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# PROBABILISTIC RISK ASSESSMENT IN DYNAMIC POSITIONING OPERATIONS

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The offshore oil and gas industry is associated primarily with high operational risks. Automated dynamic positioning of vessels involved in operations is one of the main methods of increasing navigational safety in this industry. Dynamic positioning operations contribute to high-risk tasks since incidents associated with the loss of a ship's position can lead to damage to the ship and platform, fire, significant environmental pollution or multiple casualties. For example, in 2005 the collision of a supply vessel with the Mumbai High North platform resulted in a fire and the death of 22 people. Fire losses were estimated at $200 million.

Dynamic positioning system – is a complex system designed to maintain required position and heading of the vessel or move the vessel on predefined track with slow speed. DP System contains seven components: thrusters, power generation and distribution, position reference systems (PRSs), sensors, controllers, human-machine interface (HMI) and DP Operator (DPO).

It is obvious that emergency situations inherent in dynamic positioning systems are primarily associated with the loss of position. Therefore, a DP Emergency is a system failure that results in an inability to maintain position or heading control (IMCA M103). The loss of position event can be a Drift Off or a Drive Off.

DP Drift Off is a loss of position caused by a partial or total loss of thrust leading the DP vessel/installation to drift. Drift off can be caused by a power system failure, thruster system failure, DP control system failure (DP control, reference systems or environmental sensors), fuel failure or DPO error.

DP Drive Off is a loss of position caused by an improper and undesired force applied to the DP system or a DP control system instability leading the DP vessel/installation to move on an undesirable direction (yaw, surge and/or sway). Drive off can be caused by a thruster failure (frozen pitch/RPM and/or azimuth), a reference system failure, a common failure on two or more reference systems, a DP control system failure, DPO error and sudden changes in weather/current.

Statistics made by the International Maritime Contractor Association (IMCA) on the basis of DP Station Keeping Reports shows that 'Thruster/propulsion' failure has the highest percentage (more than 30%) of main failure causes, which lead to DP incident, DP undesired event or DP observation, for last 5 years.

Some of the top secondary causes of failures are taken by "Human factors". For instance, all 30 causes reported in 2020 could be categorized as 'unintentional behaviour' for which there are four categories: 'sensory error'; 'memory error'; 'decision error'; and 'action error'. 'Decision' and 'action' errors led to proportionately more events and the loss of DP control than any others. 'Decision' errors are defined as errors where a clear decision was made to operate in a particular way and 'Action' errors − where a function or control was selected incorrectly.

In the context of ensuring the safety of operations, two types of risk assessment are possible: preliminary and operational. A preliminary risk assessment is made at the operation planning stage, considering the known conditions and factors. Operational risk assessment takes place in real time and takes into account changing conditions and emerging hazards.

The goal of this research is to create a decision support tool that will monitor the condition of the DP system, location of the vessel, and environmental conditions, and predict the most likely scenario based on previous states of the system.

Probabilistic risk assessment (PRA) is a structured method of quantitative risk assessment to navigate the design and operation of systems for achieving a certain safety or operational goal. Probabilistic Risk Assessment (PRA) has been utilized by NASA in a variety of space oriented projects.

Reliability of the system components, time interval available for reaction of Dynamic Positioning Operator (DPO), qualification and experience of DPOs, decision taking response time affect PRAs significantly.

Therefore, it is important to develop a method that can address time-dependent effects in PRAs and provide precise estimations. Dynamic PRA (DPRA) has been used to understand unintended time-dependent interactions between system components, including technical, environmental, and organizational factors, over time.

Different methods have been reviewed for considering these system interactions in risk assessment of which most are based on the dynamic/continuous event tree, dynamic fault tree, and dynamic Bayesian network methodologies.

In these methods, instead of a unique event sequence diagram (ESD) connected to specific fault trees (FTs) and BNs, multiple ESDs/FTs/BNs are developed for an incident scenario that can be updated over time according to the environmental and operational characteristics of the system.

