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A BIM-based framework for lift planning in topsides disassembly of offshore oil and gas platforms

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ABSTRACT

Offshore oil and gas platforms (OOGPs) usually have a lifetime of 30–40 years. An increasing number of OOGPs across the world will be retired and decommissioned in the coming decade. Therefore, a safe and efficient approach in planning the disassembly of the topsides of OOGPs is required. One commonly applied disassembly method is reverse installation, which moves the OOGP modules from the platform deck to a heavy lift vessel (HLV) in reverse order of their installation. Considering the high risk and cost of working offshore, shortening the lift time is crucial. In contrast to the traditional experience-driven lift operations, this paper describes minimizing the lift path for each OOGP module during disassembly, leveraging building information modeling (BIM) technology and an improved A* algorithm. BIM models provide accurate component-based geometric and semantic information that can be used for planning and optimization. However, there has been no previous study on the use of BIM for offshore disassembly. Industry Foundation Classes (IFC), which is a neutral data model of BIM, is used in this study to represent OOGP models. In particular, the *IfcBuildingElementProxy* entity is used to represent the OOGP components, and the information in *IfcBuildingElementProxy* is automatically extracted to obtain the location and dimension information of each OOGP module. Then, for a given layout of modules on the removal vessel, the lift path and removal sequence of different modules, with the shortest lift path distance, are obtained. The lift path distance is calculated using the A* algorithm, which has been widely applied in 2D environments and is modified in this study to suit the 3D environment. Finally, the genetic algorithm (GA) technique is applied to optimize the layout plan on the removal vessel by minimizing the total lift path distance. The developed BIM-based framework is illustrated and evaluated through an illustrative example. The results show that the proposed framework can generate and visualize the shortest lift path for each OOGP module directly and automatically, and significantly improve the efficiency of OOGP disassembly.

1. Introduction

An offshore oil and gas platform (OOGP) is a large structure with facilities or modules to drill wells, to extract and process oil and natural gas, and to temporarily store products until they can be brought to the shore for refining and marketing. Usually, an OOGP also provides accommodation for workers. Several types of OOGP, including fixed platforms, artificial island platforms and floating platforms, are available to fit different circumstances. A fixed platform usually has four parts from the top to bottom, as shown in Fig. 1. The topsides is on the top of the platform, which contains different functional modules, such as drilling rigs, production facilities and crew quarters. The jacket is the structure, steel or concrete, that supports the topsides. The wells connected with the topsides are used for the drilling. The last part refers to the piles used to fix all the other parts.

There are now over 7000 oil and gas installations and platforms on continental shelves in over 53 countries around the world [45]. OOGPs generally have a lifetime of 30–40 years, and the decommissioning of offshore platforms is a major issue in the oil and gas industry. Between 2010 and 2014, the Gulf of Mexico decommissioning cost was approximately US $9 billion. Over the next 30 years, almost all the 470 offshore installations in the North Sea's UK Continental Shelf, such as offshore platforms, will need to be decommissioned, according to the UK's Oil & Gas Economic Report 2013 [2]. Twenty-seven offshore oil and gas platforms in southern California will be decommissioned by 2030 as the platforms reach the end of their useful production lifetimes [27]. In Malaysia, the number of decommissioning activities for fixed offshore platforms are expected to increase significantly. There are approximately 300 oil platforms in Malaysia, many of which are approaching the end of their service life [55]. As the next decades will witness a big trend in

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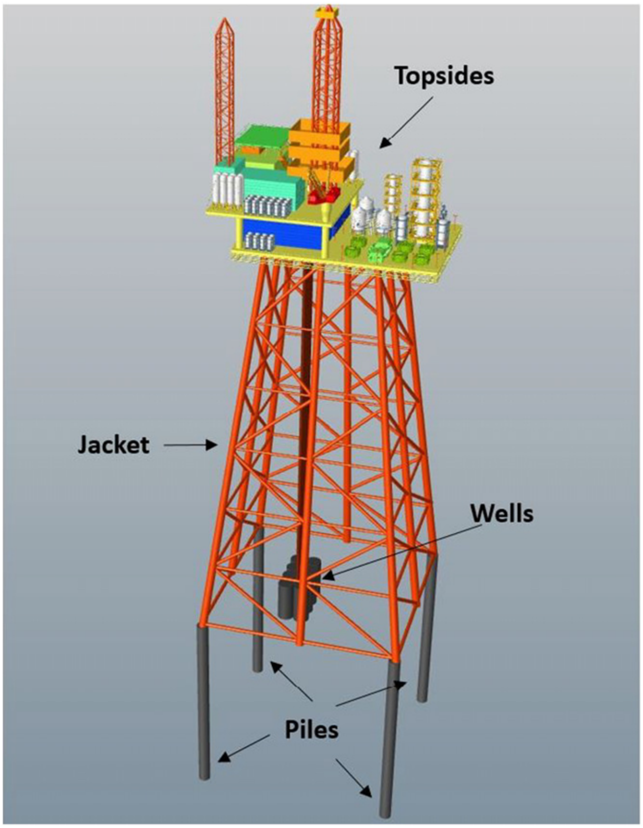

Fig. 1. Four major parts of an example offshore oil and gas platform (OOGP).

