JackVR: A Virtual Reality Training System for Landing Oil Rigs

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Abstract. We propose JackVR, an interactive immersive simulation prototype aiming to train domain experts to land jackup oil rigs. Jackup rigs are among the most common offshore drilling units for extracting oil, but the process of landing the rigs is mostly challenging because of the unpredictable sea and weather conditions, lack of clear vision, and the possible risk of damaging the ocean floor. We designed JackVR to support oil engineers and technicians by allowing them to practice landing the oil rig within a safe and semi-realistic training environment. Furthermore, the design explores various superimposed spatial indicators that provide visual warnings on unexpected task conditions. The implemented prototype supports two modes for training, and utilizes the ray-casting interaction technique to enable seamless and direct control of the rig. . . .

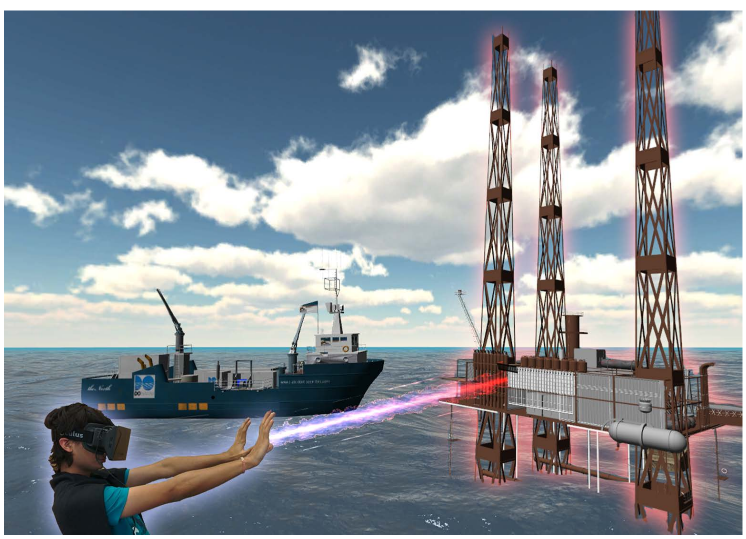

Fig. 1. JackVR's Concept: immersive landing of oil rigs with Ray selection technique

1 Introduction

Virtual reality (VR) training applications are widely used to prepare users for tasks that may be too costly or dangerous to practice in real world settings [1]. Within the oil-and-gas domain, some VR training systems were proposed and implemented in order to support domain experts who train for challenging oil-and-gas processes and tasks (e.g. [2], [3]).

One such task, which is the focus of this paper, is the process of landing a jackup oil rig. This process involves many environmental challenges including unpredictable weather conditions, varying (deep) ocean forces, and uneven seabed topography. During the landing process operators are provided with a very simple user interface to control the oil rig (e.g., move its legs up/down) with minimal visual feedback, which is arguably insufficient to satisfy the complete set of task requirements. During the landing the operator must stably and correctly position the rig to previously defined positions at the seabed, while being aware of dynamically changing environmental conditions, and carefully avoiding risks of damaging the topography of the seabed. These challenges motivated the design of JackVR, a training system that provides domain users with an immersive environment that helps them understand the multifaceted challenges of landing the oil rig, and practice landing it in a semi-realistic environment.

Bin He [4] proposed a virtual prototyping system to validate the design of an offshore drilling platform including its jacking systems. However, to our knowledge, there is no immersive system that supports practicing offshore oil rig landing.

We propose JackVR, an interactive training system that supports domain experts train in landing jackup oil rigs in a variety of simulated scenarios. We implemented JackVR as an immersive virtual reality simulation of jackup oil rig landing that allows control of various environmental aspects, such as ocean waves and wind, enabling spatial interaction using ray-casting interaction technique (Figures 1, 4). This paper details the main components of JackVR, its usage in landing simulation tasks, and our plans for future improvements.

2 Jackup Rigs

Drilling is one of the main processes in hydrocarbon extractions with onshore or offshore drilling units, the latter are mounted mostly in the middle of the ocean. Jackup rigs [5] are among the most common offshore drilling units due to their low operation and maintenance cost. A jackup rig usually consists of the rig itself, the legs, spud cans (heavy objects attached to the legs to facilitate seabed penetration), and the hull. The legs and the hull of most jackup rigs usually can be lifted down/up through the rigs' jacking system. The weight of the jackup rig impacts the landing at certain points and proper utilization of the rig's hull with the water level inside the hull must be maintained. The stability of the rig mostly depends on the rig's weight and the environmental forces applied (e.g. wind and ocean pressure).

