 4: What are the real and calculated data, the evaluation based on?
QUESTION 5: What are the reasons for the current state of the dangers?
QUESTION 6: What is the complexity of the processes and can I still manage?
QUESTION 7: What can I do and what effects produce my actions on the process states? (feedback as a simulation)
QUESTION 8: What is my "inner model" and how long I've needed for its formation?

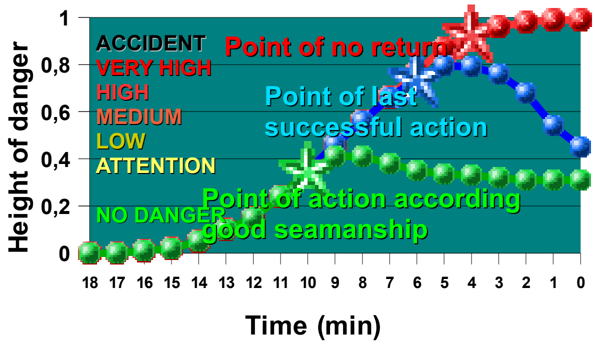


Figure 2: Operational areas and action points of NTM

The NTM - assistant ***"knows"*** in which operation area a partial process is and how big is the chance to solve the problem (see Fig. 2). He knows at what point a reasonable action can show what effect.
**Crucial to the action regulation is knowledge of the navigator regarding current altitude of the danger** to the fulfillment of the quality of the partial nautical tasks.

**Statement :** A task-structured, dependent upon operating conditions, technically plausible, holistic, qualitative picture of the ship's navigation is enabled by means of process indicators.

A distinction is made between ***design indicators*** and ***impact indicators***. While the design indicators representing the suggestible quality parameters, the impact indicators express primarily the operational process conditions, under which occurs the navigation. Both groups of indicators form a unity, because this is necessary for the definition and standardization of process conditions and for the calculation of the quality of services provided under these conditions.
The total package of **NTM (Nautical Task Manager)** also includes the partial processes "Anti-Collision" and "Environment Impacts". For "CC" was the course of the design indicators "Anti-grounding" and "Track-Keeping" up to the grounding of particular interest. Another program package deals similarly with the so-called "effect indicators" (4 complex indica-tors with process-specific input parameters) (see Fig. 3).

By means of the **“diagnosis at a glance”** the bridge officer may not only recognize the current **"operating area"** immediately but also query the **development in the last few minutes** as well as **predict the future development** in the next few minutes.

With three evaluations of situations:

- ACTUAL STATE OF THE PERFORMANCE OF A PARTIAL TASK
- PREVIOUS DEVELOPMENT OF PROCESS
- PREDICTION OF PROCESS DEVELOPMENT IN LACK OF ACTS

can already be met basic needs of the diagnostic process.

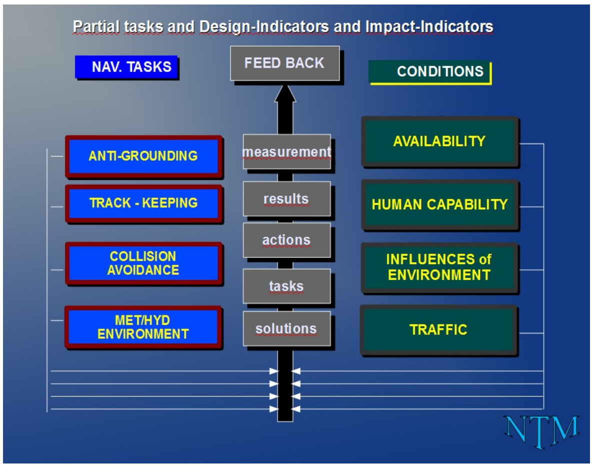


Figure 3: Design and impact indicators of NTM as parameters of the process state description

In the evaluation of dangers to the tasks in "ANTI - GROUNDING" and in "KEEPING TRACK" answers to the following professional issues of the navigator are included :

1.Does the recent speed comply with the available manoeuvring area under consideration of the planned safety contour ?

2.Does the recent speed complywith the conditions in limited and unlimetd waters ?

