INTERACTIVE SIMULATION OF WELL PLACEMENT TECHNOLOGY

BY

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INTERACTIVE SIMULATION OF WELL PLACEMENT TECHNOLOGY

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Dedication

I dedicate this work to my family.

Acknowledgement

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Abstract

We attempt the design and development of an educational game based on the Input-Process-Outcome model. This tool helps students and other professionals to learn and appreciate the decision-making processes carried out by geophysicists and petroleum engineers, concerned with the activity of well placement, to maximize production from oil fields. It also stimulates learning and application of technology to support decision making.

Chapter 1: INTRODUCTION

In this work we apply software engineering to simulate well placement in oil fields located in the Niger-Delta terrain of Nigeria, West Africa. Software engineering is concerned with developing and maintaining software systems that behave reliably and efficiently, are affordable to develop and maintain, and satisfy all the requirements that customers have defined for them (1). Well placement Technology is the combination of sub-surface reservoir development technology, formation evaluation and pressure analysis to ascertain a favorable position to drill oil wells in oil fields.

The process of well placement begins with exploration of the oil field. Seismic reflection analysis is carried out to determine the presence and location of trap and fluids in the reservoir. If results are favorable, wells are drilled in order to determine rock and fluid properties in the reservoir. If potentially economic accumulations of hydrocarbon are found, more wells are bored or more seismic is shot to carry out an appraisal of the field; this results in the delineation of the reservoir. More detailed data is collected from outcrop and reservoir's stratigraphic studies. Well tests such as pressure and flow rates tests are carried out. With all these data, a model is built. The model is dynamically simulated to predict oil production. The simulation results inform the decision on location to place well in the oil field. (See Chapter Three).

1.1Objectives

The objectives of this work are as follows:

- To build an instructional game that simulates the activities and processes carried out by geoscientists and petroleum engineers in different oil field terrains during well placement.
- To begin by simulating the operation of a dynamic model, designed to provide production forecasts to guide well placement in land terrain.

1.2 Motivation

This thesis has been presented because Prof. David Ogbe, a visiting Professor from Petroleum Engineering Stream of the African University of Science and Technology has requested that software be developed to fulfill the following requirements:

- Game for trade show exhibition, open house, seminars for secondary schools.
- Fun-filled academic learning tool for students and other professionals to learn and appreciate the decision making processes carried out by petroleum engineers and geoscientists to maximize production (reserves) from oilfields
- Provide a playful environment to stimulate learning and application of technology to support decision making.

There is strong indication that this software will be embraced by secondary school students because when a survey posed the question, "Educational computer/video games should be embedded in all taught courses" to a hundred and forty one secondary school students from Edo, Rivers, and Anambra states, the results analysed using the Likert scale reveal that

- 60.28 % responded Strongly agree
- 27.65% responded Agree
- 4.25% responded Don't care
- 2.13% responded Disagree and
- 5.68% responded Strongly Agree

1.3 Expected Results

- The developed software can be best described as a prototype. It is a 2D game that forms the basis of future work which may use more powerful 3D graphics to realize a fanciful game interface.
- Users should be able to play the game and learn from it.

1.4 Deliverables

At the end of this work we expect to have the following three deliverables

- Documentation on well placement technology used in the oil industry.

- A two-dimensional instructional game that simulates well placement in oil fields
- A meta-model of JavaFX platform.

1.5 Approach

We carried out an extensive literature review on computer games and well placement technology in order to have a good understanding of what features the software must have. On software development, we apply the spiral model of software engineering process to software building. We iteratively analyzed & specified, prototyped, designed and implemented, verified and validated the model to get the current level. We employed the Model View Controller (MVC) architectural pattern and leveraged on tools like Scene Builder and JavaFX Platform which tries to enforce this.

1.6 Thesis Organization

The remaining of this work is organized as follows: Chapter two discusses computer games and instructional games, their uses and benefits, early games etc. Chapter three is a literature review on well placement technology; it highlights the different scientists involved and their role in well placement. Algorithms used to compute reservoir performance over time is also provided. The chapter ends with examples of existing oil exploratory/well placement games. Chapter four presents the game; its functions and structures are depicted by the UML diagrams. It also describes the tools and technology used in realizing the software. Chapter Five is on implementation and Design while Chapter six presents documentation on how the game is played. Chapter seven is about future work and concluding remarks.

Chapter 2: COMPUTER GAMES, INSTRUCTIONAL GAMES

In this chapter we discuss the computer games and Learning games. We also explore the Input-Process-Outcome game model that defines how to make instructional games interesting for the player.

2.1Definition: Computer games

Jouni Smed et al in 2003 approached game definition from three perspectives, first by defining the properties common to all game, second by fitting computer games into model-view controller architectural pattern and discerning common software component and third, by listing features that players expect from an enjoyable computer game. On the first perspective, he points out five components, seven relationships and three aspects of a game. The components are the rules, goal, player, representation and opponent; the relationships are concretization, correspondence, definition, agreement, motivation, indeterminism, and obstruction; the aspects are play, challenge and conflict. These are described as follows:

Players are people willing to participate in game; rules define the limits of the game, and goals give rise to conflict among players. A player is motivated by the goal, he also agrees to the rules (rules that define the goal) thus represents the challenge aspect. A player is also obstructed (by other unpredictable players) from achieving his goal thus represents the conflict aspect. In the player aspect, the rules are abstract but correspond to real-world objects. These representations concretize the game to the player.

On the second perspective, a computer game is seen as a game carried out with the help of a computer program. Three roles which closely resembles the model-view-controller architectural pattern for computer program is identified. These are coordinating the game process (model), illustrating the situation (view), and participating as a player (controller).

On the third perspective, the sought after game features include freedom of players in the Game world, multi playing, customization, extensions, replaying and synthetic players (computer-generated actors) (2)

After reviewing several definitions of game, Juul(3)proposes that “a game is a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome the player feels attached to the outcome and the consequences of the activity are optional and negotiable and video games are “games using computer power, where the computer(pc and Macintosh games, console games, arcade games, cell phone games etc) upholds the rules of the game and the game is played using a video display (ibid page 1). Juuls claims the existence of a classical game model which computer games have evolved from.

2.2 Early Computer Games

Computer games date back to the days of early computers. According to Dave mount (4), one of the oldest examples was from 1958at the Brookhaven National laboratory, a research institute of the American government. It was a pong-like game called Tennis for two which was developed by William Higinbotham of Brookhaven National lab. Higinbotham converted an oscilloscope into a kind of pinball game. For him it was a way to demonstrate the operation of a piece of technology. One interesting aspects of Higinbotham’s creation was the interaction between player(s) and machine. He managed to make a scientific instrument attractive for a non-scientific audience, simply by obscuring its complexity and making it easy to manipulate. In this game, two tennis players would smash a ball back and forth, with the ball realistically bouncing off the ground and net, apparently under the influence of gravity. Though the game kept no score, there was clearly a winner and a loser after each volley.

The first time game was purposely designed for computer use was in 1961. Steve Russell, a student at Massachusetts Institute of Technology (MIT) developed Space War on a DEC PDP-1 computer. The goal of the game was for each player to maneuver his spaceship while trying to shoot the other players’ spaceship with torpedoes. Unfortunately, It could only be played by those who had access to a DEC PDP-1 (5).

Educational games are made to teach instructional concepts in an entertaining manner. The first notable of these games is The Oregon Trail, originally developed in 1971 by Don Rawitsch, Bill Heinemann, and Paul Dillenberger. The player assumes the role of a wagon leader guiding his party of settlers from Independence, Missouri, to Oregon's Willamette Valley over the Oregon Trail via a covered wagon in 1848(6). Other notable games in this category are *Carmen Sandiego* Series and *Mavis Beacon Teaches Typing (Wikipedia)*.

2.3 Educational/Instructional Computer Games

There is claim that digital games are used for Educational purposes because they are based on sound learning principles; provide more engagement for the learner; provide personalized learning opportunities; teach 21st century skills; and provide an environment for authentic and relevant assessment. This claim has been proven through the research work of Katie et al (7)

2.3.1 Simulations and Games

According to Greenblat, Simulation is an operating model of some system(8). Rosemary et al specified that key features of simulations are that they represent real-world systems; they contain rules and strategies that allow flexible and variable simulation activity to evolve; and the cost of error for participants is low, protecting them from the more severe consequences of mistake.

There is such a thing as simulation- games. Such combination would be defined as a low-stakes contest with rules with or in an operating model of a real thing. An example of such game is a three-dimensional, operating model of a human body where the player has to manipulate caloric intake and metabolic rate to achieve and maintain a target health level. Oregon Trail is an example of a simulation game. It is a functioning model of a wagon train in which the player strives to get families safely to Oregon(9). Such simulation games are used for educational purpose.

2.3.2 A MODEL FOR INSTRUCTIONAL/ EDUCATIONAL GAMES

Rosemary et al, developed a game model for instructional games (see Figure 1). It is based on the traditional input-process-output model. It emphasizes the *game cycle* as a key component.

This key component is triggered by game features which users are drawn to causing them to play the game time and again. The game cycle is viewed as iterative, such that game play involves repeated judgment-behavior-feedback loops. This means that game play can lead to user reactions such as increased interest or involvement or confidence; these reactions lead to behaviors such as greater persistence or effort; and these behaviors result in system feedback on performance in the game context.

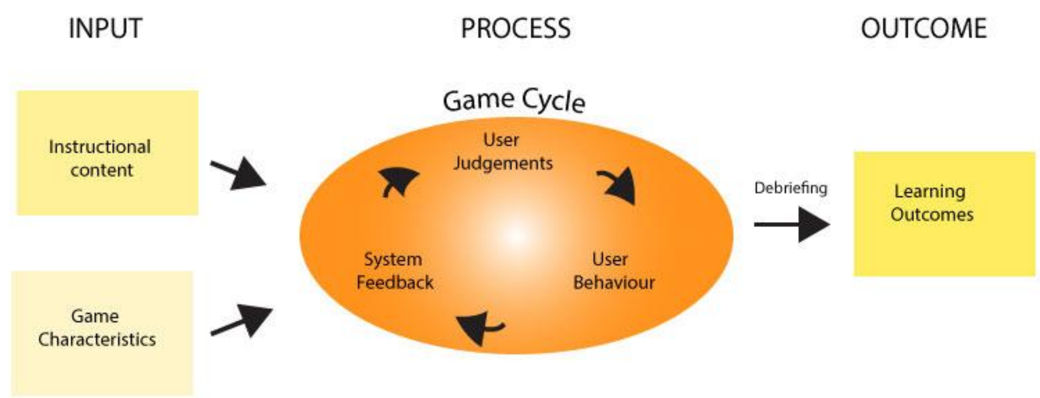

Figure 1: INPUT-PROCESS-OUTCOME Game Model (10)

These characteristics (game features) are Fantasy, Rule/Goals, Sensory Stimuli, Mystery, Challenge, and Control; they are as below.

Fantasy

Games involve activities that are imaginary and unrestricted by reality. Research has suggested that the use of fantasy in instructional games contribute to greater interest and increased learning (11). Fantasy in games causes players to be wrapped up in a unique role in a world separate from day to day activities thus making game play a priority for them (10). Fantasy context could either be closely tied or not to the learning content. When they are closely tied and fantasy is interesting, game play becomes more engaging (12)

Rules/Goals

Rules are directions that define the way a game is to be conducted. Precise rules govern game play. Rules describe the goal structure of a game; goals that are clear, specific and difficult lead to increased performance because players are able to adjust to them when their performances do not match up. There are different type of rules that operates within a game frame; they are System, Procedural and Imported rules (13). System rules define how the world in the game operates; Procedural rules define actions that can be taken in the game world examples are actions that takes you to the next level of play; Imported rules are those the players import from the real world into play examples are rules that prohibit cheating

Sensory Stimuli

The motivational appeals of games are enhanced by sensory stimuli like novel sound effect and dynamic graphics that are foreign to the senses because they catch the attention.

Control

According to Rosemary et al, research has compared effects of program control versus learner control on user reaction and motivation; positive results have consistently favored learner control.

Challenge

Individuals desire optimal level of difficulty. This means that they are challenged by activities that are neither too easy nor too difficult to perform. Optimal level of difficulty can be achieved by

- Having clear goals with uncertain possibilities of achieving them.
- Having performance feedback on progress achieved.
- Designing games that have multiple goals and employ progressive difficult levels.