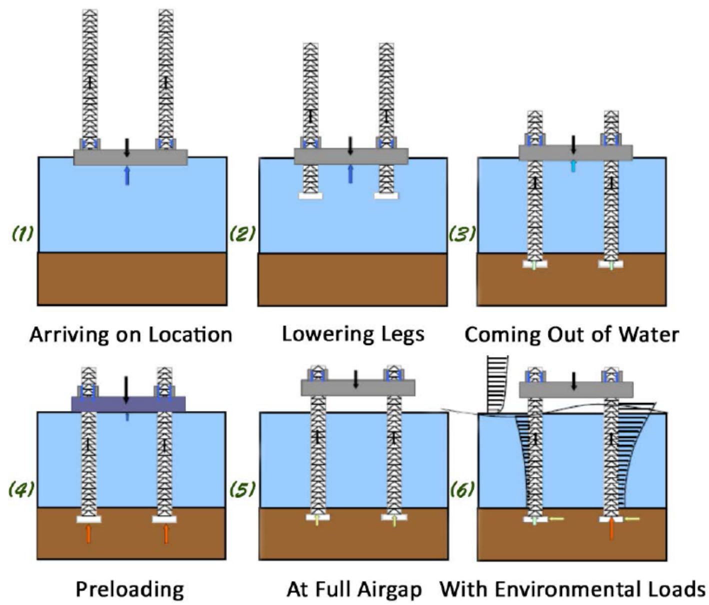

Fig. 2. Steps involved in the process of landing jackup oil rigs.

Many steps are associated with the operation of landing a jackup rig (Figure 2). The jackup rig is pulled (moved and oriented) to the target location. Then, the jacking system is used to lower the legs with careful attention to the environmental forces and the seabed depth until the legs touch the seabed. Next, the hull is raised out of the water prior to filling it with water to increase the total weight of the rig, in order to enable penetration of the seabed. Following the penetration, the hull is further raised leaving an air gap for more stability, with the rig fully landed and almost ready as a fixed platform for drilling. JackVR allows the user to train and practice all the landing phases with the exception of the pulling to the target location (the 1st phase), which reflects on towage task components that are arguably external to the core landing process.

3 Why JackVR?

Operators of oil rigs may need to control the rig through a simplified desktop interface that only supports basic interaction capabilities to land the rig along with standard 2D images of the under-ocean terrain topography. Due to the apparent lack of simulating the surrounding environment, a more realistic, safe, and engaging training environment is needed to better educate the operators about landing the oil rig, especially with the various weather and environmental challenging conditions. In this project, we propose JackVR, an immersive simulation and semi-realistic training environment for the process of landing oil rigs. In our early meetings and consultations with our domain collaborators, they highlighted the importance and the potential of having an immersive environment, such as JackVR, to support the training of landing oil rig.

4 Training Modes

The design of JackVR followed an iterative methodology [6], based on feedback from domain expert collaborators. One of the main design requirements was that JackVR will allow users to experience two training modes, “normal” mode, and what we termed a “superhuman” mode. When the normal-mode is set, users are able to completely control all aspects of the training with the same low level of insight that can be expected from the current oil rig landing interfaces. It is worth noting that domain experts often resist learning and trying new tools (e.g., [7]). By including the more familiar normal mode, we anticipate a simpler transition to learning and adapting the new, superhuman, mode. While in the “normal” mode, the visualization is lacking and only few low-level insights can be gained. The “superhuman” mode would allow us to explore intuitive interactions directly as additional features provided over the simpler “normal” mode. The “superhuman” mode enables the user to benefit from empowerment of “supervision” abilities and intuitive feedback including superimposed visualizations of the simulation and awareness of the surrounding objects in the environment. Furthermore, the superhuman mode has potential to extend user engagement beyond the use of natural interaction techniques, with a vision for future use of drones (or small submarines) that would aid in such complex simulation processes. In essence, this unrealistic mode provides a more engaging experience and better understanding of the simulation process and its various attributes, with the goal of enabling rich task awareness and as a result better and more efficient training and learning experience.

