



UNIVERSITY OF MINES AND TECHNOLOGY(GHANA)

Society of Petroleum Engineers



TEAM UMaT

Drillbotics International University Competition

Phase 1 Final Design Report

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We express our gratitude to Caleb Mantey and Nicholas Abekah Eshun for their inputs and suggestions.

We also want to thank the school of Petroleum studies and all loved ones.

TEAM

The team is made up of engineering students from the University of Mines and technology, specializing in the same field with different abilities and lecturers with high earned qualifications. Here is a brief presentation of our team:

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Benjamin Amamoo: The team leader for team UMaT. Qualifications include 3rd-year degree at Ghana oil drilling Academy, IADC Drilling and well control Technology in the North Norwegian drilling academy **in Norway**

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Summary

The main purpose of this project is to develop a full-scale drilling system model, including its corresponding control scheme, to virtually drill a directional well following a given trajectory. We present an onscreen overview of the virtual directional drilling rig, which includes the architecture of the system containing the 3d model of the rig framework, brush view of its mathematical framework, modeling control schemes, details on software's and editors, showcase, and a brief overview of a user-friendly interface, for the virtual system control for the automated system. The virtual rig sub-systems include the rig structure, hoisting system, rotary system, circulation systems, drill strings, and BHA design formulas for code structured presentation.

Table of Contents

ACKNOWLEDGEMENT	ii
TEAM	iii
Summary	v
Table Of Contents	0
Project Model.....	2
Rig Oriented movement.....	6
Unity interface	7
CSharp.....	8
Codes and Graphical user interface	9
Data acquisition	9
Drilling Parameters	11
RPM	12
WOB	12
Torque.....	13
ROP.....	13
MSE	13
PRESSURE GRADIENT	14
HYDROSTATIC PRESSURE	14
CONTROLLING DRILLING	14
HYDRAULIC HORSEPOWER(HHP)	15
DRILL PIPE/DRILL COLLAR CALCULATIONS	15
DRILL STRING DESIGN (Limitations).....	16
CONCLUSION.....	18
REFERENCE.....	19

DESIGN

The virtual rig design is focused on mainly Mobility, functionality, versatility, stability, and safety. The framework presents a cost-effective and easily accessible type of design. Training new workers for an oil or gas extracting platform represents a particular challenge, especially if the rig is stationed off the shore. Most of the knowledge and experience necessary for manual laborers to perform their job properly is gained through practice on-site, so companies incur additional expenses by ferrying potential candidates to the platform and back. However, if the workers receive their oil and gas training through a VR simulation, it can make the process much simpler and less costly.

Working on an oil platform is hardly the safest job, and workers in this industry understand that there are serious risks involved, even with the right training and precautions. Some difficult and dangerous situations are impossible or near-impossible to recreate in a training environment for various reasons, but this changes when the environment is digital and does not require any physical props. For instance, an oil simulator can recreate the occurrence of an oil leak, allowing the user to respond accordingly without ever risking their life. This kind of practical knowledge will be much more useful in the event of an emergency than a set of memorized instructions.

The Oil & Gas Industry is facing the same workforce issues as many others – experienced workers are retiring faster than new employees can be brought up to speed to support the tremendous growth in the industry. Along with the retirements goes the knowledge of first-hand skills on how to deal with all of the possible challenges that can occur on a rig or platform. This transition of the workforce is called the "Great Crew Change" and the virtual world could make the impact of ideal knowledge faster and convenient.

Project Model

The project model has two phases. They include

1. The frontend model
2. The backend model

The Frontend model represents the 3d interface of the virtual rig and its environment. These environments include user interfaces designed to give the user much easier control over the automated virtual rig.

The Backend model represents the mathematically modeled end of the project. A *conceptual* model represents our ideas about how the system works. It is expressed visually in a model diagram, typically involving boxes (state variables) and arrows (material flows or causal effects). [SEP]

- . 2 Equations are developed for the rates of each process and are combined to form a *quantitative model* consisting of dynamic (i.e., varying with time) equations for each state variable. [SEP]
- . 3 The dynamic equations can then be studied mathematically or translated into computer code to obtain *numerical solutions* for state variable trajectories. [SEP]

Mathematical models and computer simulations are useful experimental tools for building and testing theories, assessing quantitative conjectures, answering specific questions, determining *sensitivities to changes* in parameter values, and estimating key parameters from data.

In phase 2 a presentation of the mathematical modeling aspect would be shown.

The 3D Model

Blender Software was used to make a 3D model of a rig depicting the various subsystem. This 3D model may be animated to give a pictorial representation of the common movement of the subsystem of the rig during its operation. The modeled subsystems include the hoisting system and draw works, the drill string, the bit, etc.