Mystery

Mystery is something that baffles understanding and cannot be explained. Curiosity is one of the primary factors that drive learning, it resides within an individual. Mystery evokes curiosity in the learner thereby increasing motivation of game play

The types of learning outcomes that are desired from simulation games are Skill-Based, Cognitive, and Affective.

- Skill-Based learning outcome refers to performance of technical or motor skill.
- Cognitive learning outcomes include Declarative, Procedural and Strategic. Declarative refers to knowledge of the facts and data required for task performance; Procedural refers to Knowledge about how to perform a task; and Strategic refers to the ability to apply rules and strategies to general cases.
- Affective refers to attitude regarding an object or activity. They include feelings of confidence, self-efficacy, attitudes, preferences and dispositions. Meaning that attitude change is a training objective of instructional programs.

Chapter 3: OIL EXPLORATION, WELL PLACEMENT TECHNOLOGY AND ASSOCIATED COMPUTER GAMES

3.1INTRODUCTION

This chapter focuses on exposing the oil exploratory activities carried out by geoscientists and engineers. These activities must be carried out in order to locate the right zones to place well in an oil field. We also describe and expose the functionalities of computer games that are related to oil exploration/well placement technology.

3.2 FIELD DEVELOPMENT

The three main stages of field development are exploration (through to discovery), appraisal, and production. The process begins with a conceptual geologic model; then follows with seismic analysis. If the seismic data reveals a potential drill site, a well is drilled in order to determine rock and fluid properties and volumes of hydrocarbons in the sub-surface. If potential economic accumulations of hydrocarbons are found in the exploratory well, appraisal of the field is carried out to enable delineation of the reservoir. More detailed knowledge of the reservoir is required, so outcrop analog studies among others studies (like well tests) are carried out to aid the characterization process. With the hard data from these studies, models can be quantified and scaled. Graphical three dimensional reservoir geologic models can be built that petroleum engineers can use to simulate the reservoir's performance (14)

To develop an ideal reservoir scheme, the focus should be to maximize recovery, speed up production and minimize risk. Risk is reduced by having an elaborate knowledge of the distribution of rock properties. This knowledge is vital for the functioning of both the reservoir and the wellbore (15). This tells us that Geology is fundamental to understanding wellbore operation. Wellbore productivity and drainage area are affected by permeability variations, connectivity and sand body geometries. Permeability is defined as the ease with which the subsurface reservoir can transmit fluids from one location to another within the system. Connectivity deals with how the pore spaces that store the hydrocarbons are interconnected to form pathways for fluids to flow from one location of the reservoir to another.

3.3 WELL PLACEMENT

Well placement is the combination of right reservoir development technology and expert formation evaluation analysts to accompany the drilling procedure to layout wells that cross the most beneficial pay zones safely, expeditiously, and on time. With this combination, hydrocarbon retrieval is maximized, water production is deferred and well life is prolonged. Accurate well placement ameliorates the long and short term performance of wells (16).

Designing and constructing wells necessitates real-time interactions amongst geologists, who require quality formation evaluation data; drillers, who need significant input from geologist; and petrophysicists, who interpret the formation evaluation data during the drilling process in order to optimize well placement. Although the Geologist, Driller, and Petrophysicist make well placement possible but the cycle begins with the Geophysicist and ends with the Petroleum Engineer.

3.3.1 Geophysicist

In Geophysics, physics is used to study the earth and learn about its properties. Some examples of physical properties studied are the earth’s size and gravity, the weather and atmosphere, and seismology. Seismology studies seismic waves that pass through and around the earth. By studying seismic waves, geophysicists learn the nature of earth deep within surface. Seismic waves can result from natural event like earthquake or it could be artificially produced (air gun, water gun, thumper, etc.) (17).

In oil exploration, geophysicists plan and carry out land and marine surveys. They are required to ensure that a land or marine area being developed is suitable. They gather information from seismic operations and occasionally from gravity, magnetic, satellite or light detecting and ranging surveys. This information is processed and interpreted to provide an image of the subsurface. The interpretation also gives information on sediments, mineral and rock compositions and geologic structures. They therefore are able to ascertain where oil and gas deposits are most likely to occur.

3.3.2 Petroleum Geologist

Petroleum geology is the study of origin, occurrence, movement, accumulation, and exploration of hydrocarbon fuels (Wikipedia 2013).

The petroleum geologist gathers and makes use of already existing data like hydrocarbon production data, electric logs, core records, etc. The data is used to build cross-sections, maps and databases. Reservoir engineers and geologists conduct studies on their built maps, cross-sections and run computer simulations that help them select the next best location to drill.

The petroleum geologist is concerned about the makeup of sedimentary rocks he will be drilling through, the kind of traps that holds a pay zone, and the properties of the rock in the pay zone. The properties estimated are porosity, permeability, sand thickness, etc. The geologist also needs knowledge of pressure situation to be expected in a new hole to be drilled. He consults with the geophysicist in case he needs an opinion on seismic data.

The geologist has the task of supervising and appraising test holes as they are drilled. As new layers are met while drilling, he decides when to take core or drill-stem test. He also has the responsibility of deciding if a hole drilled should be completed or left alone. (18)

3.3.3 Petrophysicist

Petrophysics is the study of physical and chemical rock properties and their interactions with fluids. Petrophysicist helps reservoir engineers and geoscientists to understand the rock properties of the reservoir, particularly how pores in the subsurface are interconnected, controlling the accumulation and migration of hydrocarbons. Some of the key properties studied in petro physics are lithology, porosity, water saturation, permeability, and density. A key aspect of petro physics is measuring and evaluating these rock properties by acquiring well log measurement in which a string of measurement tools are inserted in the bore hole, core measurement in which rock samples are retrieved from sub surface, and seismic measurement. These are then combined with geological and geophysical studies and reservoir engineering to give a complete picture of the reservoir (Wikipedia, 2013).

3.3.4 Petroleum Engineer

Petroleum engineering is a field of engineering concerned with the activities related to the production of hydrocarbons, which can be either crude oil or natural gas. It is divided into Production, Drilling, and Reservoir engineering.(Wikipedia 2013)

- Reservoir engineers work to optimize production of oil and gas through proper well placement, production rate and enhanced oil recovery techniques.
- The drilling engineers manage the technical aspect of drilling exploratory, production and injection wells.
- Production engineers, including subsurface engineers manage the interface between the reservoir and the well, including perforations of the wellbore to access the reservoir, sand production control, down-hole flow control, and down-hole monitoring equipment; Evaluate artificial lift methods to supplement the natural energy of the reservoir to transmit fluids to the surface; and also select the surface equipment that separates the produced fluids (oil, natural gas, and water) for processing and transport to market.

The petroleum engineer will decide the type of casing and the method of cementing to use for the drilling process. He banks on the geologist to apprise him on various matters like formation tops, specific zones to test. etc. He uses this information to design the completion routine involving processes like perforation of the well, installation of pumps to help lift the fluids from the wells to the surface, etc. (18)

Table: Reservoir Data

CLASSIFICATION	DATA	ACQUISITION TIMING	RESPONSIBILITY
Seismic	Structure, Stratigraphy, Faults, Bed thickness, Fluid and Interwell heterogeneity	Exploration	Seismologist, Geophysicists
Geologic	Depositional environment diagenesis, Lithology, Structure, Faults, and Fractures	Exploration, Discovery and Development	Exploration and Development Geologists
Logging	Depth, Lithology, Thickness, Porosity, Fluid Saturation, Gas/Oil, Water/Oil and Gas/Water contacts, and Well-to-Well Correlations	Drilling	Geologists, Petrophysicists and Engineers
Coring	Basic: Depth, Lithology, Porosity, Permeability, and Residual Fluid Saturation Special: Relative	Drilling	Geologist, Drilling and Reservoir Engineers, Laboratory Analyst

	Permeability, Capillary Pressure, Pore compressibility, Grain Size, and Pore Distribution		
Well Test	Reservoir Pressure, Effective Permeability-thickness, Stratification Reservoir Continuity, Presence of Fractures or Faults, Productivity and Injectivity Indices, and Residual Oil Saturation	Discovery, Delineation, Development, Production and Injection	Reservoir and Production Engineer
Production &Injection	Oil, Water, and Gas Production Rate, and Cumulative Productions, Gas and Water Injection Rate and Cumulative Injections, and Injection and Production Profiles	Production and Injection	Production and Reservoir Engineers

Examples of data acquired from the team of interdisciplinary geoscientists and engineers include:

- Rock porosity - the rock's ability to store fluid
- Saturation- amount of fluid (oil, gas, water)in a unit volume of pore space in the reservoir

- Trap- presence or absence of a good seal to hold oil from migrating from the source location to another location
- Sand Thickness- the thickness of the depth interval between the top and bottom of the reservoir
- Sand-Shale proportion - the ratio of the volume of sand to the volume of shaleswithin the volume of the reservoir
- Flow rate- the volume of fluid produced per unit time from the reservoir through the well to the surface
- Permeability –rock's ability to transport fluids (oil gas and water) from one location of the reservoir to another.

The data are used to compute the volume of oil originally in the reservoir before production (i.e., the Stock Oil Initially in Place (STOIIP) and the Flow Rate (q). These two (2) parameters along with the pressure distribution measure the success of well placement. The volume of hydrocarbons the reservoir produces over a period of time can be captured by incorporating pressure, permeability, and compressibility data into the model algorithm.

3.4 CALCULATION OF STOCK TANK OIL INITIALLY IN PLACE (STOIIP), GAS INITIALLY IN PLACE (GIIP), AND DARCY'S EQUATION

STOIIP

$STOIIP = A \times h \times (NTG) \times \emptyset_i \times S_{oi} \times b_{oi}$ …………………………………………….(1)

Where $A =$ Area of the Oil Zone

$b_{oi} =$ Initial Oil Shrinkage Factor ($= 1/B_{oi}$)

$B_{oi} =$ Initial Oil Formation Volume Factor

$h =$ Thickness (Gross, Oil Zone)

NTG = Net-To-Gross Thickness Ratio (Oil Zone) related to the sand-shale proportion in the reservoir

S_{oi} = Initial Oil Saturation

$\emptyset_i$ = Initial Porosity (Oil Zone)

GIIP

$GIIP = A \times h \times (NTG) \times \emptyset_i \times S_{gi} \times (1/B_{gi})$ ……………………………………...(2)

Where A = Area (Gas Zone)

B_{gi} = Initial Gas Formation Volume Factor

h = Thickness (Gross, Gas Zone)

NTG = Net-To-Gross Thickness Ratio (Gas Zone)

S_{gi} = Initial Gas Saturation

$\emptyset_i$ = Initial Porosity (Gas Zone)

DARCY'S FLOW EQUATION

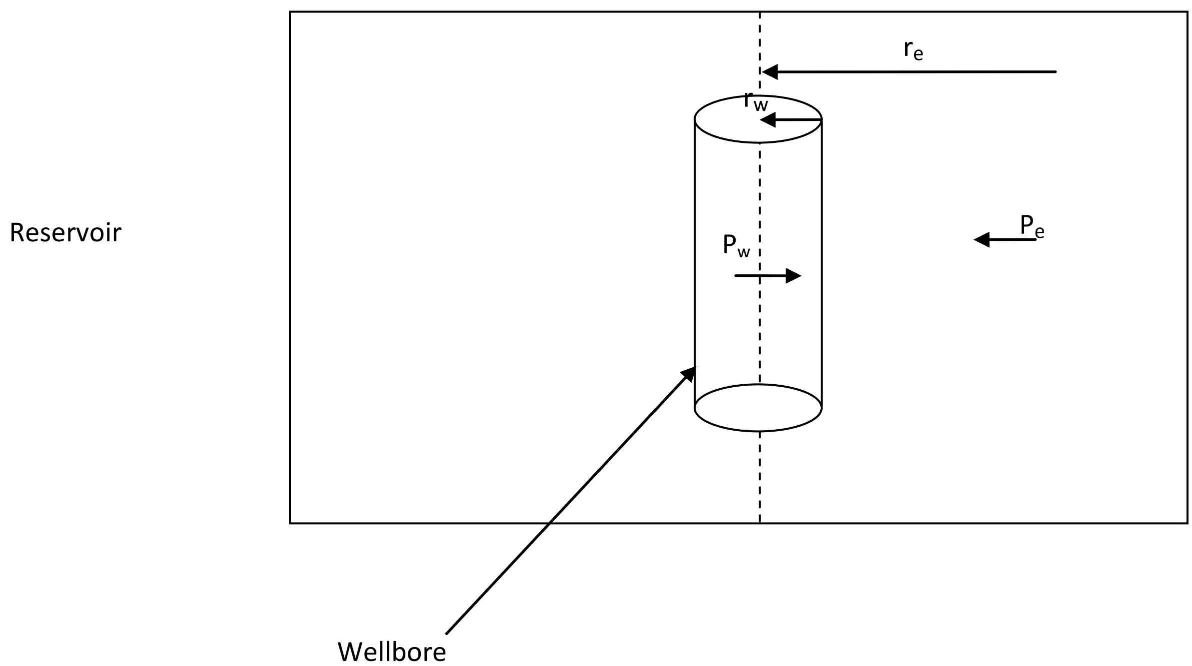

Figure 2: Well Core in Reservoir

$$q = \frac{2\pi Kh(P_e - P_w)}{\mu\left[\ln\left(\frac{r_e}{r_w}\right) + S\right]}$$

……………………………………………………………………………… (3)

Where q = Flowrate

h = Reservoir sand thickness

K = Permeability

P_e = Pressure at the reservoir boundary

P_w = Pressure at the wellbore

μ = Fluid viscosity

r_e = Radius of the reservoir boundary

r_w = Radius of the wellbore

S = Skin factor

3.5 EXISTING OIL EXPLORATION/WELL PLACEMENT COMPUTER GAMES

There are a host of computer games available which aim to expose the economic, political, business, educational, and strategic nature of petroleum oil as related to exploration down to production and distribution. Examples of such games are not limited to Virtual Oil Well, Oiligarchy, Oil Blue, Oil Rush, and Oil Platform simulation games. They are as described.