5 Simulation Attributes

The design of JackVR simulation included the following simulation elements: (1) a module that simulates the environmental forces, (2) a notification and warning messages generation module, (3) a state-machine module that continuously evaluates the possible outcome of the training, and (4) interactive visualization module which renders the 3D rig model and supports the various spatial VR interactive techniques.

JackVR continuously simulates the environmental conditions impact on the rig’s tilt and movement. We use simplified physics simulation with two parameters that affect the rig tilt, ocean condition and depth, as a simplified representation of any horizontal or vertical environmental forces such as wave current and hull weight. We assume that the sea condition is the main (angular) variation that affects the rig tilt, and modeled it using a simplified 1D noise function. The output from the noise function is a random angle that is generated periodically as the new rig orientation, and is interpolated over time to smoothly reflect the

Table 1. Training difficulty levels

		Seabed terrain topography	
		Smooth	**Rough**
	Calm	Easy	Normal
Sea Condition	**Normal**	Normal	Hard
	Stormy	Hard	Very Hard

new tilt status. Ocean depth is the secondary parameter that affects the tilt according to the current depth of the rig's legs. When the legs arrive at the seabed, we consider the internal rig weight to be at the highest and stop the tilt motion.

Table 2. Training outcome according to JackVR difficulty levels

If	**Easy**	**Then**	**Failure never occurs**
If	**Normal**	**Then**	**Failure if mistakes ¿ 2**
If	**Hard**	**Then**	**Failure if mistakes ¿ 1**
If	**Very Hard**	**Then**	**Failure for any mistake**

The warning messages module is integrated as a visual notification reporting the status of the landing. A warning value is issued by continuously taking into account the following simulation parameters: sea wave conditions (e.g. calm, normal, or stormy), the depth of the rig's legs relative to the total depth of the ocean floor, the status of the hull (either raised or lowered), and the type of the seabed terrain topography (either smooth or rough). We designed the warning notifications to allow trainees that miss early notifications continuous indication of the simulation status and better chances of recovering from problems that might have been ignored initially.

A state-machine component was designed to continuously evaluate the overall simulation status, and determine landing success or failure. Prior to the simulation start, the user customize a set of parameters that determine the difficulty level, which is later translated into a set of simulation variables (Table 1). This customization phase allow the simulation to better fit the varying expertise of potential users. Afterwards, the training outcome is evaluated based on the simulation difficulty level in combination with the total number of users' errors (Table 2). For instance, in the 'very hard' difficulty level the user can fail the entire task if the rig's hull is raised in the VR immersive environment earlier than it should.

The visual user interface of JackVR was designed to be rendered in stereo head-mounted display (HMD). Text messages were rendered only within the center of the user's view, while other indicators such as some of the system statistics were rendered via alternative cues such as sound and graphics elements. Along this line, we explored superimposed visualization as on-demand visuals which are attached to certain objects within the immersive environment. Such

Fig. 3. Landing a jackup oil rig with JackVR

superimposed visuals are scaled relative to the user's eye (or camera location), allowing to simplify the user interface while still providing awareness of the simulation variables and status.

6 Interaction

Interacting with JackVR requires the user to wear an Oculus Rift HMD enabling immersive depiction of the 3D environment and its surroundings (Figure 3). Within the JackVR immersive environment the user is interacting with a rich set of simulation graphical representations including animated 3D ocean waves (with a simple buoyancy), sky and clouds (through a skybox), a set of floating ships over the sea surface, a jackup rig 3D model, and underwater effects (implemented using Unity3D, Figure 4). Furthermore, basic audio support has been integrated to further enhance the immersion of the experience.

In the actual landing process, the operator needs to observe the rig and its legs from different perspectives during the landing, and to be able to interact with the rig by moving its legs up and down, or by raising the rig's hull as needed. We mapped these task interactions to fit the design of VR simulation. We realized that the simplicity of the ray-casting interaction technique [8] (Figure 4) makes it a seamless and a suitable choice for such mapping.