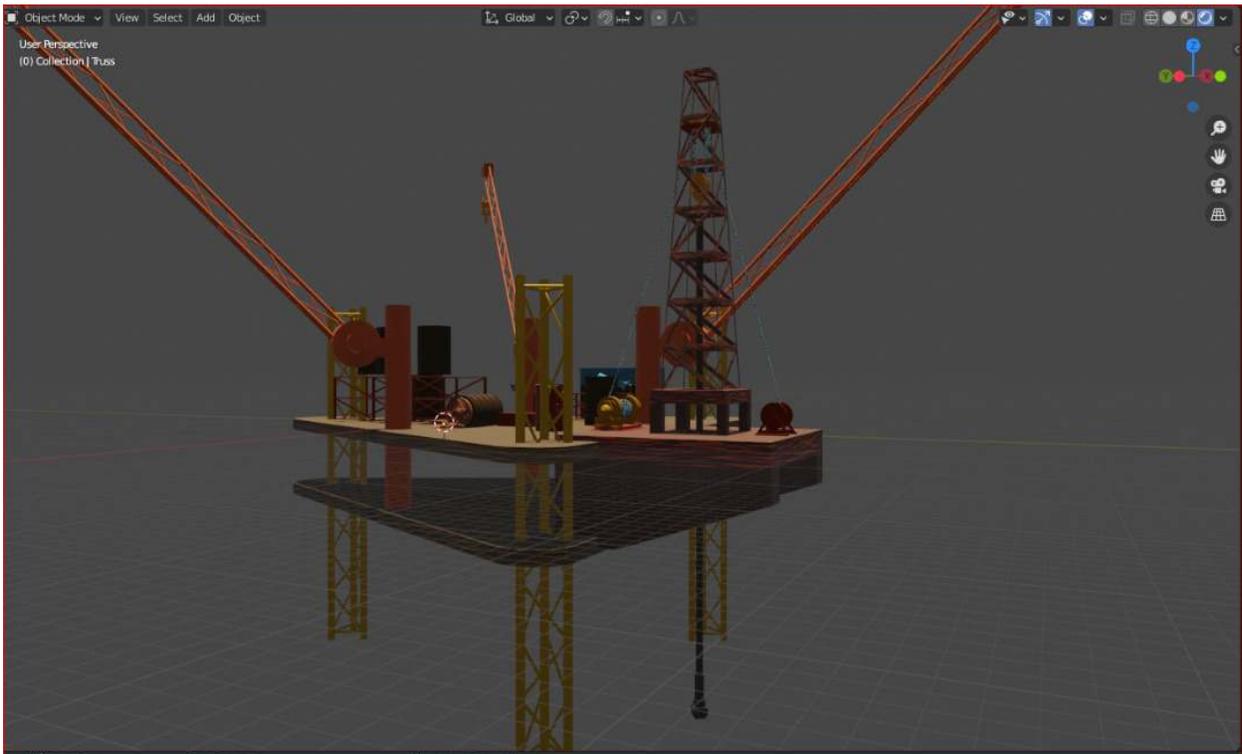


Fig 1.1