3.5.1 Virtual oil well game

The game is built for learning some geological issues involved with oil exploration, particularly about interpreting seismic data. Emphasis is on exploratory cost, working with consultants and meeting regulations. Players are expected to know about seismic stratigraphy and well logging.

Players are expected to

- find oil with limited budget
- Interpret seismic data to search oil traps for petroleum
- File environmental impact statements before drilling and
- Use drill logs to determine when to start pumping.

Access to library (with several pages on how oil is trapped and how to find the trap using seismic data) is provided. The game was designed for introductory level college students

3.5.2 Oiligarchy

Oiligarchy is a simulation game for teen/high school students, to teach entrepreneurship to kids. It combines large scale industrial development with money making strategies. The emphasis while playing is to become very rich over time in the oil industry by

- Sending exploratory vehicles to find the reservoir over land or sea and deploying wells to drill from them.
- Managing performance of reservoir overtime and tracking the variables that affect business.
- Donating money to presidential candidates that can support you to keep drilling for oil when they get the presidential seat. Also making friends in Washington ("oiled representatives") that will help enact laws that increase the economy's oil addiction or cut taxes on player's activities
- Managing resistance that may arise from local communities and use political means to overcome problematic scenarios

3.5.3 Oil platform simulator

Game play focuses on hunting for oil both the North Sea and Gulf of Mexico. Player is put in charge of operations. He manages the process involved in locating drill sites, assembling components for drilling, transporting oil to refinery and distribution of oil around the world. Players show savvy by successfully carrying out these jobs in face of break down that may occur in any equipment.

3.5.4 The Oil blue

This a game produced by vertigo gaming. The play is characterized by drilling of oil in the world's oceans, selling barrels of oil on the market, and exploring new islands after completing objectives set by your employer (each new island is unique for a game play). The play is also characterized by a set number of days and oil barrels to make on entering a new island. A player has to also watch the oil barrel market in order to sell at the highest price and repair any faulty machines; all carried out within a limited time.

3.5.5 The Oil Rush

This is a naval strategy game powered by UNIGINE. Game play is built around a fantasy world of boundless water caused by flood. There are two things to fight for oil and water, and player has to capture and defend oil rigs and destroy enemy in the sea and land.

Chapter 4: RESEARCH METHODOLOGY

In this chapter, we propose an instructional game for well placement technology. The functionalities and structure of the game are discussed.

4.1REQUIREMENT ANALYSIS

Introduction

In this game, the player is taken to the Gulf of Guinea region in Nigeria, West Africa. He poises as a geoscientist who decides what terrain he would want to place his oil wells. After selecting a terrain, he considers the properties of a reservoir and decides on the best position he would want to place his oil wells. He rewards himself with virtual income if he selects appropriate pay zones.

Features

The software

- Provides choices of terrain to select from.
- Displays reservoir properties when player requests geologies from the selected terrain
- Has algorithms to calculate revenues derived from volume of oil produced
- Contains tutorials on game play and reservoir properties
- Players can navigate through screens before actual game play

Design Goals

We intend to realize a game that

- Simulates the activities and processes related to well placement carried out by geoscientists and petroleum engineers in different oil field terrain.
- To begin with a module that simulates the operation of a dynamic model in a land terrain.

Since the system function as both a game and an instructional material, it will attempt to integrate the Input-Process-Outcome Game model and the instructional contents of well placement technology.

Genre

- Educational-it educates on reservoir properties and how they affect the amount of oil that can be produced from a well drilled through the reservoir.
- Simulation- The game simulates the behavior of the dynamic model of a reservoir.

Platform

Any computer with java run time installed.

Competition

Existing oil exploratory related games in the market are as tabulated

Name	Audience	Genre	Goal	Description
Virtual oil	Low level college students	Educational, Strategy	Motivating students to learn geological issues involved with oil exploration particularly interpreting seismic data	Players prospect for oil using seismic profiles on limited budgets.
Oil Strike	Student between age group eleven and sixteen	Educational	Motivating students to learn chemistry particularly fractional distillation	Students are expected to search and drill for oil, transport it to the refinery and produce different oil products
Oiligarchy	older kids and teens	Strategy	Motivating students to develop money making strategies required in the oil industry.	One plays the role of a big-time Oil Tycoon, and has to earn as much virtual income as possible by drilling for oil and making political deals, influence world leaders, and maximize profits to succeed.

Unique Selling Points

ISWEPT, though an oil exploratory game, is different from all other games because from my extensive search I have not seen any game that attempts to teach the petrophysical properties of a reservoir and the concept of static and dynamic simulation of a reservoir model.

4.2 GAME PLAY REQUIREMENT SPECIFICATION

Core Vision

When the player launches the game, he will have the options to launch a tutorial on reservoir properties that determine well placement, change game settings (like sound or music), or play a game. If he is playing a game, he is presented with a new scene with options of terrains to explore. On selecting a specific terrain (land, swamp, shallow offshore, or deep offshore), he encounters three statically modeled reservoir (geologies) and chooses one which he considers for well placement. He makes virtual money if he can select the appropriate locations to place his oil wells so that the revenue generated from the sale of oil produced exceeds the cost of drilling the wells.

Design Philosophy

The most important design goal is to educate on how reservoir properties affects well placement but the player must be motivated hence the proposed game will attempt to satisfy the Input-Process-Outcome Game model suggested by Rosemary et al. Their model specifies that instructional curriculum should integrate certain game characteristics that would in turn begin the game cycle that leads to the desired learning effects. The game characteristics are Fantasy, Rules/Goals, Sensory stimuli, Challenge, Mystery, and Control. They are determinants for motivation in game play. The Game cycle is achieved when game leads to repeated cycle of user judgment, behavior and feedback. Desired Learning outcomes for the purposed game are Affective and Cognitive.

The following game characteristics are of priority to the game play

Rules/goals	A Player can select only one terrain and one geology during a game play; Players will select a maximum of five infill well positions; their

	goal is to select the best part of the reservoir to place their wells;
Sensory stimuli	They will be stimulated by sounds and animations that respond to the actions during game play
Challenge	They will be challenged by the task of determining the best combination of properties that affects well placement
Mystery	We will incorporate game elements that evokes player curiosity

Objectives

In well placement technology, information from the geophysicists, geologists, petrophysicists and the petroleum engineers are integrated to make decisions on well location. Their activities culminate to the building of a model with reservoir discretized into grid blocks and the well location defined by block in the discretized model. The model will be simulated to determine the volumes of oil produced by a well over a period of time for a certain well placement. Decisions on position to place well is made from the simulations; if the favorable position is picked, they make good money but if not they incur losses.

Our objective is to develop a game world model of a reservoir. Properties of the reservoirs are known; appraisal wells used for delineation of reservoir are automatically place during game play. A player has a maximum of five choices of reservoir location to drill for oil.

The objective of the player is to make virtual money, but in the process he learns about activities involved in oil exploration, reservoir geological properties and how they affect well placements.

Actions

The user can perform different actions during game play; these are specified by the use case diagram below.

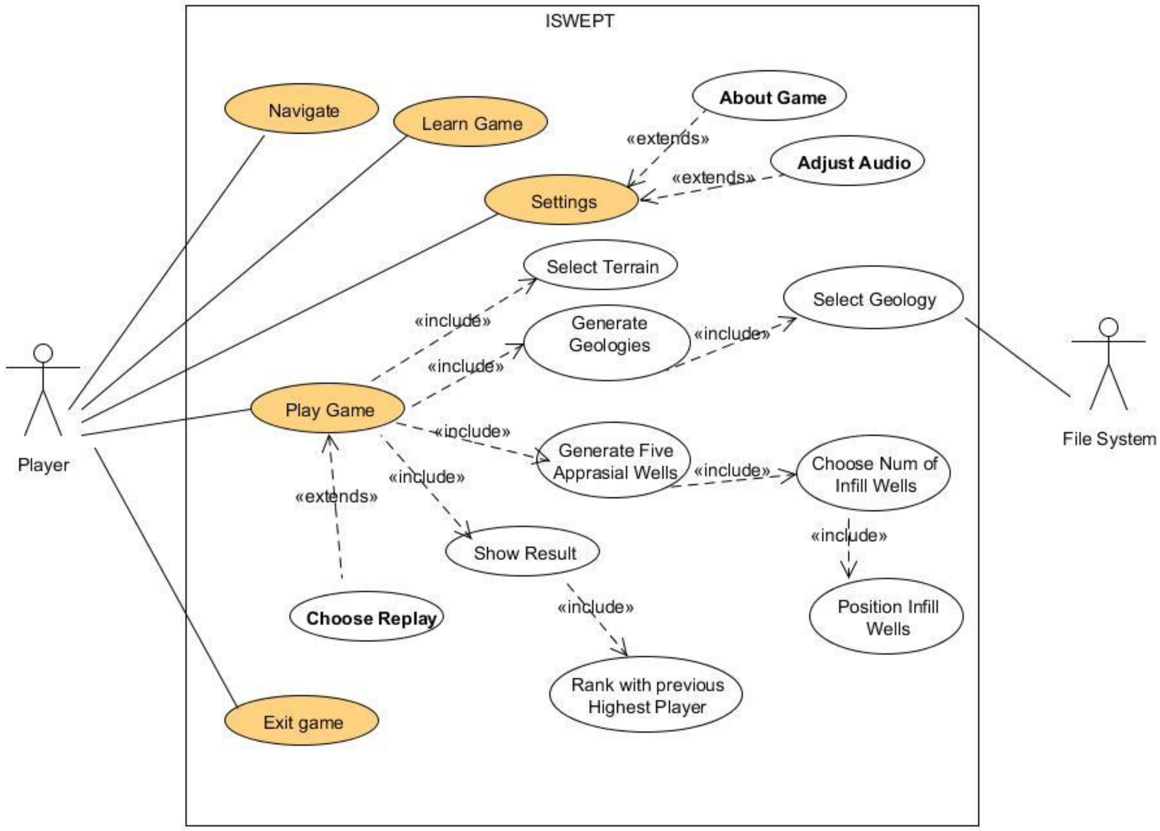

Figure 3: Use Case Diagram

The tables below explains the role of the actors and the goals of the use cases

ACTORS

Type	Role	Description
Primary Actor	Player	A person who initiates the interaction with navigate, learn game, settings, play game, and exit game use cases.
Secondary Actor	Store Data	It is a file system that stores production data for the game