3.Is the total draft Increasing of the ship by internal and external influences regarding the available depth of water under the keel to answer yet ?

4.Can be tolerated the cross track distance with respect to the theoretically required, planned and tested track width in compliance with the current operating status?

5.What size is the available maneuver area? How to assess the maneuver area currently required?

6.What is the current water depth ? How is to assess the maximum possible draft including a fixed UKCL

The assistance system NTM is capable of this and other questions to be translated from existing data / information in the **"language of the Navigator"** (supporting the "cognitive integration"). The processes are not only represented but rated. **With this capability, it provides the necessary action regulating signals !**
Back to Situation Analysis at 21:35. Of course, belongs to **production of "trust"** between Navigator and NTM assistant that he can query the **causes** of the condition ratings.

ANTI-GROUNDING
ratio recent/possible speed in available manoeuvring area: **190 %**
***„high dangerous speed in man. area“***
ratio total draft increase/depth below transducer : 0 %
*„no draft increase danger“*
ratio recent/critical speed (due squat): 0 %
*„no speed danger due squat“*
TRACK-KEEPING :
ratio xtd/TRL : 120 %
*„xtd near limit“*
ratio stopway/available manoeuvring area: **170 %**
***„high dangerousstopway/man. area “***
ratio water depth/max. draft+UKCl: 0 %
*„no depth/draft + UKCl danger“*

Finally, it must be examined in any remaining time as a precaution, how the recommendations affect the state development. A **"trial - error - method"** in the management of high-risk processes is excluded. **The simulation is well suited as a test method.** The recommended speed reduction to 9.9 knots results for 21:36 and thereafter the following state development (see fig. 4 and 5).

The **assistance system NTM** has supported the **"cognitive integration"** in the head of the navigator. For the **illustration of the situation** at 21:35 and the evaluation, the **NTM has required less than 15 s :**

The ship is located in the partial process Anti-Grounding (AGP) in the operating condition ***"VERY HIGH DANGER"***; the danger in this process has grown in the last few minutes and will continue to rise. The partial process Track-Keeping (TKP) is located in the operating state ***"ATTENTION"***. The performance of the tasks is in serious danger. Compared with the requirements of a "good seamanship" is found a ***"serious quality lack"*** in the AGP. The TKP is ***"just above limit"***. The complexity is in the AGP very small (***"very low complexity"***), the controllability therefore ***"very high"***. In the TKP the complexity is small (***"low complexity"***) and the controllability is mediocre (***"medium"***).
The indicator values in the partial process Anti-Grounding point out, that the current speed in the available maneuver area caused a great danger (***"high dangerous speed in manvrg area"***), that the draft increase is negligible compared to the water depth under the keel (***"no draft increase danger"***) and that of the current speed in comparison to the critical speed no risk arises by squat (***"no speed danger due squat"***).

In partial process Track-Keeping indicators show the following states: the current cross track distance is compared to planned / theoretical track width near limit (***"xtd near limit"***), the specific indicator has deteriorated further.
Also, the stopping distance available for the maneuvr. area is no longer sufficient (***"high dangerous stopway / man. area"***). From the maximum attainable depth including fixed keel clearance is due to the large water depth no danger ("***no depth / draft + UKCl danger"***).
The final question of the navigator after this condition analysis is: How will develop the processes further and what actions may be necessary?
The answer of the Assistant regarding partial task „Anti-Grounding“ is :
***If you don't change anything you will enter a very dangerous state of nautical task management in minute : 36***
This means that every effort must be made to get out of the "red operation area". The recent speed is too high.
The answer of the Assistant regarding partial task Track-Keeping is:
***If you don't change anything you will enter a very dangerous state of nautical task management in minute : 36***
In the next few minutes the whole concentration in this partial process must be placed on the dangerous track situation.
These conclusions are confirmed by the **recommen-dations** :

ANTI-GROUNDING : ***„possible spd in restricted manoeuvring area: 9.9 kts“***
***„recommended max.speed : 9.9 kts“***
TRACK - KEEPING : ***„keep attention for dangerous track situation !“***

The **total time** of the navigator for the receiving, selection, compilation, evaluation and derivation of actions is reduced by the Nautical Task Manager (NTM) **to less than 15 seconds**, which for the visual detection

of the current state and its development up to date :
< 1 sec.
of the causes :
< 10 sec.
of the development :
< 2 sec.
of the recommended actions and the simulation of effects :
< 2 sec.