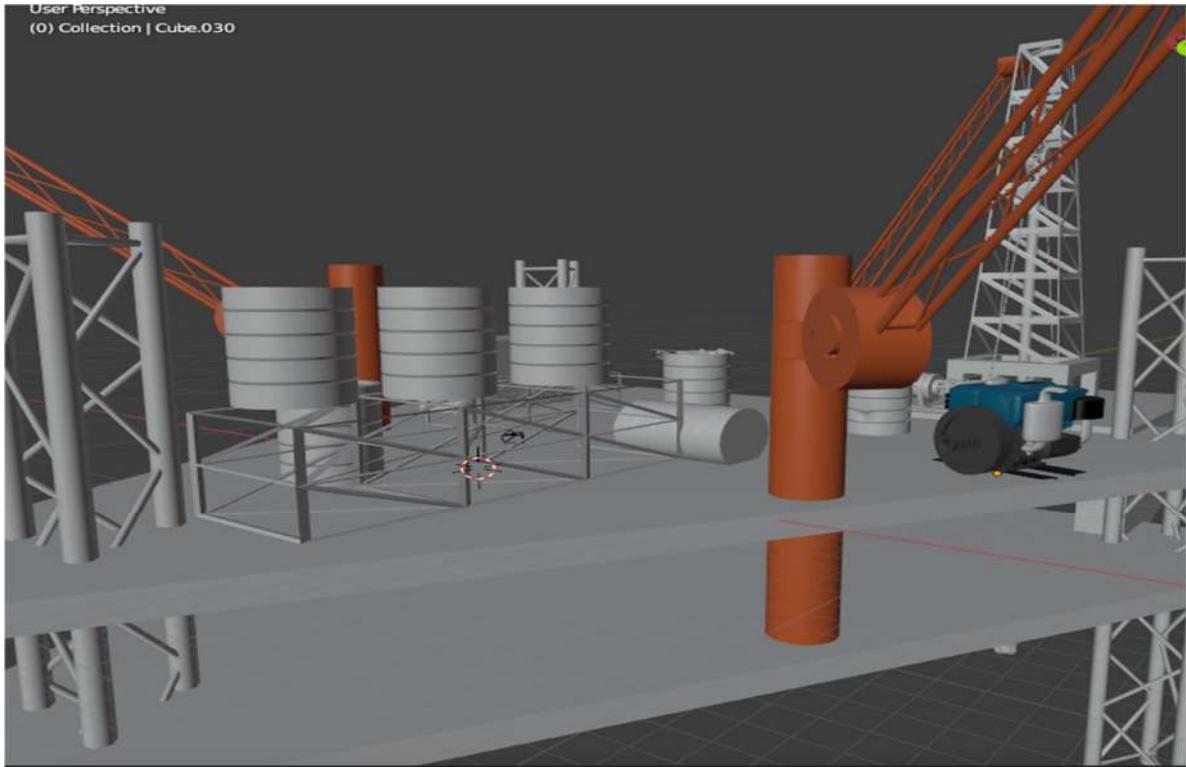
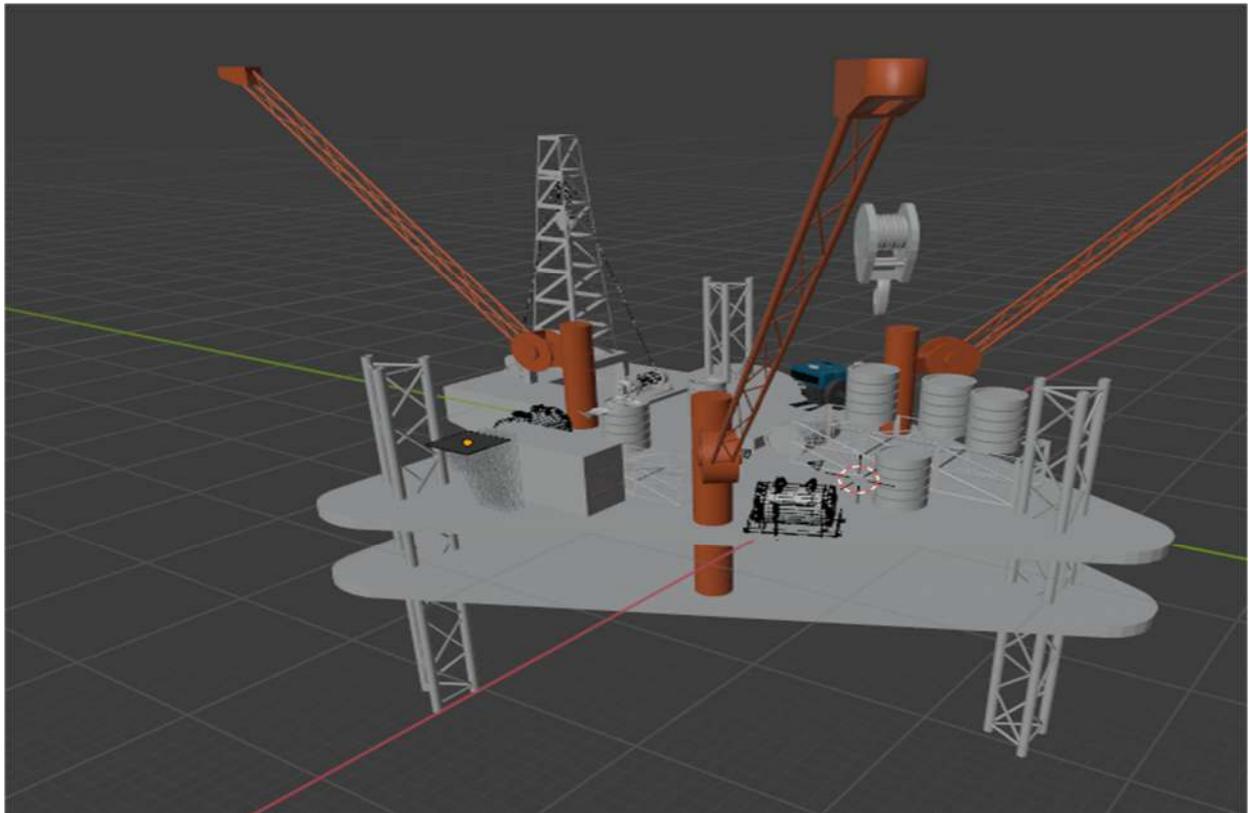