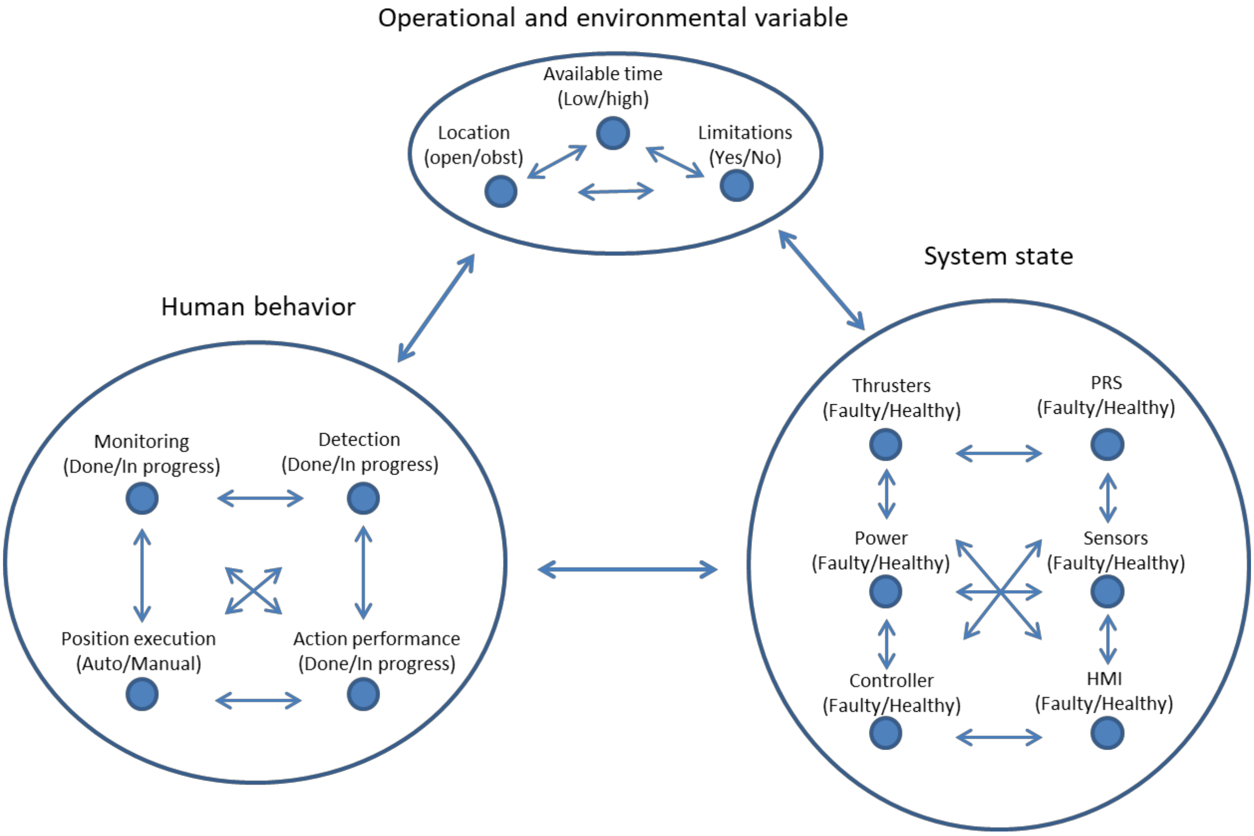


Fig. 1 – Agent based conceptual model of the DP system

Complex systems are mostly nonlinear and nondeterministic due to the heavily interdependencies among their elements. Considering nonlinearity and stochastic characteristics in risk modeling would enable a more accurate analysis and prediction of the complex system behavior. Such predictions can provide a valuable basis for decision support regarding the need for risk mitigation and accident prevention to operators. Generally, a complex system behavior is affected by human machine interactions, and operational and environmental conditions.

The agent-based conceptual model of the DP system is presented on fig. 1. The DP system has three main agents which are interconnected including “human behavior”, “system state”, and “operational and environmental variable”. The behavior of these agents and their interconnections with other agents is presented by edges that are governed by complex rules. The whole DP system is modeled by coupling the elements and edges governing principles and rules. DPO is excluded from agent “system state” to a “human behavior” as actions of DP operator require precise assessment and thorough consideration. For example, recognition of failure on early time intervals might save situation and avoid undesired consequences and in opposite, improper conclusions, and actions of the DPO may degrade entire DP System.

It is important to note that this is the most common model, which covers in general the great variety of DP operations. Level of complexity might be increased, and subagents might be added depending on the specific vessel and operation, which may increase the total number of alternative scenarios. Those scenarios are of different probabilities and the most probable needed to be considered first.

The objective of DPRA is to find scenarios with high risk level, e.g., scenarios with high probability and low consequences and scenarios with low probability and high consequences. In these cases, the objective function is equal to the risk level evaluation.

**Conclusions and further research perspectives**

In this study, three structured methods of quantitative risk assessment were analyzed: event sequence diagram, fault tree diagram and the Bayesian network.

In order to consider the effect of the Human error into the DP component, the Bayesian network for Human Risk Analysis was implemented into this study. As the Event Sequence Diagram includes both system failures and human errors, this method helps to combine Fault tree and Bayesian network together.

Proposed method of Dynamic Probability Risk Assessment allows predicting all failure scenarios based on agents and sub-agents model. By considering occurrence probability and consequences, it is possible to highlight most probable scenarios with high or low consequences. The probability is based on statistics of incidents and studies of human behaviors.

The method of real time scenarios assessment will be researched and proposed in further studies.

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