USE CASES

Goal	Description
Navigation	Player can navigate through the scenes of the game before actual play begins.
Settings	It extends the “About Game” and “Adjust Audio Settings” use case
About Game	Presents information about the game product
Adjust Audio Setting	Player decides to turn off or on audio.
Game Tutorial	Shows a tutorial on oil exploration and well placement
Launch game	Used to initiate game play
Select terrain	While performing “play game” use case, players will have to select what terrain they want to work with. Choices available are land, swamp, shallow offshore, and deep offshore.
Generate Geologies	This action randomly allocate values to the properties of the different geologies in a terrain
Select Geology	This action receives the player’s choice of geology and makes it the focus of the game play.
Generate Appraisal Wells	Five appraisal wells are randomly placed in the geology in a way that depicts a delineation of the reservoir.
Choose Number of Infill Wells	Players are prompted to enter the number of infill wells they would like to drill in the reservoir.
Position Infill Wells	Players are allowed to select location which they want their infill wells to occupy.
Compute result	Based on the player’s selected location of infill well and randomly placed appraisal wells,

	data look-up and computations are carried out to determine the result of game play
Show result	This module projects the result of game play in form of a chart and text.
Rank result with previous players	This use case is included in “show result”. To indicate progress report users, are ranked with previous players.
Choice of replay	After completing game play a player could choose to replay the game thereby starting a new cycle of play
Exit game	Player can choose to terminate a game play

CLASS DIAGRAM

We show the static nature of design using UML class diagrams. First we use a class diagram to realize the Meta model of the JavaFx Platform. This is to allow us have a clear understanding of how our work will integrate with the platform