Fig 1.2



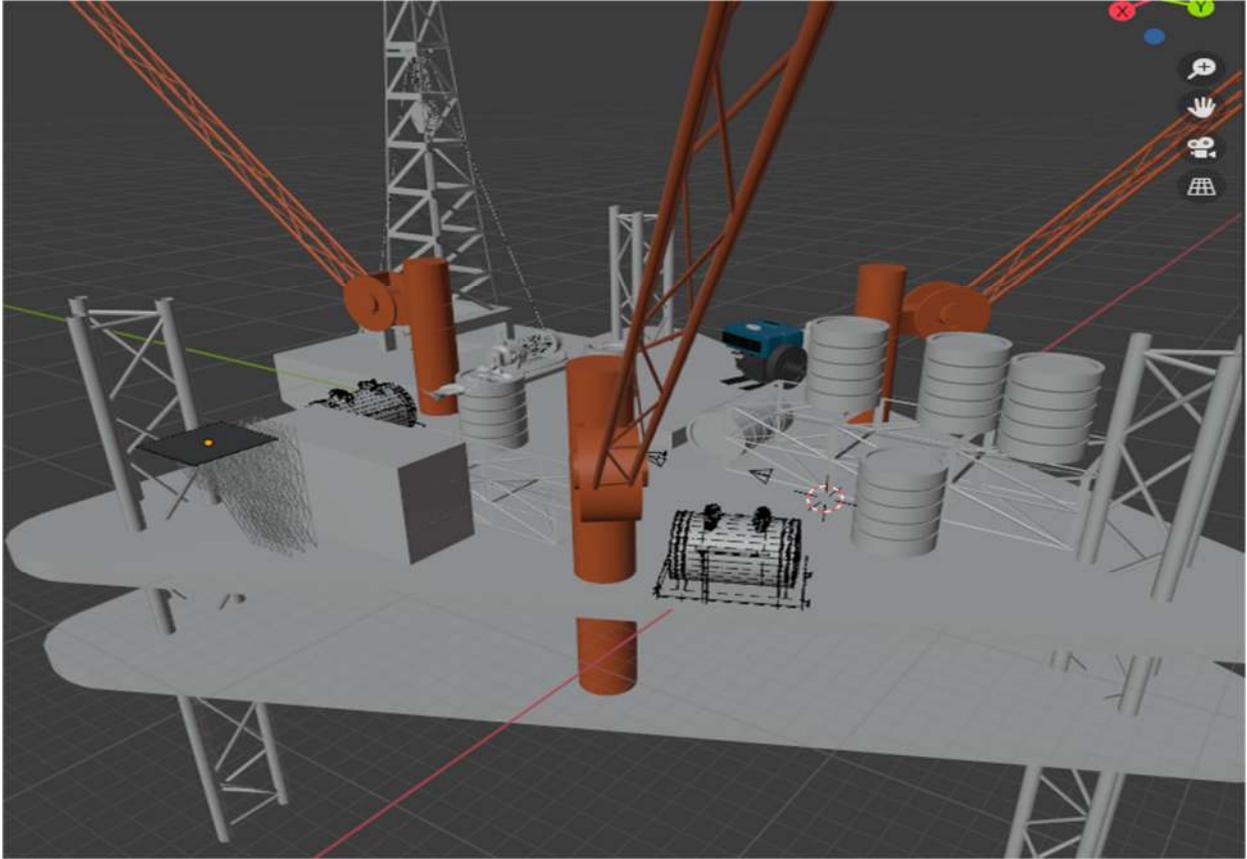


Fig 1.3

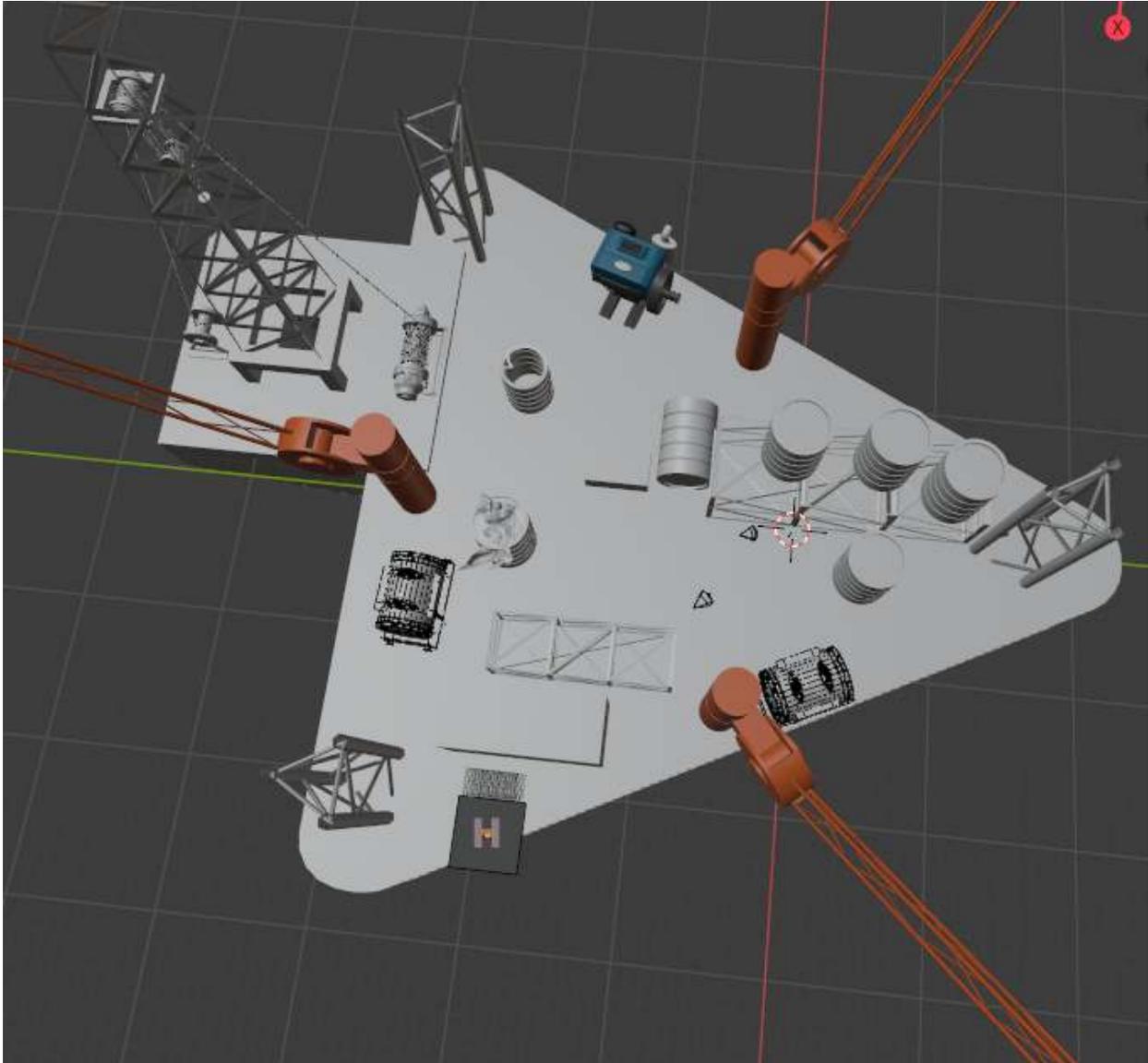


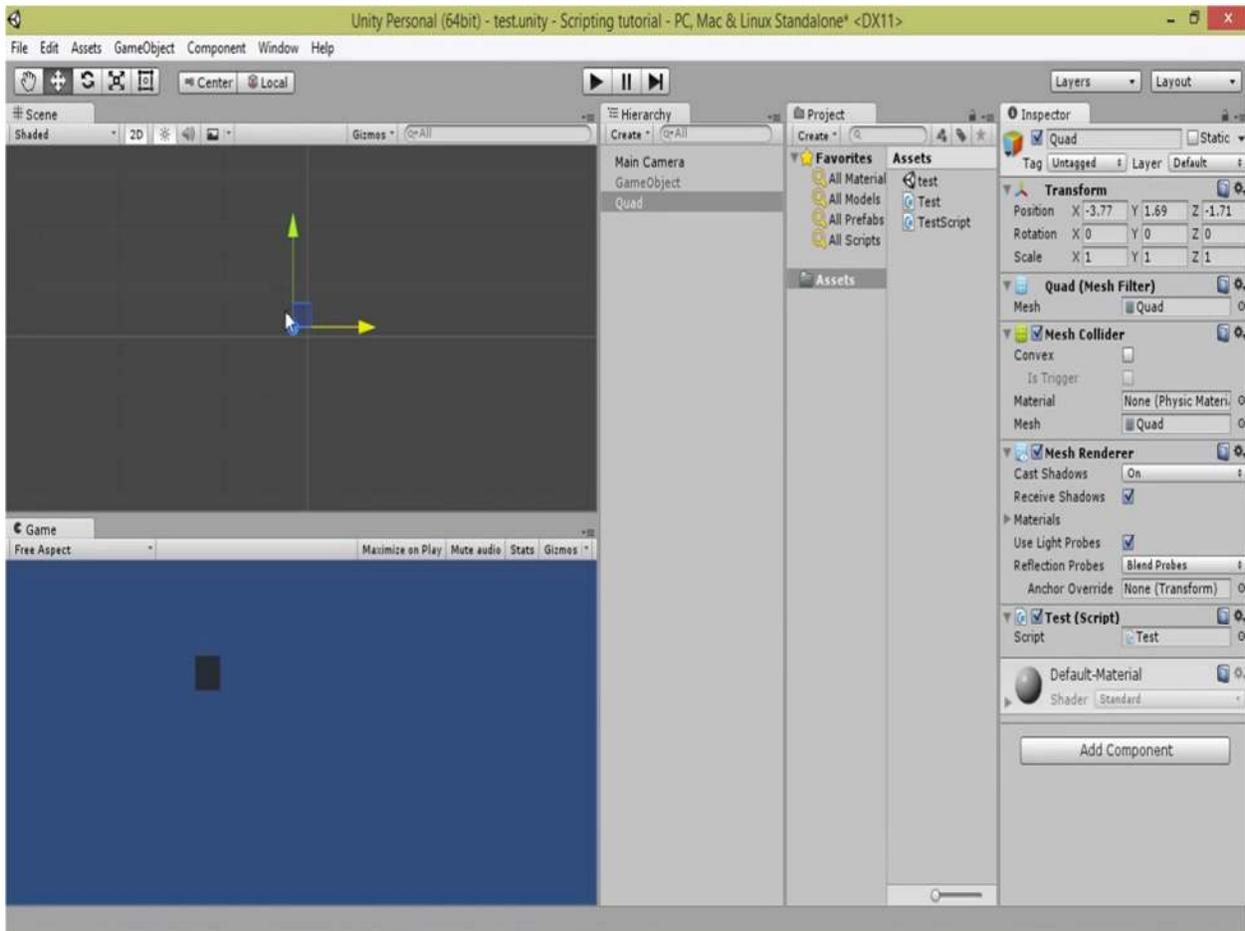
Fig 1.4

Rig oriented movement

The rig is selected completely after modeling and imported to unity (game engine). For a good simulation, unity and other gaming engines can render scenes with a fewer number of game objects, and thus the rig in full is cloned to create a duplicate, selected, and imported into the game engine.

