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Next Generation Subsea Inspection, Maintenance and Repair Operations

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Abstract: This paper presents the latest developments in the project Next Generation Subsea Inspection, Maintenance and Repair (IMR). Subsea IMR operations are frequently carried out in the offshore oil and gas business. Increased efficiency in such operations will reduce time of operations and costs. Autonomous functionalities constitute an enabler for such reduction. To this end, the project is focusing on technologies, algorithms and methods required for enabling the right level of autonomy and human-machine interaction in IMR operations. This includes new perception, localization, path-planning, and shared control technologies, as well as new methods for risk management. Although NextGenIMR has a particular focus on subsea operations in the oil and gas industry, the technologies developed will also be highly relevant for IMR operations in fish farms and in deep sea mining.

Keywords: Autonomous operations; Localization; Risk management.

1. INTRODUCTION

Maintaining high regularity with subsea facilities requires reliable installed equipment, but also *efficient ways for inspection, monitoring, early detection of equipment fault, maintenance and repair.* This paper presents some preliminary results from the project Next Generation Subsea Inspection, Maintenance and Repair (NextGenIMR). The project is headed by the Norwegian University of Science and Technology (NTNU), funded by the Norwegian Research Council, Statoil Petroleum AS and FMC Technology AS and SINTEF is a research partner. Subsea processing is the factories of the future for the oil and gas industry and is being developed for deep water and artic areas. The Norwegian oil and gas company Statoil aims to install the first subsea factory in 2020 and has in 2015 installed the world's first subsea compressor in the Åsgard field (statoil.com). Subsea factories of the future constitute complex installations including pump stations, compressors, storage tanks etc. The next generation of inspection tools and sensor platforms may be situated on the sea floor in garages next to the factory in an on demand state, as e.g. AUV inhabitants. Vessel independent hot-stab operations, automatic connector inspection, autonomous docking, and component replacement is the foreseen future. There exist more than 5000 subsea wells on the Norwegian Continental Shelf and with aging equipment it is expected that the need for inspection and repair operations will increase significantly during the next years. Moreover, there is a risk for damage to the subsea equipment due to collision with unknown objects, entanglement in fish net, as well as component failure.

Today most subsea IMR operations are performed with the support of offshore vessels of the type shown in Fig. 1. Currently, all IMR operations require support from an offshore vessel, remotely operated vehicle (ROV) systems, tools and experienced ROV operators. The day rate for a support vessel is in the range of hundreds of thousands of dollars, depending on the vessel size and zone of operation. Vessels available in the spot market operate on-demand and this may increase the prize and time of operation. Moreover, there is always a need for open weather windows to be able to perform IMR operations. Current most industrial ROV operations are manually controlled, with little or no automatic control functions nor autonomy. Efficiency in operations is highly dependent on the experience of the ROV operator (Schjølberg, et.al (2015)). Autonomy in ROV operations is a stepping stone towards increasing the efficiency and thereby reducing the costs. Shared control in ROV operations is the solution to reduce work load on operators, reduce human errors in operations and increase efficiency (Henriksen et.al., 2016)). In shared control some operations are performed autonomously and some directly by the operator. There is a need for developing a flexible control architecture which can be implemented on existing ROV systems, supporting shared control and enabling the operator to switch between different control modes.

Typical IMR vessels have on-board ROV system, a ROV operation room and ROV operators (Fig.2). The operation room has camera images giving the operator continuous information on the operation. The operators perform direct control of all ROV degrees of freedom as well as ROV manipulator arms. Success and efficiency in operation is

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totally dependent on the operator's experience and situation awareness at any instant of time.

ROV control can be divided into three main modes of operation.

- Direct control. The operator controls each degree of freedom directly via joystick or similar unit.
- Shared control. A selection of modes is performed autonomously, while others are performed by the operator. The operator is in the loop, can interrupt and initiate the modes.
- Autonomous control. A task or a whole operation is performed autonomously. The operator has a supervisory role.