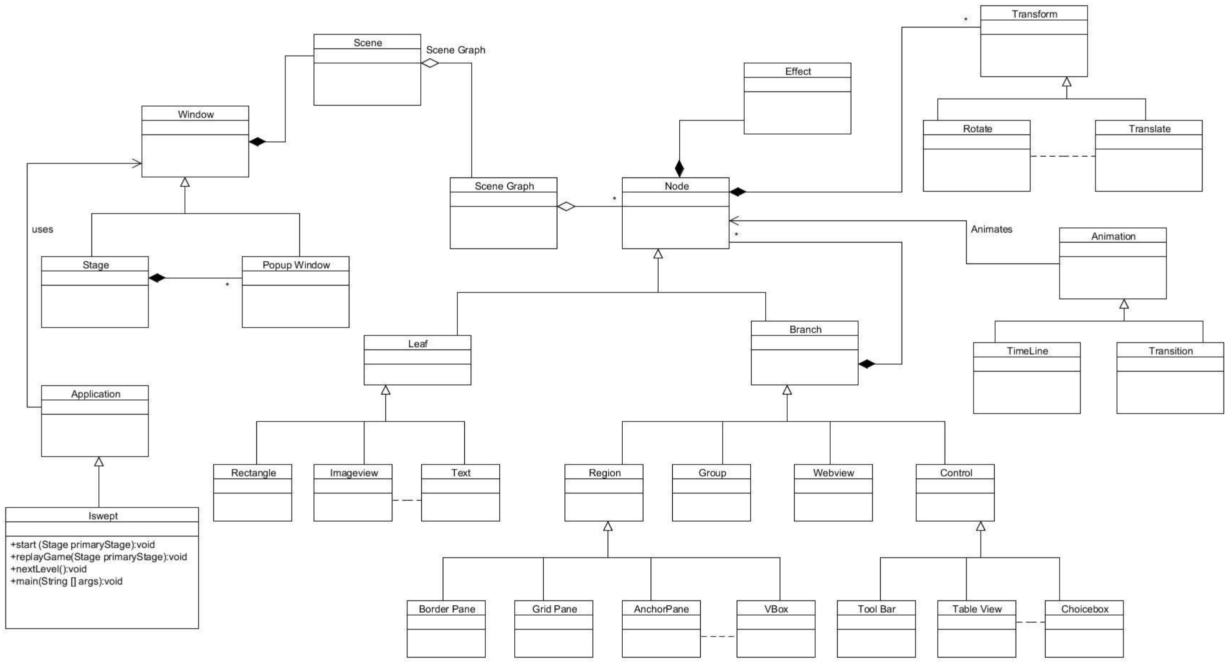

Figure 4: View and controller classes of javaFX

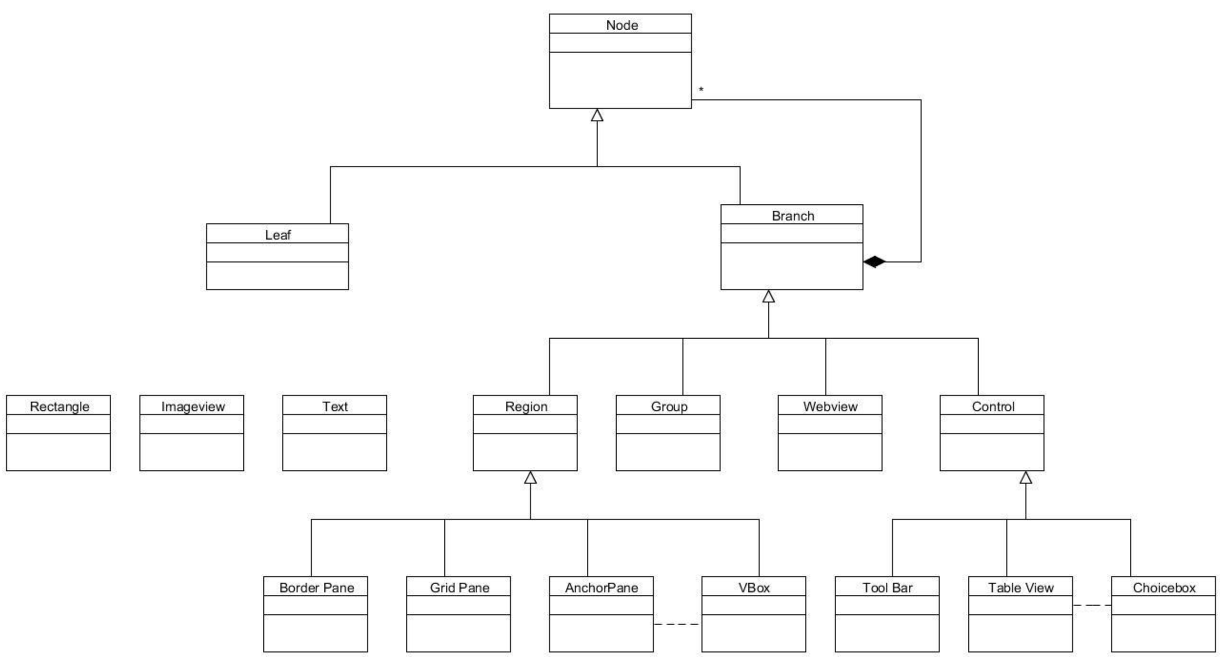

Figure 5: View Classes of JavaFX

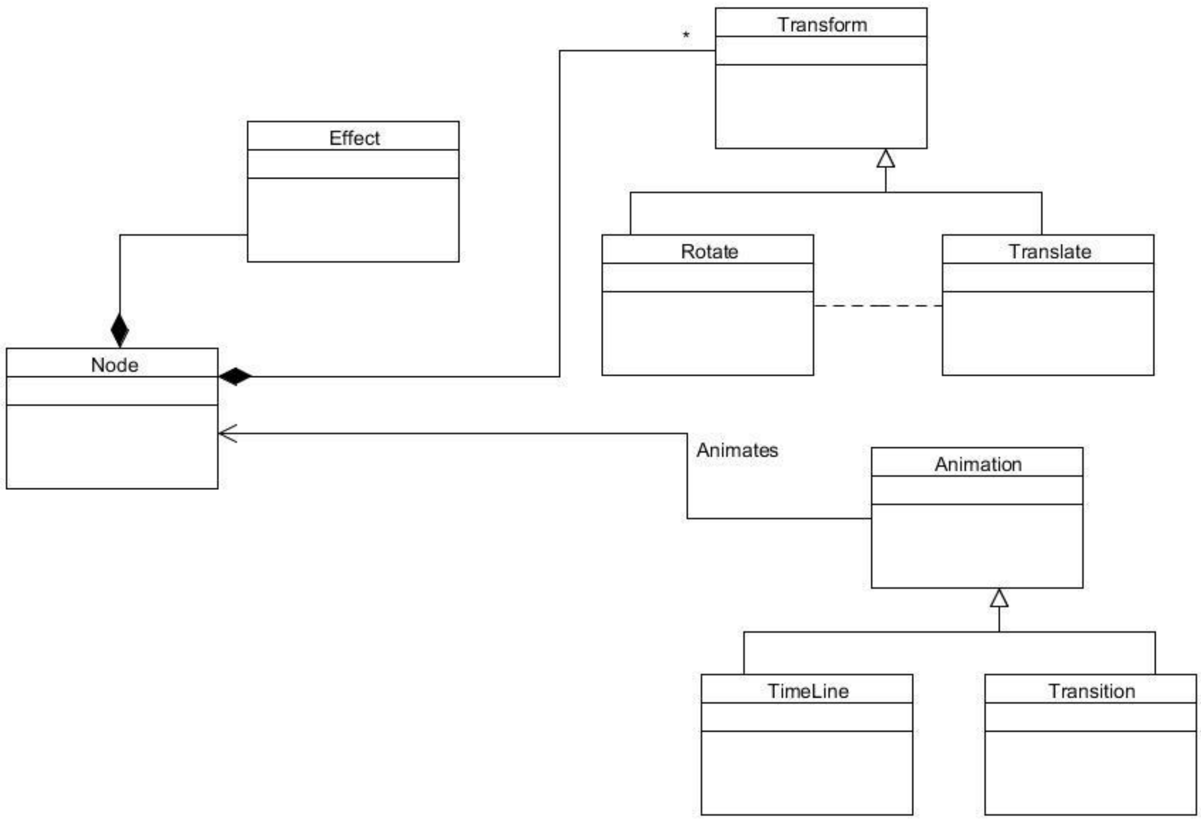

Figure 6: Controller classes of JavaFX

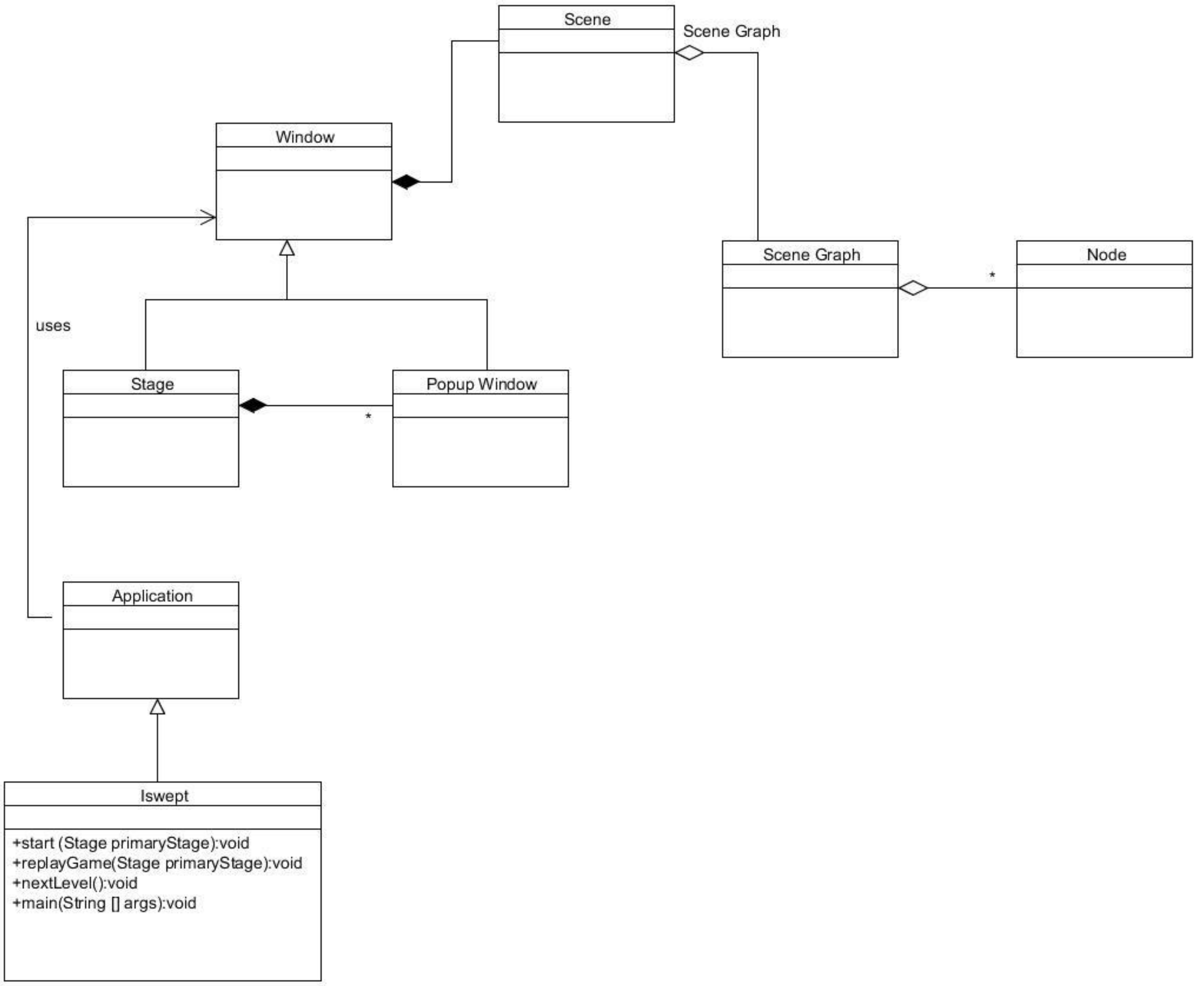

Figure 7: JavaFx view classes and the starting class of the software

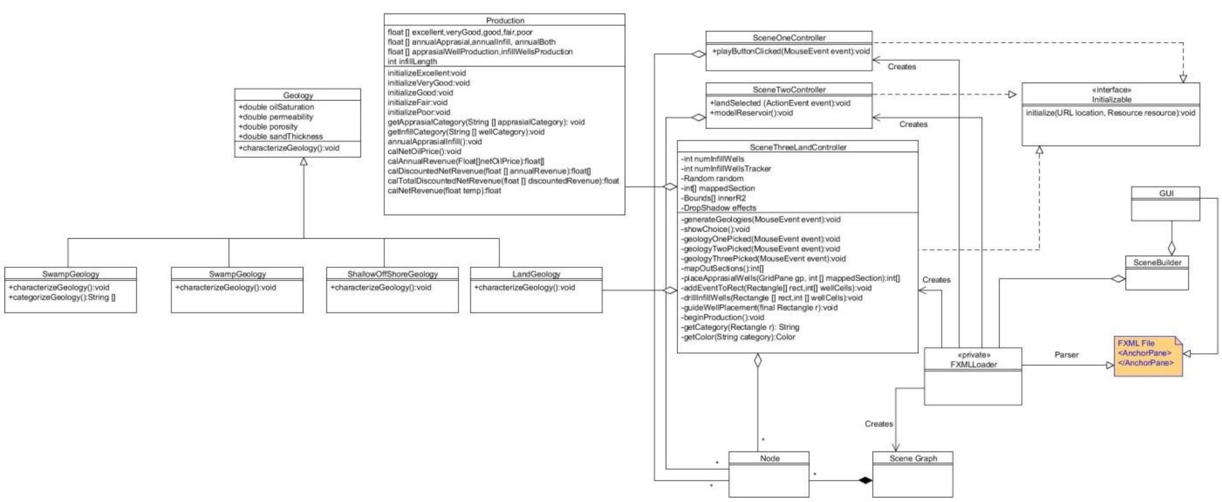

Figure 8: Relationship between coded classes and Scene Builder

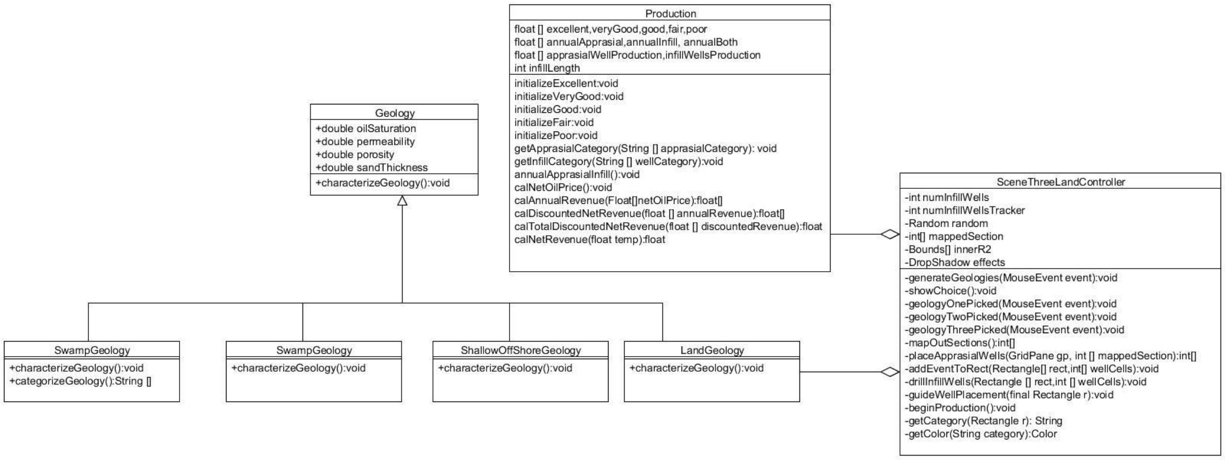

Figure 9: Relationship between controllers and model

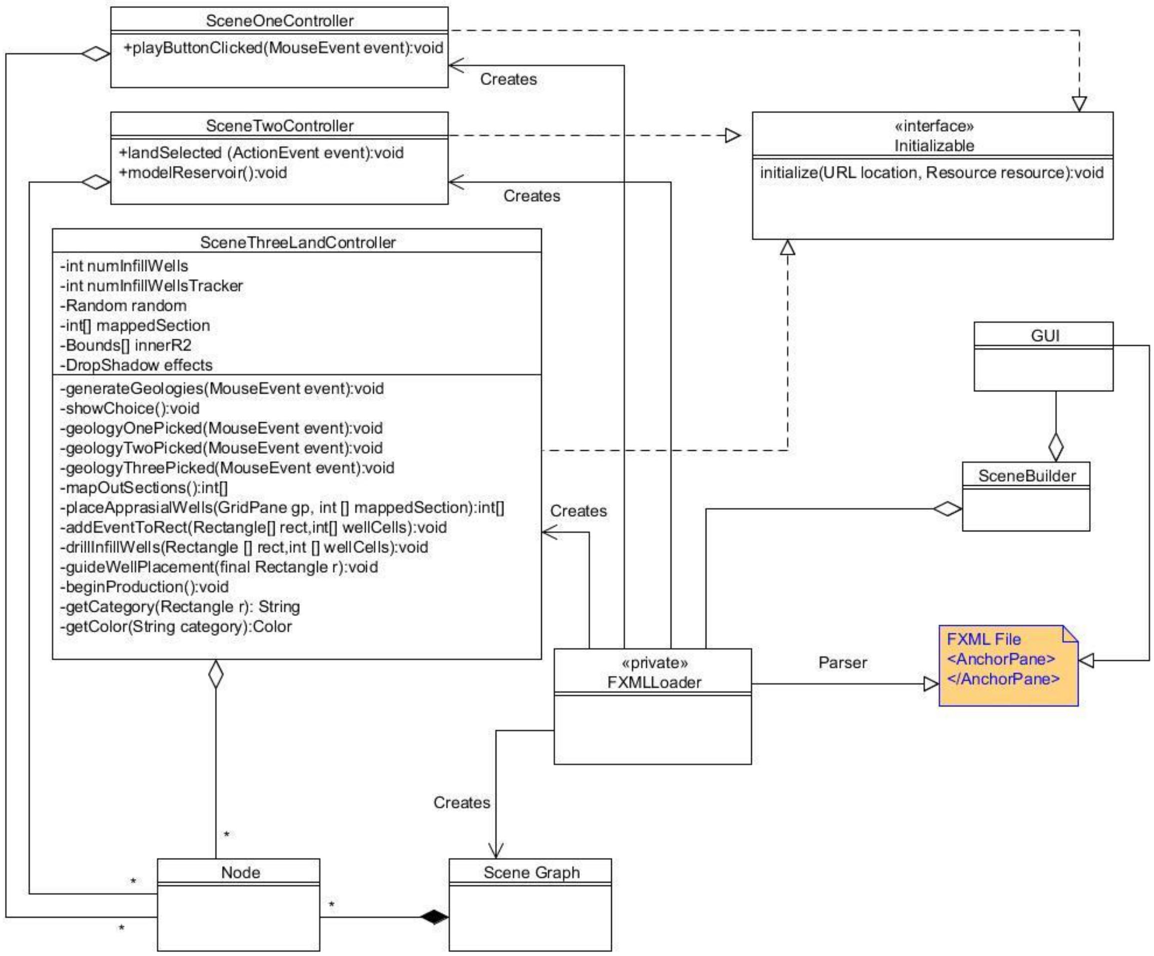

Figure 10: Relationship between Controllers and Scene Builder

CLASS: ISWEPT

This class initiates the game play. It has no properties; its methods are described below.

Method Summary

Name	Return Type	Description
start(Stage primaryStage)	void	Initiates game play
Main(String [] args)	void	Launches the Application
replayGame()	void	Deletes current instance terrain and player; creates a new one; launches a new game play

CLASS: SCENE THREE LAND CONTROLLER

This is the controller class for the third scene of the game. It is injected with the graph object of "SceneThreeLand", an FXML file; hence it can manipulate the scenes graphical elements. We add the following functionalities to the controller class.

Property Summary

Name	Type	Description
numInfilWells	Int	It holds the number of infill wells players have decided to drill. The maximum allowed is five.
numInfilWellTracker	int	It keeps track of the number of infill wells players have drilled.
Random	Random	Generates random numbers that identifies location in grid to place appraisal wells.

mappedSection	Int []	Keeps account of the section a cell in the grid belongs.
innerR2	Bounds[]	Keeps track of the positions of the infill wells with reference to the scene.
Effects	DropShadow	Holds the style applied to text on the scene.

Method Summary

Name	Return Type	Description
generateGeologies()	void	Creates three grid panes (geologies) and populate it cells with rectangles. The rectangles are initialized with properties of a reservoir as described by their colors.
showChoice()	void	Manipulates the opacity of buttons related to the geologies created in “generateGeologies” method above.
geologyOnePicked (MouseEvent event)	void	Describes what happens when “grid pane (geology) one” is picked. It removes the other grid panes from the scene and makes the selected pane occupy a larger portion of the scene.
mapOutSections	Int []	The rectangles in the grid cells are mapped into twenty sections.

		This method controls how the mapping is done.
placeApprasialWells(Gridpane gp, int [] mappedSection)	Int []	This method controls how appraisal wells are placed in the grid pane. It makes sure they are randomly placed in five sections of the grid pane.
addEventToRect(Rectangle [] rect, int [] wellCells)	void	On mouse moved on scene it directs player on safe areas to drill for oil.
drillInfillWells(Rectangle [] rect, int [] wellCells)	void	Manages the activities of drilling a well.
guideWellPlacement(final Rectangle r)	void	Directs player on areas to place infill wells
beginProduction()	void	Manages oil production from all the wells drilled
getCategory(Rectangle r)	String	A utility method that returns the category, depicting the petrophysical properties, of a rectangle
getColor(String category)	Color	Also a utility method. It returns the color associated with a category

CLASS: PRODUCTION GEOLOGY

This class is part of the model. Its' primary purpose is to store and manipulate data used to calculate a players production over twenty years. The game looks up this class when calculating a player's production.

Property Summary

Name	Type	Description
excellent,veryGood,good,fair,poor	Float []	Holds the annual oil rates associated with the respective reservoirs
annualApprasial, annualInfill, annualBoth	Float []	Holds the calculated annual data for appraisal, infill and both wells respectively.
apprasialWellProduction, infillWellProduction	Float []	Holds production data for selected appraisal and infill wells in an array
infillLength	int	Holds the number of infill well users select.