The unity work interface provides the user with toolkits that allow the

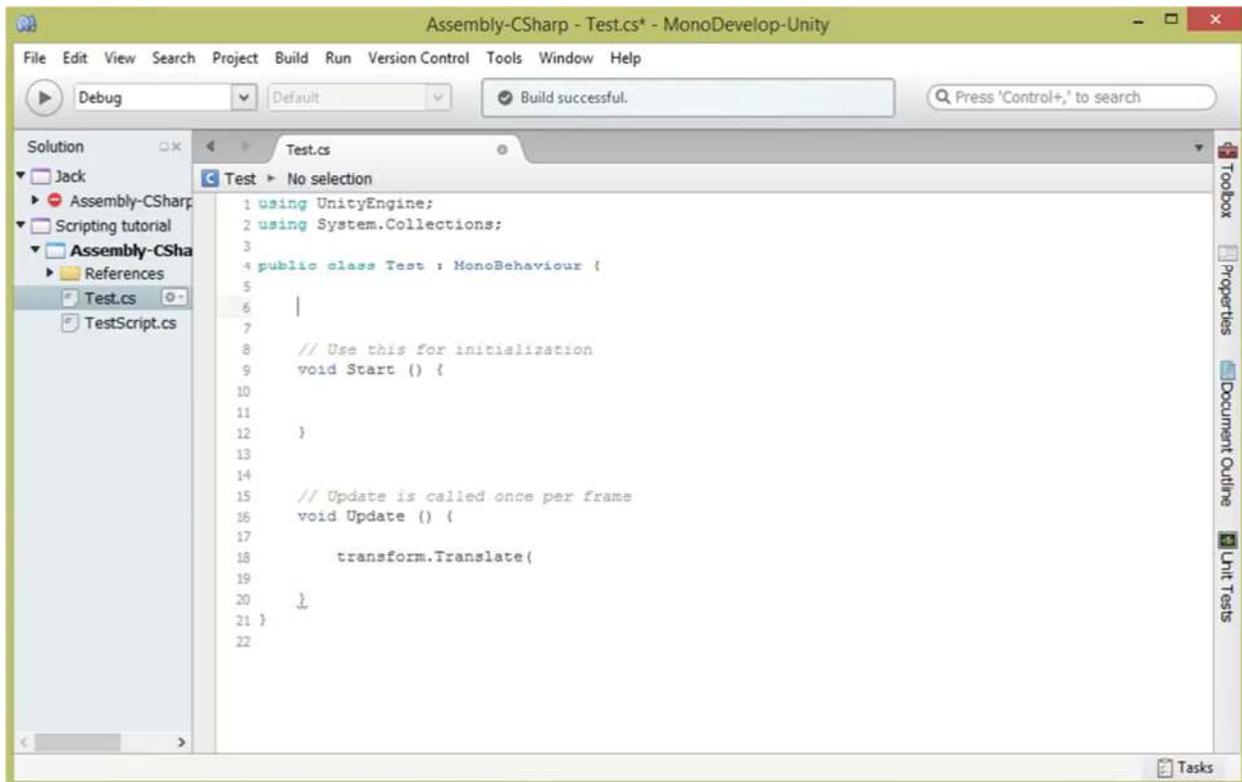
movement of modeled objects and the substitution of programmable features such as CSHARP for simulations based on parameter inputs built-in codes.



Unity interface

Codes are written in CSHARP using downloadable packages, mainly for this project, the Unity engine, and system. Collection with codes of orientation written based on the known axis of movements x, y, and z.

The CSHARP editor is shown below but could be written in other editors with c# such as visual studio code etc.



CSHARP

Codes and Graphical user interface

The control system GUI, we've chosen is PLC-based control while using LabVIEW in the supervisory role, which proposes using a Programmable Logic controller for I/O control and a computer for data collection and acquisition as the main hardware while at the same time using LabVIEW as the software development platform,

Data logging can be triggered by input. Also, once the data is collected through text input, it'll be placed in the backend of the written code, then displays simulation virtually via 3d display.

Data acquisition

The use of sensors and transducers to measure all the needed parameters in our autonomous design, these parameters are also converted into measurable electric signals (voltage) which are next transferred into the PLC which is the main I/O control unit (centralized system). Then transferred to the computer via Ethernet protocol to exploit this data for different uses. The advantage of this system is that it can realize synchronous data acquisition, as well as real-time display and preservation, also since we'll be using LabVIEW it is known to not only effectively play performance of an ordinary data acquisition system, but also beautify interface through LabVIEW (for data visualization) which has powerfully visual HMI editor and graphical programming function.

The Driller's Console (User Interface)