We decided to enable interaction with the JackVR immersive environment using the ray-casting technique, as it fits the navigation and control around the rig. First, with regards to navigation, we wanted to support users with a first-person flying experience to be able to directly see the 3D rig from any point during the simulation. Second, to control the rig, it must be "selected" first, and

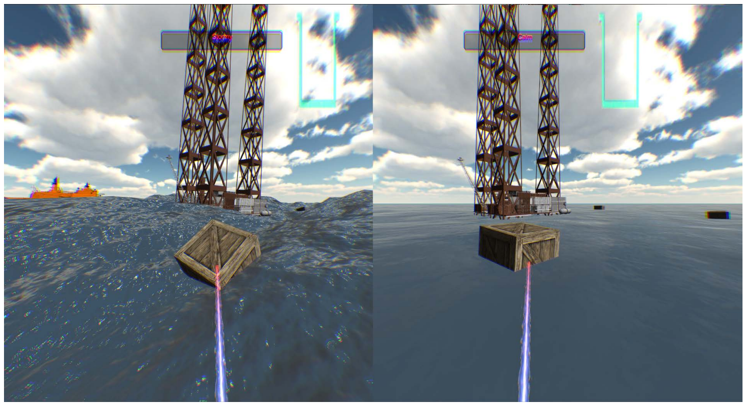

Fig. 4. JackVR and the ray-casting interaction technique in two ocean conditions: high stormy waves (left), and calm waves (right)

the design of the ray supports that as follows: the ray is rendered as a virtual screen-inward laser pointer reflecting the user direction. When the ray intersects objects within the 3D world, it can cause specific visualizations to appear and can enable direct interaction with objects. For example, when the user is oriented towards the rig model, the ray will enable a specialized visual element attached to the rig which indicates its current status (Figure 5). The ray casting approach and the superimposed visualization provide details-on-demand, which prevents over-population of the user's view, and allows direct access to faraway objects.

JackVR uses a Xbox controller to support a gaming-like interaction within the simulated environment. The user can navigate the environment using both the left-analog stick and HMD movement. The controller's buttons are used to control the rig itself. For instance, the "X" and "B" buttons are used to control the rig's legs while the "A" and "Y" are dedicated to raising and lowering the rig's hull.

Sound is utilized as a second sensory element in addition to visual elements. Our initial implementation only supports sound-based feedback when the user is traveling within the virtual environment. For instance, the sound of air while moving above surface differs depending on the user's traveling speed, and moving under the sea level will result in ambient underwater sound effects. Sound can be used beyond the aforementioned effects, e.g., as auditory warnings that aim to notify the user of sever issues regarding the landing process, which we are exploring as future work.

JackVR design is focusing the user's attention on the immersive experience. For example, when a landing problem is indicated it will not be reported numerically or as text, but rather via visual notification cue, such as a red overlay that is blended over the final rendering frame with a transparency that is relative to the current warning value (Figure 6). While JackVR can integrate the more typical notifications (e.g. textual-based messages, or 2D graphs), it enables with

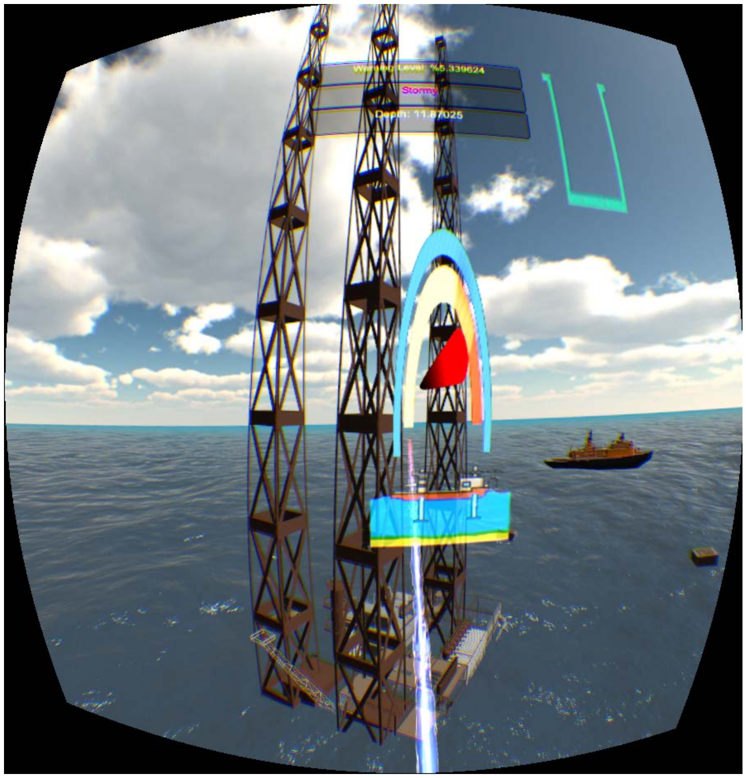

Fig. 5. JackVR's "superhuman" mode is active

rich superimposed visualization that provides more direct seamless information superimposed on the main rendered simulation objects.