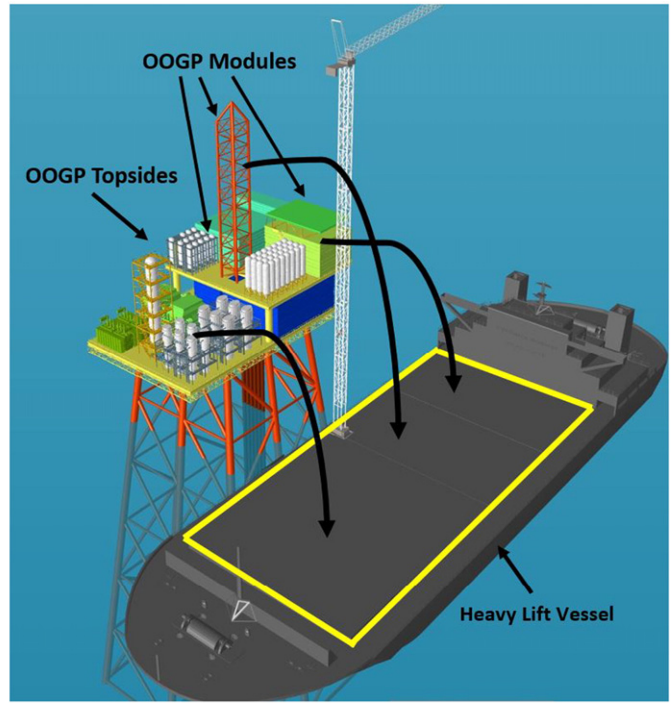

Fig. 2. Illustration of reverse installation for disassembly of OOGP topsides.

OOGP decommissioning, evaluating different decommissioning options will be significant.

Based on previous studies, decommissioning cases and waste hierarchy [19], all potential decommissioning options can be divided into three categories: reuse, recycle and disposal, among which the reuse options have the top priority considering their sustainability, as the energy consumption of reuse is relatively small compared to recycling [54] and reuse is more environmentally friendly than disposal. Different decommissioning options can be realized with more than one method or technology, some of which are shared by the reuse and recycling options, for example, offshore deconstruction, reverse installation or single lift for the disassembly of the topsides. Among all commonly used methods, the reverse installation method for removing a topsides is currently the most widely used. Therefore, this study focuses on reverse installation (see Fig. 2).

Reverse installation for the removal of topsides is to disassemble the topsides offshore following the reverse sequence of its installation onshore. A heavy lift vessel (HLV) or heavy lift ship, which is designed to move very large loads that cannot be handled by normal ships, is required to conduct the lift operation. Some HLVs can load the modules or facilities from the OOGP and transport them to land, while some can only lift and put items onto another cargo ship.

Whatever type of HLV is used for the heavy lift, necessary planning and preparation are required to reduce risk at sea, save energy and reduce disassembly time. The planning process includes locating the lift points and optimizing the module layout and lift schedule. The reasons for calculating and optimizing the layout as well as the lift schedule are to (1) avoid any clashes among the fixed OOGP modules, moving OOGP modules and the lift equipment, and (2) shorten the total lift distance of all the heavy lifts. Preparations include planning the required equipment such as HLV, conducting necessary preparatory work on the topsides such as emptying and cleaning pipes, disconnecting the service links such as piping and electrical wiring, removing or securing loose items, installing lift points on modules, and separating structural connections between the modules. However, currently the lift planning is conducted manually by experienced project engineers from decommissioning companies, and is time-consuming and error-prone when facing a large OOGP with many modules. In addition, as all the tasks are conducted manually using 2D drawings and people have different interpretations of the same 2D lift plan, communication problems sometimes occur during the implementation of the heavy lifts. Any fault and accident during the heavy lifts could lead to serious consequences, impacting on both disassembly workers and stakeholders of OOGPs. Therefore, this study tries to conduct reverse installation lift planning automatically in a 3D environment.

In order to automatically conduct module lift planning in a 3D environment, three things are required: (1) 3D digital representation of OOGP, (2) the actual lift path calculation of each module from OOGP to HLV, and (3) an algorithm to generate the optimized OOGP modules layout on HLV and lift schedule. Although an OOGP can be represented as a 3D digital representation by software applications such as AVEVA and Intergraph that are commonly used in the oil and gas industry, interoperability among these applications is still limited. Building information modeling (BIM) has been widely used in the architecture, engineering and construction (AEC) industry for the past decade. Open BIM standards such as Industry Foundation Classes (IFC) support interoperability among most applications in the AEC industry. In addition to the building industry, BIM has also been applied in the oil and gas industry to achieve similar functions as in a building project. For example, Zhou et al. [57] conducted a study on investigating the feasibility and benefits of 4D BIM in supporting Liquefied Natural Gas (LNG) construction projects. In addition, Cheng et al. [17] reviewed the application of civil information modeling in civil infrastructure including the oil and gas industry. Bradley et al. [14] reviewed and analyzed the current industry positioning and research state of the art regarding BIM within the infrastructure domain and its use, from the constructor perspective. However, BIM application in the oil and gas industry is still limited.

As for the actual lift path, currently many path planning studies are conducted in a 2D environment. The lift planning problem described in this paper cannot be treated as a 2D problem since the modules are lifted in a totally 3D environment. The last thing required for the