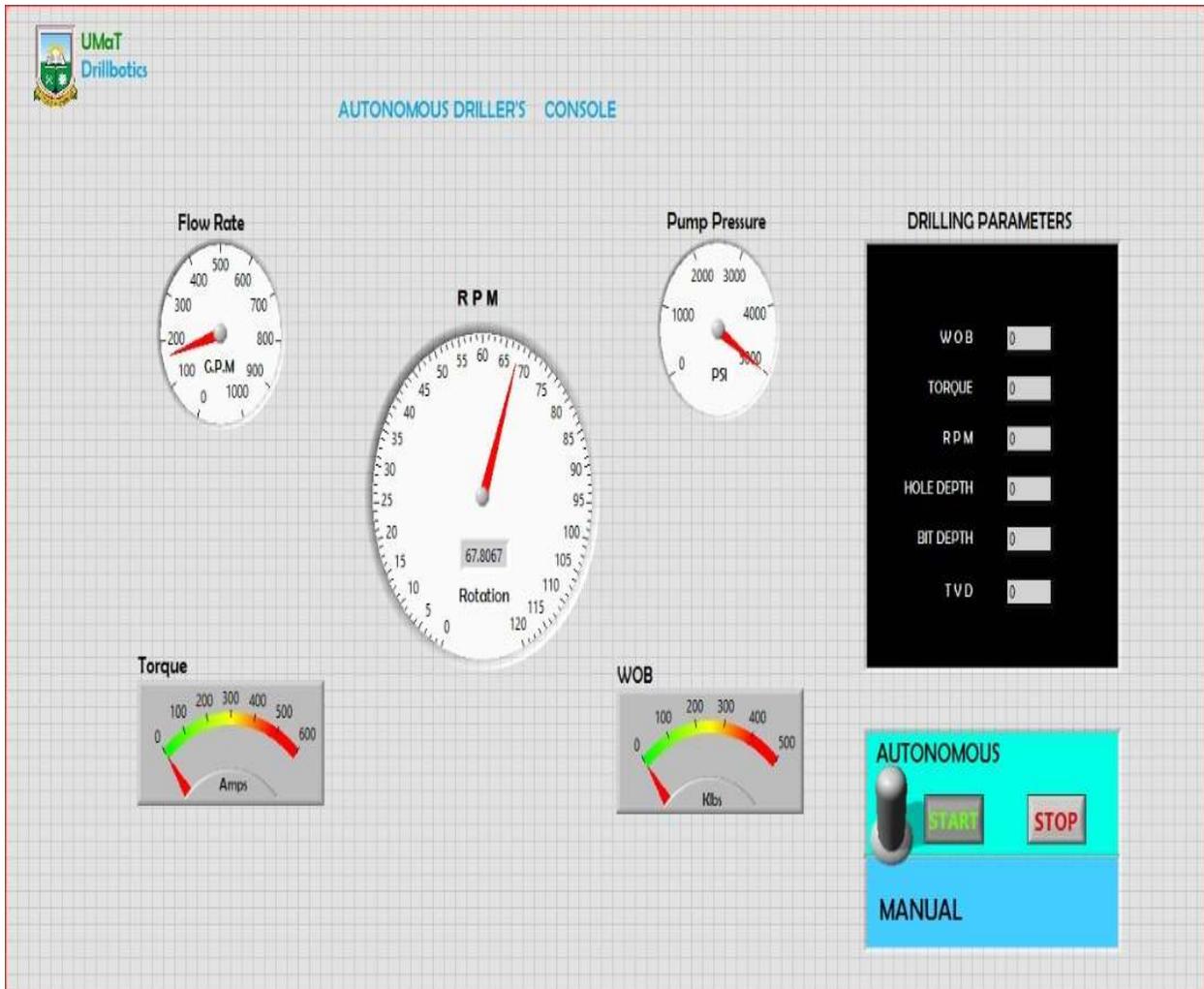
The User interface was designed using National Instrument LabView. The console displays in graphical form the change of drilling parameters as drilling operations proceeds. It uses gauges to display the RPM, WOB, and ROP as they change with time.

The true vertical depth, the measured depth, bit depth (which differs from the measured depth during tripping) and other parameters are displayed. There is a switch to toggle between the autonomous state and

the manual state in cases where automation must be overridden. In the autonomous state there is a start and stop button to commence or halt drilling operations.

The LabView user interface will update the displayed values as it receives values from the mathematical model. Since the mathematical model is written in the python programming language we will use the python node in the LabView software to communicate with the python codes and functions. Another option may be investigated into as we try to communicate between the model and the user interface. This other option is to run the LabView software as a server to the python model or vice versa. Its application would depend upon how it affects the performance of the virtual rig

The graphical user interface system for control is shown below.



Drilling Parameters: RPM, Depth (in.), WOB (lb.), Torque (lb.-in), ROP (in/min), MSE (psi),

Pump Rate (GPM), Standpipe Pressure (psi), Inclination (degrees), and Azimuth (degrees).

Analysis charts would be based on command simulations and also graphically represented as ROP vs Depth

The mathematical model

We are developing a mathematical model of the various subsystem of the drilling rig. The various subsystem under consideration is the drill bit model , the drill string model , the steering model, the hoisting system model, Bottom hole assembly model , rock/wellbore model.

Each systems properties will be defined using sub functions and the appropriate equations will be used to represent the physical interactions and operations of each model. Output values for one model may become the input of another model or these values would be used to set constraint and conditions for the operation of other subsystem models. Essential drilling parameters would be updated with time and the graphical display shown on the driller's console in real-time. Some of these parameters include the WOB, ROP, RPM, Torque, mud flowrate, etc.

RPM

Knowing how to calculate drilling speeds and feeds is critical for successful drilling. In this section, you find the drilling formulas and definitions needed for your drilling operations, such as cutting speed, feed per revolution, and specific cutting force.

WOB

An essential part of the drilling process is adding force to the drill bit to successfully break the rock. Weight on the Bit, or WOB, is the amount of downward force exerted on the drill bit provided by thick-walled tubular pieces in the drilling assembly that are known as drill collars. The downward force of gravity on these steel tubes provides the force for the drill bit to effectively break the rock.

The weight of the drilling assembly is controlled and measured while the drill bit is just off the bottom of the wellbore. Then, the drill string is slowly and carefully lowered until it reaches the bottom. As the driller

continues to lower the top of the drill string, more of the weight of the assembly is being applied to the bit and harmoniously less weight is hanging at the surface.

Torque is the rotational force between the drill string and the formation. There are two main causes of torque and drag, side forces and friction.

ROP

Rate of penetration (ROP), also known as penetration rate or drill rate, is the speed at which a drill bit breaks the rock under it to deepen the borehole. It is normally measured in feet per minute or meters per hour, but sometimes it is expressed in minutes per foot.