The JackVR visualization status varies based on the selected mode. When the normal-mode is active, the user interface relies on basic textual status indicators, while still allowing the user to fully control all simulation aspects. When the superhuman-mode is enabled, the user is empowered with a set of superimposed visualizations including visual bars, indicators and meters which are integrated within the immersive environment components. For instance, a visual meter (similar to cars speedometers) reflecting the current warning level would appear when facing the rig (Figures 6).

In the superhuman mode, various graphical interface elements have been implemented aiming to assist users and inform them of the simulation's status. For instance, the parameter representing the water level inside the rig is simulated through an icon reflecting two states of the water level inside the rig's tank (either empty or full). Similarly, the leg depth parameter is represented by a floating 3D indicator showing the current depth relative to total depth of seabed (Figure 6).

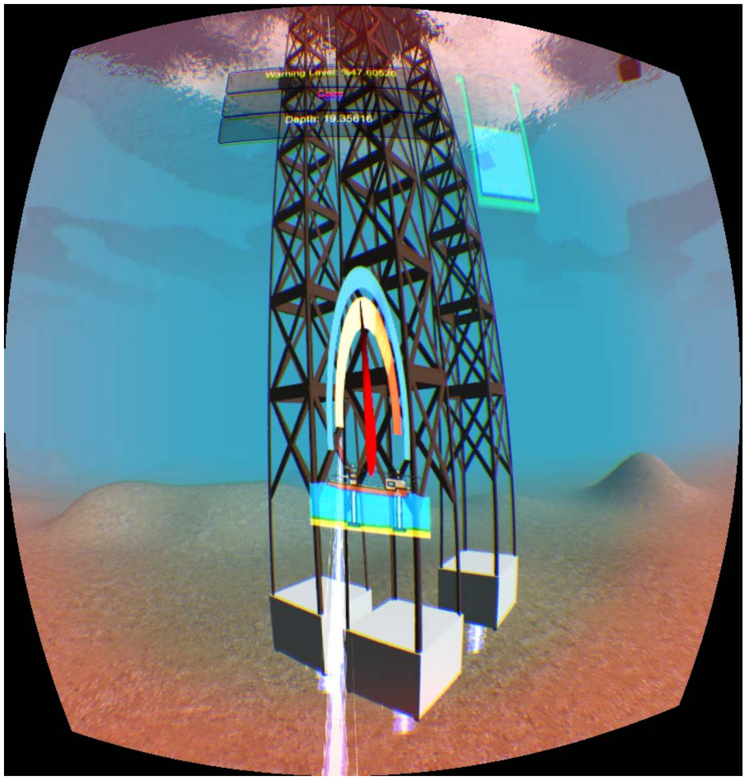

Fig. 6. Warning level representation in superhuman mode

Upon completion of the training, a graphical notification of either success or failure is shown. The user can still navigate around the environment after finishing the training, but at this point cannot change or interact with any object within the virtual world. We enabled this post-task view in order to provide the user with an opportunity to reflect on the task performed and on the reasons for landing success or failure.

7 Discussion And Future Work

JackVR is still a proof-of-concept prototype, and while it was designed iteratively with domain experts, we still did not evaluate it as a practical training tool. Current preliminary feedback from a senior domain expert points to JackVR potential help to engineers who are learning the oil-rig landing process, its ability to provide a sense of difficulty and unexpected hazards, which might happen and cost companies millions of dollars.

We plan to run a user-study of JackVR to gather in-depth feedback from its potential users to refine the representation and better support the domain users expectations.

8 Conclusions

We presented JackVR, a VR simulation aimed at training oil-and-gas practitioners in landing offshore oil rigs, focusing on the process of landing a jackup rig as a widely used offshore drilling unit. JackVR incorporates features that simulate the landing process as well as the surrounding environment, including seabed topography and ocean waves. Users can change the simulation parameters, and practice a variety of scenarios. JackVR also supports a superhuman mode which superimposes 3D indicators with the immersive environment, and enables a ray casting interaction technique.

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