The stated objective of realizing a new level of process control in that the NTM shows the same decision behavior like the user (expert) seems to have been reached. The chain ***"Recognize - Rate - Decide"*** in support of the behavior of experts in risk diagnosis could be modeled. With classic "sharp" mathematical methods, the tasks could not be solved.
The chain links **RECOGNIZE and EVALUATE** were mapped mathematically using fuzzy logic and the result of comparison operations plotted. Conditions were, inter alia, sufficient process knowledge, establishing criteria for "good seamanship" (expert knowledge), process adequate ma-thematical solutions and effective graphs for "diagnosis" of the process hazards (see Fig. 4 and 5).


Figure 4: Possible situation assessment at 21:35 with the NTM - Assistant using expert knowledge and fuzzy logic

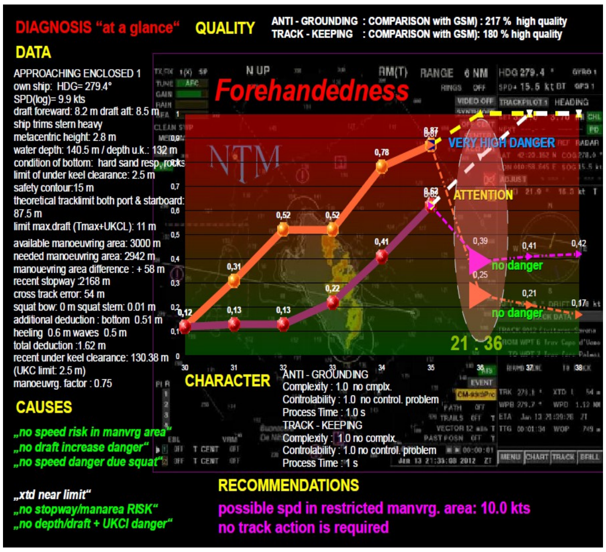


Figure 5: A complex picture of the past, current and future process flow as well as the simulation of a action recommendation with the NTM - Assistant using expert knowledge and fuzzy logic (situation analysis for 21:36)

## 5. Conclusion

**The NTM delivers with this "diagnosis at a glance" a complex image of the real situation with the most important decision-making process variables that provide the conditions for intelligent process control in safety-critical situations.**
The further improvement of sensors, indicators, reliability, ease of service, among other things does not bring much new quality of process control. This is only possible if the systems human - technology is considered as an unit and this unit allows a high **dependability** of

process control.
**Regarding to ship navigation process** means that : Control of the "*movement*" (movement as a state change over time) of the vessel from the starting point to the destination port. It uses the set of principles, procedures and methods for receiving, processing, storage and disclosure of information between the needed elements for the process control in their way, appropriate selection and rational combination for process control. The control process has to satisfy under the environment and the function-related stresses and taking into account the technical characteristics of the equipment and the mental and physical factors influencing the manpower for a specified period of time and in a given space with the requirements of reliability (with the required qualities: efficiency and safety), and thus to preserve the stability of the system.
Research into the causes and conditions for specific forms of process control with a view to their optimization should become a permanent issue of resource use future-oriented companies. For addition of functional-technical integration by the cognitive integration knowledge is required. The application of fuzzy logic for the detection and realistic modeling of complex ship management processes as well as the calculation and prediction of nautical hazards by handling large amounts of data are an example.
In a process control by means of man-machine systems, which is characterized by information and communication as well as knowledge and experience, the research is not confined to academic institutions. It becomes a concern of modern corporate governance. The resulting obligation arises in particular from the causes of the grounding of the cruise ship "Costa Concordia".
**Such human errors can be reduced if weaknesses in human performance can be balanced with modern information processing solutions.**

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