Method Summary

Name	Return Type	Description
initializeExcellent	Void	Initializes the array “excellent” with data.
getApprasialCategory (String [] apprasialCategory)	void	Uses the category of the appraisal well to initialize the “apprasialWellsProduction” array.
annualApprasialInfill()	Void	Computes the corresponding sum of the annual production data for both the infill and appraisal wells.
calNetOilPrice()	float	Computes the net oil prices and stores the values in an array
calAnnualRevenue(float netOilPrice)	Float []	Computes annual revenue from the netOilPrice.
calDiscountedNetRevenue(float[] annualRevenue)	Float []	Computes the discountedNetRevenue from the

		annual revenue.
calTotalDiscountedNetRevenue(float[] discountedRevenue)	Float	Calculates the totalDiscounted NetRevenue from the discountedRevenue.
calNetRevenue(float temp)	Float	Calculates the netRevenue from the TotalDiscountedNetRevenue

4.3 DESIGN PATTERN EMPLOYED

This chapter describes the design pattern and design tools employed to realize the instructional game. We make use of the Model-View-Controller (MVC) pattern of design in software engineering; MVC comprise of three forms of object: Model, View, and Controller. The Model is the application object, the View is the screen presentation, and the Controller defines the way the user interface react to user input. There is of course interaction between the various objects. The model and view have a subscribe/notify protocol between them such that the view always updates its appearance when changes are made in the model linked with it. This arrangement allows for multiple views to be linked with a model. Separating concerns this way helps to increase flexibility and reuse of object.

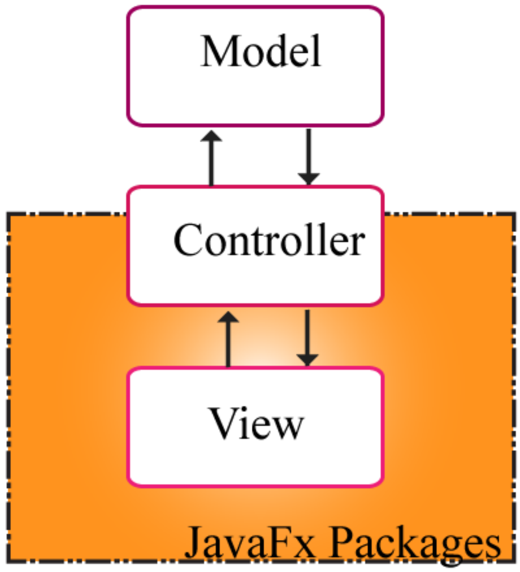

Figure 11: Model-View-Controller

4.4 TOOLS AND SOFTWARE PACKAGES EMPLOYED

We make use of JavaFXPlatform, Scene Builder, JDK 7, Net Beans, and Adobe Illustrator.

JavaFX is a set of graphic and media packages that enable developers to design, create, test, debug, and deploy rich client applications that operate consistently across diverse platforms.

We adopt JavaFX platform because of the following features it has

- Java APIs –As it is a Java Library, software developed with it can run on any computer with the Java runtime installed.
- FXML and Scene Builder-instead of coding graphics element from scratch, we can use FXML (an XML-based language)or Scene Builder to interactively design the graphical user interface. Enabling us to concentrate on the business logic.
- Built-in CSS- components can be skinned with standard web technologies like CSS

- Hardware- accelerated Graphics Engine- JavaFX offers smooth graphics that render quickly through Prism engine when it is used with a supported graphics card or graphics processing unit (GPU). If user system does not support one of the recommended GPUs supported by JavaFX, the engine defaults to the Java2D software stack.

Scene builder is a development tool for the JavaFX platform. It provides a visual layout environment that allows quick design of user interface for JavaFX platform without needing to write any code.

We adopt it because it has the following features

- A drag-and-drop WYSIWIG interface- allows to quickly create a UI layout without the need to write source code.
- Tight integration with Netbeans IDE
- Live editing and preview – lets you quickly visualize the UI layout changes made without needing to recompile, thus helping to minimize development time
- CSS support

Using Scene Builder with JavaFX help to enforce the MVC architectural design pattern as described in figure 10

We use this **Netbeans IDE** because it lets us quickly and easily develop JavaFX applications. It also tightly integrates with Scene Builder.

We use the **Java Development Tookit Version 1.7** because it comes bundled with JavaFX packages. Since JavaFX is a new package, previous versions of Java Development Tool kit do not contain it.

We use **Adobe Illustrator CS6** to develop its powerful graphics ability.

Chapter 5: IMPLEMENTATION AND CODING

The implemented code has been segmented using the MVC pattern. It has a total of six models, four controller, four views, one style sheet, and images. Classes in the model include Geology, Land Geology, Swamp Geology, Deep Water Geology, Shallow Water Geology, and Production. Classes in the controller include   including Scene One Controller, Scene Two Controller, Scene Three Land Controller. The views are FXML files called Scene One, Scene Two, and Scene Three Land. The view has been implemented and styled with the Scene builder tool. We briefly discuss some of the implementation

The application begins with the **ISWEPT** class.

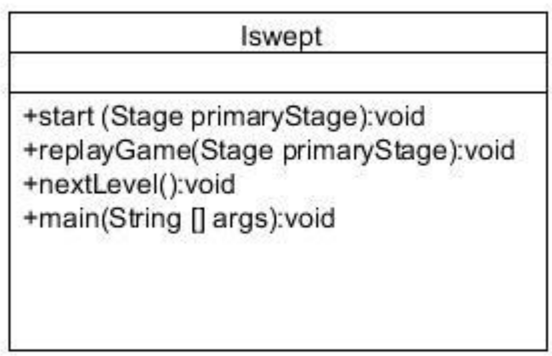

Figure 12: Iswept class diagram

This is the main class that triggers the game play. The start method receives the stage instance, attaches the scene instance to it and renders the view. The stage size resizable feature is set to false so that its size remains fixed throughout the game play.

```java
import javafx.fxml.FXMLLoader;
import javafx.scene.Scene;
import javafx.scene.layout.AnchorPane;
import javafx.stage.Stage;

/**
 *
 * @author Emamurho
 */
public class Iswept extends Application {

    @Override
    public void start(Stage primaryStage) {

        try {
            AnchorPane page = (AnchorPane) FXMLLoader.load(Iswept.class.getResource("SceneOne.fxml"));
            Scene scene = new Scene(page);
            primaryStage.setScene(scene);
            primaryStage.setResizable(false);

            primaryStage.setTitle("ISWEPT GAME");
            primaryStage.show();
```

Figure 13: code session of Iswept class

Production is one of the classes in the model. It records and manipulates data used for calculating players revenue at the end of the game. This class provide data for calculating revenue for game play related to land terrain. The class diagram (Figure 13) and snippet of its code is shown below.

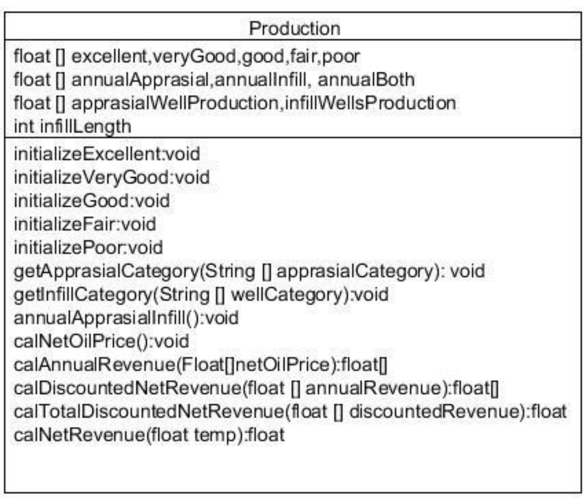

Figure 14: Production class

```java
public float[] calNetOilPrice() {
    float[] netOilPrice = new float[20];

    for (int i = 0; i < 20; i++) {
        netOilPrice[i] = (float) (30*Math.pow((1 + 0.02), (i + 1)));
     System.out.println("Net Oil Price "+i+" "+ netOilPrice[i]);
    }

    return netOilPrice;

}

public float[] calAnnualRevenue(float[] netOilPrice) {
    float[] annualRevenue = new float[20];
    for (int i = 0; i < 20; i++) {
        annualRevenue[i] = netOilPrice[i] * annualBoth[i];
        System.out.println("Annual Revenue "+i+" "+ annualRevenue[i]);
    }
    return annualRevenue;
}

public float[] calDiscountedNetRevenue(float[] annualRevenue) {

    float[] discountedNetRevenue = new float[20];
```

Figure 15: Code session of Populate Geology class

"SceneThreeLandController" is responsible for handling all events from "SceneThreeLand" FXML file. This class responds to the operation of the player during game play.

SceneThreeLandController
-int numInfillWells -int numInfillWellsTracker -Random random -int[] mappedSection -Bounds[] innerR2 -DropShadow effects
-generateGeologies(MouseEvent event):void -showChoice():void -geologyOnePicked(MouseEvent event):void -geologyTwoPicked(MouseEvent event):void -geologyThreePicked(MouseEvent event):void -mapOutSections():int[] -placeAppraisalWells(GridPane gp, int [] mappedSection):int[] -addEventToRect(Rectangle[] rect,int[] wellCells):void -drillInfillWells(Rectangle [] rect,int [] wellCells):void -guideWellPlacement(final Rectangle r):void -beginProduction():void -getCategory(Rectangle r): String -getColor(String category):Color

Figure 16: Scene Three Land controller class

```
        }

        else{
            layoutGrid.getChildren().remove(choiceBox);
            layoutGrid.getChildren().remove(numWellsButton);
            beginProduction();

        }


           }

    void beginProduction(){
        //first remove event handlers from all the rectangles/cells in the scre
        for(int i=0;i <24000;i++){
            choosenRect[i].setOnMouseClicked(null);

        }
        //get classification of apprasial wells
        String [] apprasialWellsCategory =new String[5];
        for(int i=0;i <5;i++){

        apprasialWellsCategory[i]= getCategory( apprasialWellCells[i]);
```

Figure 17: code session for scene three Land controller

Chapter 6: RESULTS

The following are the current result for the game play

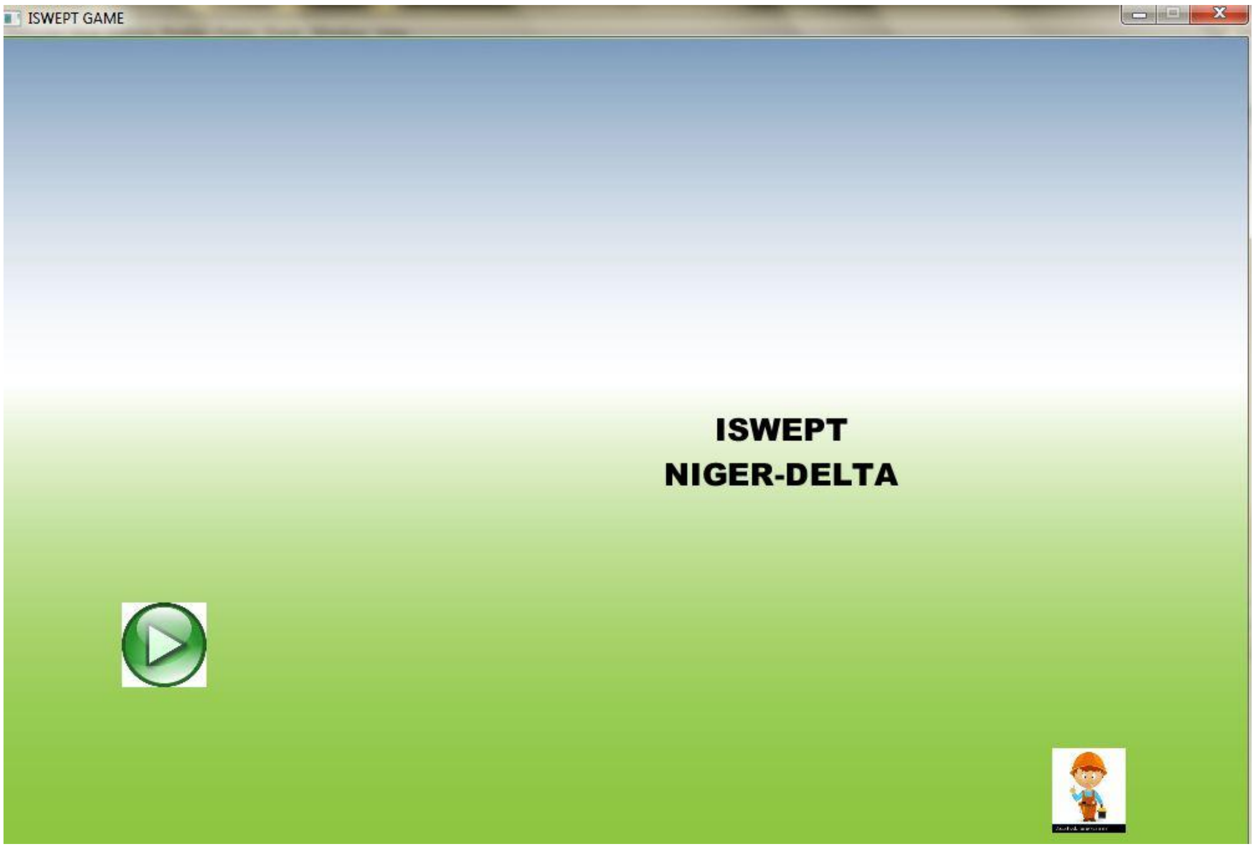

Figure 18: scene one

Figure 18 is a picture of what a user encounters on launching the software, his options are either play game or explore settings.

