A Novel Approach for Training Crane Operators

Serious Game on Crane Simulator

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***Abstract*—Any large scale construction related activity generally requires the use of cranes. A crane operator must be appropriately skilled to avoid any mishap at the construction site. This can be accomplished by training crane operators on all the safety procedures and methods of crane operation to be practiced. In this paper we explore a method whereby anyone who is being trained as a crane operator, must first learn all the operational procedures and safety norms by playing a simulation of operating a crane in a serious game. Once the user successfully completes the different levels of this serious game, he can then 'graduate' to operate an actual crane. Serious games are proven method of cost effective and risk free simulated environments where a player can learn all the nuances of any simulated activity, herein operating a crane. We implemented a learning methodology, Gagne's 9 Events of Learning, in order to ensure the player develops a high level of understanding. We used an actual crane as a reference model (Ace14XW) for this game. We surveyed several crane operators and found that this crane model game enhanced their knowledge of handling and precautionary measures. The users also reported an increased confidence level while operating a real crane.**

Keywords—Unity3D; Animations; Crane Simulation; Mobile crane; Simulator; Training system; Serious Game; Gagne's 9 events model;

I. INTRODUCTION

Cranes are an integral part of many large scale construction activities such as building highways and skyscrapers. The use of cranes provides economical benefits by reducing man power. Crane operation requires great precaution and thorough understanding of its operational guidelines, to prevent any onsite accident causing loss of life and property. One of the main reasons accidents occur is due to insufficient training. The process of training a crane operator requires considerable time and money, the process entails some hidden costs and 5 major challenges [1]. We focusing on a type of crane used in the Indian state of Kerala, where there are very few training centres available for training crane operators, moreover the training process has its own risks. The type of cranes used in Kerala differ considerably cranes used in other places. In Kerala mobile cranes are commonly used, which can carry loads from one location to another easily through public roads, therefore there is an imminent need to provide training specific for this crane model. The process of driving a crane requires special expertise compared to other vehicles. It require formal training to manoeuvre these heavy machines on the roads. In this paper, we propose a training method with the help of a serious game. Serious games have a proven record for improving professional and operational skills of an operator to ensure safety [2].

Due to complex operational procedures, cranes require well-trained operators. If the operators lack sufficient training, accidents are more likely to occur. Traditional training methods and materials are often outdated, offering limited actual operation conditions [2]. This causes ineffective training and increase the rate of accidents [3]. Therefore the objective of our research is to train a crane operator effectively with low cost and zero risk factor".

Game engines are the core of any game development process [4]. Unity 3D game engine is used for developing the proposed crane simulator. There are many applications of Unity3D, such as serious games, multiplayer games,

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augmented and virtual reality applications, etc. It supports development on multiple platforms such as web, mobiles, etc. [4]. In mobile platform it supports both Android and IOS. As per the studies conducted among the game engines, Unity3D was justified by its popularity, where more than 47% of game developers are using this engine which is constantly growing, with 45% share of the full feature game engine market and 600 million gamers spending more than US$110B [5]. Game development in Unity3D uses the component model for providing a scalable programming architecture [4].

There are various technologies that can be used as educational instruments such as serious games, virtual reality, and augmented reality. When comparing these technologies, serious games have significantly lower costs and only a computer is needed, whereas the other methods rely on additional devices. We are developing this serious game because not only is the cost lower and devices are not needed, but research shows that these games enhance the learning process, a method known as Game-based Learning [6]. Nowadays serious games are considered to be a branch of the Computer Game field which introduces the concept of games for serious purposes rather than entertainment [7]. Educational games allow the learners to simulate situations which are very difficult in the real world due to reasons such as cost, time or safety [8]. The success rate of an educational game is directly related to the effectiveness of interactive learning experience which responds to the learner's evolving needs and requirement [9].