Fig.1. Boa Jarl (2015) offshore vessel (Photo: boa.no).

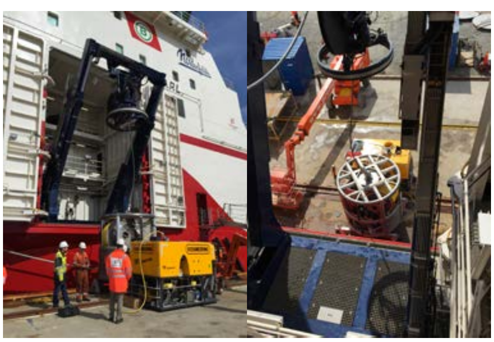

Fig.2. Working class ROV and support system on Boa Jarl.

There is a need for discussing and evaluating which operations can be performed autonomously and which functionalities should be located on the ROV. The target is always to find the *best* degree of autonomy and human-machine interaction in operations which optimizes factors such as efficiency, safety, cost (development, engineering, operations, de-commissioning), and reliability (Grøtli, et al., 2015a,b).

Typically, ROV tasks include (oceaneering.com)

- Cleaning of subsea systems
- Inspection and survey, capture of digital video and still photography documentation
- Hatch operations on subsea structures and valve stations
- Cathodic Potential (CP) measurements of structures and pipes
- Cutting operations
- Handling of rigging equipment: ROV hooks, shackles, soft slings etc.
- Installation and recovery of seawater intake blinds on platforms and Floating Production, Storage and Offloading units (FPSOs)
- Electrical faultfinding and hydraulic leak detection
- Valve operations using ROV manipulator, torque tool, or skid under the ROV
- Replacement of flying leads, jumpers, cables and hoses
- Replacement of sensors and meters
- Support during remotely operated tool (ROT) operations
- Tool transportation

The above mentioned operations require a high degree of flexibility in the ROV system and in the operation as unexpected events may occur. This is especially during installation and support operations. Performing such operations autonomously is therefore very demanding. Moreover, robust ROV systems are required to handle the splash zone (during launch and recovery), strong current and to supply sufficient manipulator torque.

A distributed control architecture is required to enable autonomous functionalities in ROV control. An assessment of which functions to place remotely and which to place locally on the ROV is needed. Fig.3 shows a possible allocation of functionalities. Placing as many a possible locally on the ROV is an advantage as it reduced the data traffic on the communication link and ROV is less dependent on surface support.

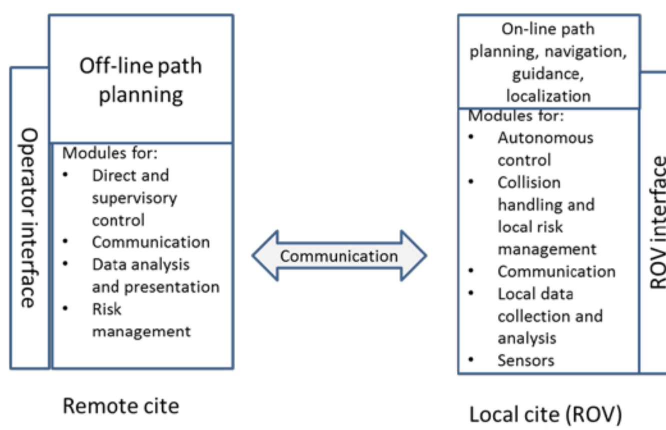

Fig.3. Allocation of functionalities remotely and locally.

The most advanced installed functionality on working class ROVs is Dynamic Positioning (DP) or station-keeping. DP uses on-board sensors and is further described in Dukan et.al (2012). Including other functionalities such as autonomous inspection and intervention modes requires navigation and guidance which include localization and path planning. These functionalities are today performed by the operator. Fig. 4 suggests technology steps in NextGenIMR project.