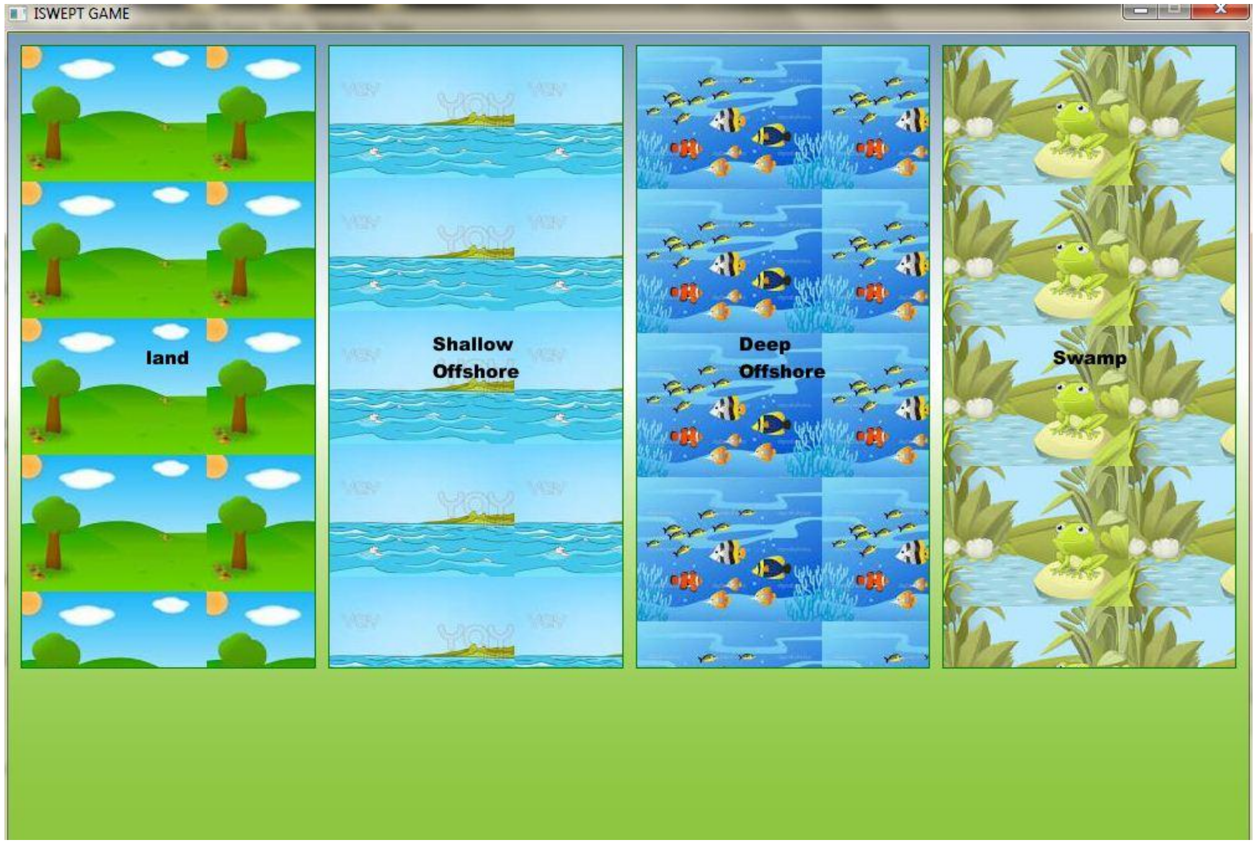

Figure 19: Scene two

If the user chooses the play game option, he is presented with a new scene as shown in figure 19. At this point, he selects the terrain where he wants to perform his oil exploratory activity.

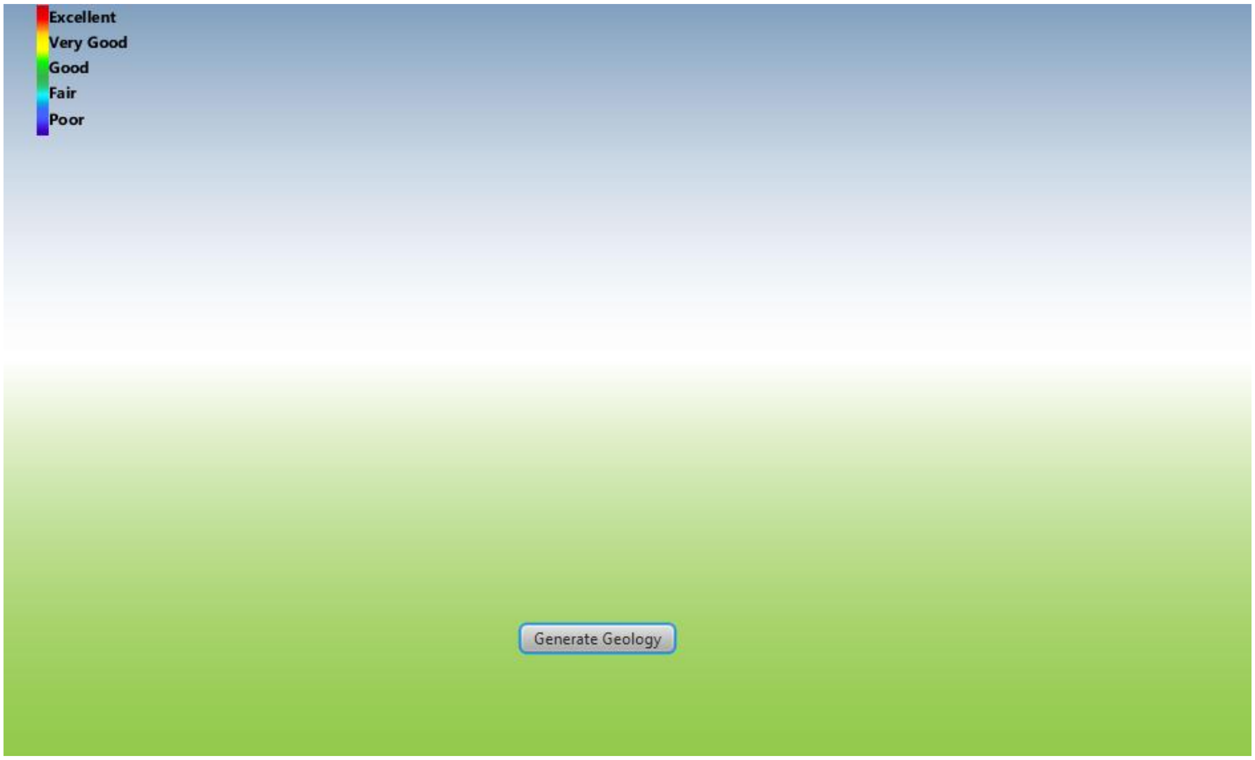

Figure 20: Generate Geology view.

Selecting the land terrain in figure 19, will display the view in figure 20. The player's only option is to generate geologies within the terrain.

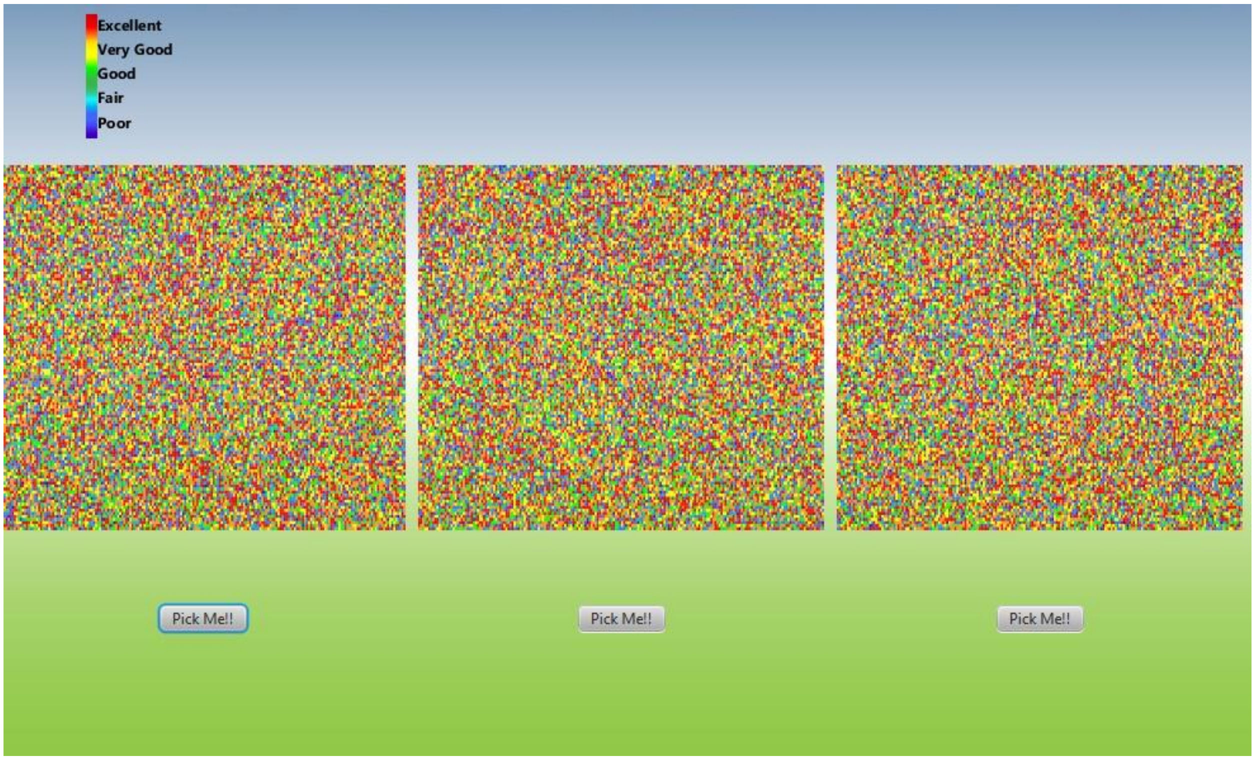

Figure 21 : Select Geology

Figure 21 presents randomly generated geologies. At this stage of implementation, petrophysical properties of the field are modeled in a color map. Color maps are categorized as Excellent, Very Good, Good, Fair and Poor. The map intent is to inform players selection of geology.