MSE is the amount of energy required to destroy a unit volume of rock and it provides a means of evaluating and optimizing drilling performance. By comparing MSE to the predicted CCS, as well as by comparing actual ROP to the predicted ROP, drilling performance and bit condition can be evaluated. Efficiency in drilling is measured by Mechanical Specific Energy (MSE).

Further tests will have to be conducted to determine the effective relationship between Weight on Bit, Rate of Penetration, Torque, and BHA design angle. This will be done in Phase 2 and will provide values to optimize the control algorithm to efficiently reach the drilling target with minimum time and in a virtual automated presentation.

PRESSURE GRADIENT

The change in pressure per unit of depth, typically in a unit of depth, typically in units of psi/ft. or kPa/m, hence this parameter helps us know the slightest pressure change per depth drilled.

Pressure gradient using psi/ft., using weight, ppg

Psi/ft. = mud weight, ppg x 0.052 Example 12.0ppg fluid

Psi/ft. = 12.0 ppg x 0.052

Psi/ft. = 0.624

HYDROSTATIC PRESSURE, psi, using pressure gradient, psi/ft.

Hydrostatic pressure (HSP) is simply, **pressure** due to a column of fluid that is not moving. That is, a column of fluid that is static, or at rest, exerts **pressure** due to local force of gravity on the column of the fluid.

This is mathematically represented as:

HP = psi/ft. x true vertical depth, ft.

Example: Pressure gradient = 0.624 psi/ft. true vertical depth = 8500 ft.

HP= 0.624 psi/ft. x 8500 ft.

HP=5304 psi

CONTROLLING DRILLING

Maximum drilling rate (MDR), ft./hr., when drifting large diameter holes (14-3/4 in. and larger)

MDR ft./hr. = $\frac{67 \times (\text{mud wt. out, ppg} - \text{mud wt. in, ppg}) \times (\text{circulation rate, gpm})}{D_h^2}$

Example: Mud weight in = 9.0 ppg Circulation rate = 530 gpm Hole size = 17-1/2 in. Mud weight out = 9.7 ppg

$$\text{MDR, ft./hr.} = \frac{67(9.7-9.0) 530}{17.5^2}$$

$$\text{MDR, ft./hr.} = 81.16$$

HYDRAULIC HORSEPOWER (HHP): GPM x psi / 1715 = **hydraulic horsepower** is the horsepower equivalent of “lifting” a continuous volume rate of fluid to the height in ft. represented by the pressure involved (as if a tall, open overflowing stand-pipe were connected to measure the pressure).

The mathematical representation is shown below.

$$\text{HHP} = \frac{P \times Q}{1714} \quad \text{Example: Circulating pressure} = 2950 \text{ psi}$$

$$\text{circulating rate} = 520 \text{ gpm} \quad \text{HHP} = \frac{2950 \times 520}{1714} \quad \text{HHP} = 894.98$$

DRILL PIPE/DRILL COLLAR CALCULATIONS

Capacities, bbl/ft., displacement, bbl/ft., and weight, lb/ft., can be calculated from the following formulas

$$\text{CAPACITY, bbl/ft.} = \frac{ID, \text{ in}^2}{1029.4} \quad \text{Displacement, bbl/ft.} = \frac{OD, \text{ in}^2 - ID, \text{ in}^2}{1029.4}$$

$$\text{Weight, lb/ft.} = \text{displacement, bbl/ft} \times 2747 \text{ lb/bbl.}$$

DRILL STRING DESIGN (Limitations)

The following will be determined:

Length of the bottom hole assembly (BHA) is necessary for the desired weight on bit (WOB).

Feet of drill pipe that can be used with a specific bottom hole assembly (BHA).

1. Length of bottom hole assembly necessary for the desired weight on bit:

Length, ft. = $\frac{WOB \times f}{W_{dc} \times BF}$ = Desired weight to be used while drilling

W_{dc} = drill collar weight, lb/ft.
 f = safety factor to place neutral point in drill collars

BF = buoyance factor

2. Feet of drill pipe that can be used with a specific BHA

Tensile strength for a new pipe can be obtained from the cementing handbook.

- a) Determine buoyance factor:

$$BF = \frac{65.5 - \text{mud weight, ppg}}{65.5}$$

- b) Determine the maximum length of drill pipe that can be run into the hole with a specific BHA

$$\text{Length}_{\max} = \frac{[(T \times f) - MOP - W_{bah}] \times BF}{W_{dp}}$$

Where T = tensile strength, IB for new pipe

F = safety factor to correct new pipe to no. 2 pipe

MOP = margin of over pull

Wbah = BHA weight in the air, IB/ft

Wbp = drill pipe weight in the air, Ib/ft. including tool
joint

BF = buoyance factor

- c) Determine the total depth that can be reached with a specific bottom-hole assembly:

Total depth, ft. = length_{max} + BHA length

CONCLUSION

We did our best but not all because we had a lot of work to do in a short period and tough conditions especially during this pandemic. Although, we are pretty sure that our virtual drilling rig can do the work that has been constructed regarding the guidelines and the restrictions given.

Working as a united team helped in the completion of this phase of the project and there is no doubt all members learned a lot and we hope we pass through the first phase successfully, to deliver a more strategic and complete work in phase 2.

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