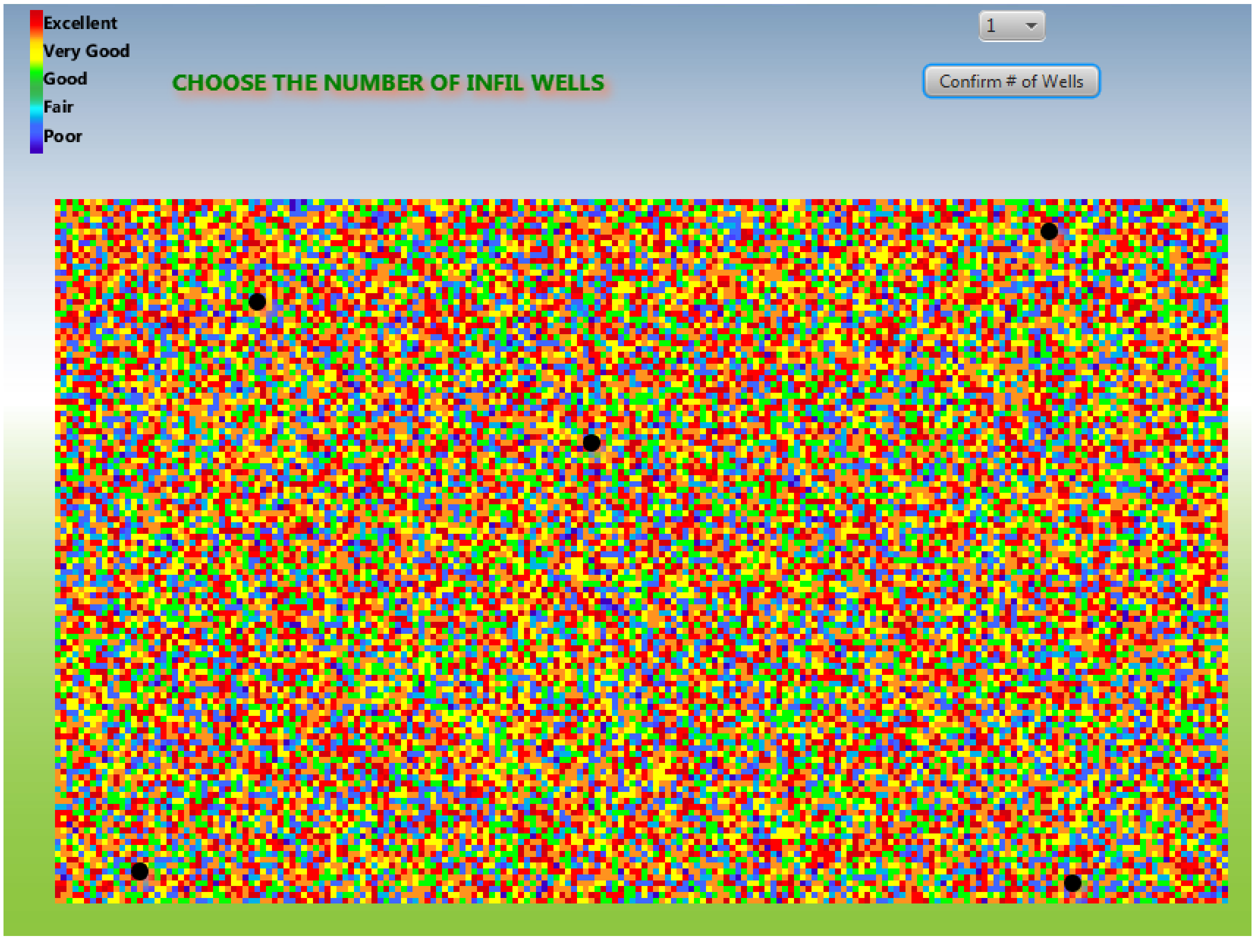

Figure 22: Selected Geology

Figure 22 show how the screen looks like when a user has selected the geology he would want to drill from. Appraisal wells are automatically randomly place in the geology in a way that represents a delineation of the reservoir. Players choose the number of infill wells they want to drill then click the confirm button.

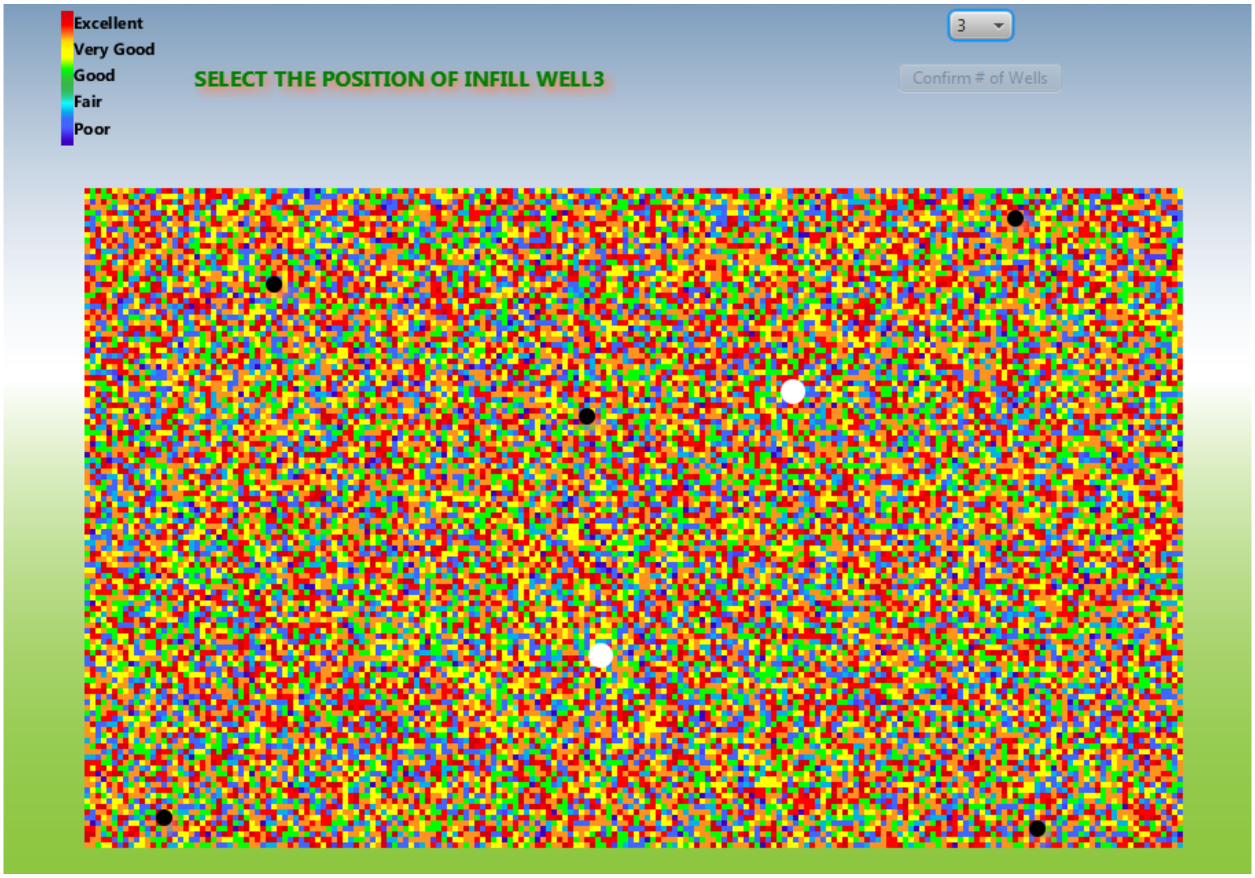

Figure 23: Drilling Infill Wells

Based on the number of infill wells selected users are able to select well locations to drill that number of wells. (See figure 23).

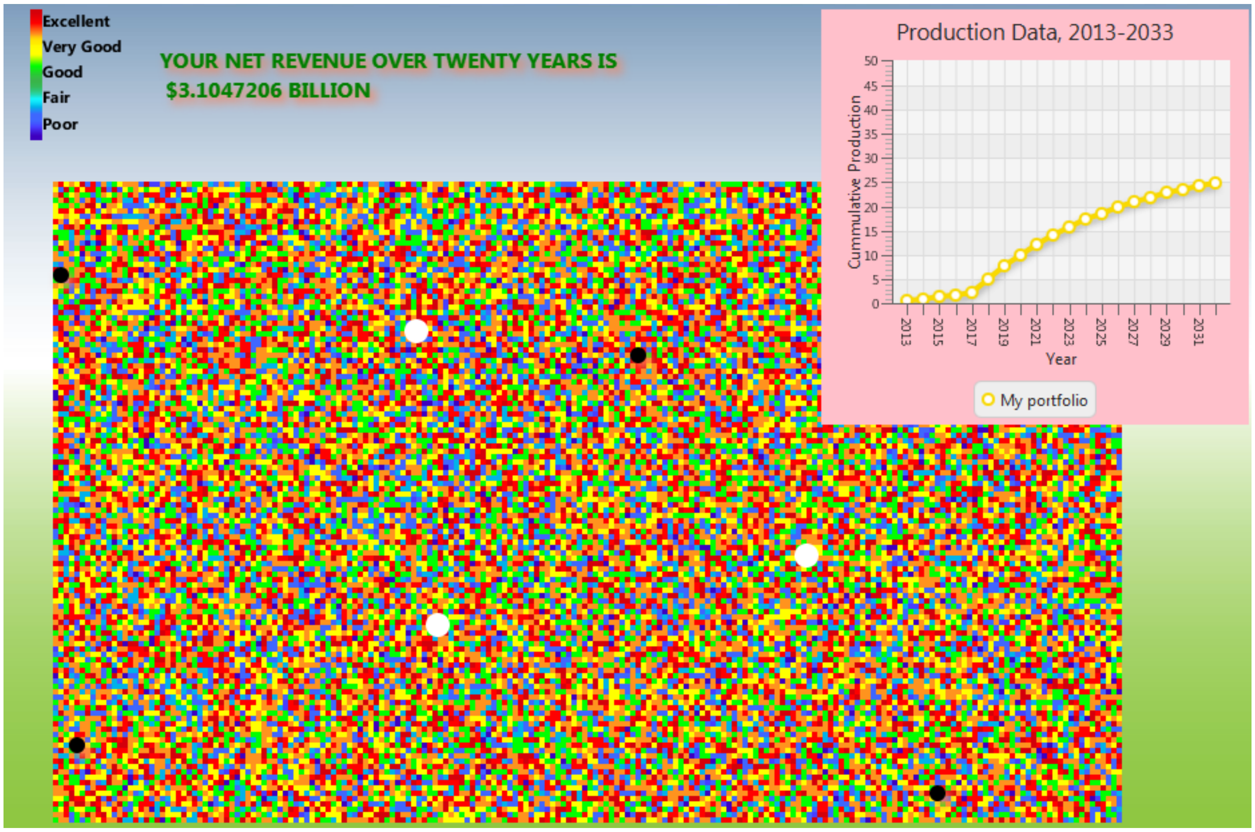

Figure 24: Game Play Result

The result of game play is a graph of the cumulative production from all the wells over a twenty year period and the net revenue from all the wells drilled (including appraisal wells).

Chapter 7: CONCLUSION AND FURTHER WORK

7.1Discussion and Conclusion

We initially set out to develop fun-filled academic learning tool for students and other professionals to learn/appreciate the decision making process carried out by petroleum engineers and geoscientist to maximize production (reserves) from oil fields. Our intention was to a game that dynamically simulated the production from a reservoir.

The following are the milestones we created for the work:

- A literature review of well placement technology and computer/instructional games
- Requirement analysis, Requirement specification and Architectural design
- Integration of game characteristics as described by the Input-Process-Outcome Model
- Implementation of a dynamic algorithm for well placement in all terrains
- Incorporating the reservoir data
- Adding the learning of the game
- Implementing fully all use cases
- Realizing the view of all terrains

7.2 Current position

Figure 25: Areas covered

Figure 20, shows parts of the use case diagram we have implemented fully/partially. The 25% mark is given because only implementation for land terrain has been realized. Three others are still pending.

We have been able to fully implement

- A literature review of well placement technology and computer/instructional games.
- Requirement analysis and Requirement specification.
- Game play, including data and algorithm incorporation, for land terrain.
- Exit game use case.

We have partially implemented the following areas

- Navigation- users can only navigate one direction.
- Game play for swamp, deep water and shallow water terrain.

- Rules/Goals are the only game characteristics, as described by the Input-Process-Outcome Model, we have implemented.

7.3 STRENGHT AND LIMITATION OF WORK DONE

STRENGHT

This work done serves as a foundation for further work. We have been able to realize a Meta model for JavaFx platform. This contribution can be used by developers coding for other areas because JavaFx platform is not only used for gaming. It will help them understand the static structure of the platform and see how their components will integrate with it

LIMITATION

- The Input-Process-Outcome Model has not been fully implemented hence a satisfactory level of aesthetic appeal has not be achieved.
- Implementation does not yet exist for swamp, deep water and shallow water terrain.

7.4 CHALLENGES

- In developing this software I had to model the UML class diagram of the Platform used. This was a challenging task for me because I had to realize the big picture of how the platform functions and how my design will integrate with it. Successfully achieving this forms part of my contribution for future work with JavaFX.
- To develop this software, deep knowledge on the area of oil exploration is needed. This was challenging because it was a completely new area and I had to comprehend it quickly in other to develop the software.

7.5 PERSPECTIVE

We hope to realize all the functionalities that were set out at the beginning of the work. This would give us a complete prototype for bigger software that is aesthetically appealing and graphically intensive. 3D software systems like Maya can help to realize this.

In addition, we hope to realize a frame work for oil exploratory learning games. In this frame work, users will be able to plug in their developed game contents for game play. This will serve to provide and reinforce the idea of game learning environment for young people.

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