Our proposed method for training crane operators is a simulation of the operation of a real crane machine. In this we took a model of a mobile crane commonly used in Kerala and we simulated the functionalities of this crane in our game model. Using simulation models is safer than learning with real world simulations [10]. In the proposed method, the desired learning outcomes are achieved with the help of a serious game demonstrating a positive impact on players while developing skills and acquiring knowledge [8]. We use a 3D model, which gives more information about the real system. We created a 3D model of the crane using MAYA modeling software. We provided a module on driving and test cases which are based on the real crane mechanism. These test cases are controlled by: weight to lift, boom length and angle. These 3 parameters will decide the stability of the machine. In the game learners will find solutions by trial and error method [9], thus allowing the learners to stay alert and motivated in the serious game.

II. PROBLEM DESCRIPTION

Different types of cranes have varying operating mechanisms, therefore the crane operator should be trained for a specific crane model that the operator will be working with. Crane operators must have good skills, knowledge and experience in order to safely and efficiently do their job. Providing training in real systems could be costly and perilous and the actual operating conditions are limited [2]. Another interesting fact is that only a heavy vehicle licence is required to operate a crane according to the Indian Motor Vehicle Act 1988. A fixed crane operator doesn't need a driving license to operate that.

The main objectives of this research are to:

- Provide low risk and low cost training on crane operation. by simulating the crane environment in a serious game
- Instruct how to reduce accidents caused by improper usage of cranes.
- Provide exceptional training and improve skills in selected crane model

In our research process, we used the Ace 14XW model, which is a driving model that is commonly used in Kerala. More than 2 manufacturing companies also produce similar cranes. This is a carry deck type crane, which operates hydraulically. The preferred model is a mobile crane, which can drive from one location to another via public roads. All the operations of this crane are controlled by 4 levers. There is no steering wheel to drive the vehicle, therefore it requires careful driving.

In our proposed system we divided the operations of this crane machine into 2 parts, (1) a driving part and (2) a load lifting-dropping part. This classification is made according to the inputs from crane operators who have a great deal of experience in using the preferred crane model.

III. RELATED WORKS

Haoming Dong and Guifang Xu [2], have introduced virtual reality based design of training for bridge (overhead) cranes. Their method incorporates an expert system of examination and assessment. Their work is still in the design stage but their understandings of the important mechanisms is well thought out.

Haoming Dong, Shaojun, Zou, Dingfang Chen and Hongliu Xu [3], have also introduced a virtual reality crane training system for distributed bridge cranes. The above works [2] and [3] uses virtual reality technology for overhead cranes, and in both cases they use static cranes. In our work we are using cranes which are mobile in nature.

IV. SOLUTION APPROACH

We are developing a training process that would reduce accidents caused by lack of training. A system where a potential crane operator first learns in a virtual environment, thereby reducing potential risks as well as lowering the cost of training. In a simulation of a real world scenario the operation of a crane the player would have to face all the challenges as though he were operating an actual crane. A well defined learning outcome would help the operator become a better informed driver. Serious Games and simulations are actually a combination of E-Learning and multimedia games. E-learning enhances the learning through electronic media.

We also are implementing an effective instructional design process into the content to ensure good knowledge acquisition. While there are several methods in the field of pedagogy, we feel that the 9 events of Gagne's learning model [11] are very useful as they provide a complete scenario for learning. Each

event represents a task that should be performed in the game to obtain the desired outcomes. Most training games do not have Gagne's pedagogical aspects [12]. When compared to other learning models, Gagne's model provide testable and accessible outcomes [12]. Gagne's 9 events in our simulation:

- *Gaining attention*: The model itself helps to gain user attention.
- *Informing objectives:* Objectives are listed at beginning of game.
- *Stimulate recall of prior knowledge:* Learner can click on crane parts in game. Either he has some experience with cranes, or he can relate to vehicle parts.
- *Present stimulus material:* The crane basics section will give the information about the material or model that the learner is going to work on it.
- *Provide learner guidance:* If the player makes a mistake a message will come up explaining how to correct the mistake.
- *Elicit performance*: After guidance section, the user will work on his own. A serious game in itself elicits performance because of entertainment factor.
- *Provide feedback:* Feedback and assessment are generated after each task.
- *Assess performance:* Assessment by multiple choice questions with feedback.
- *Enhance retention and transfer:* By practice on a real crane.

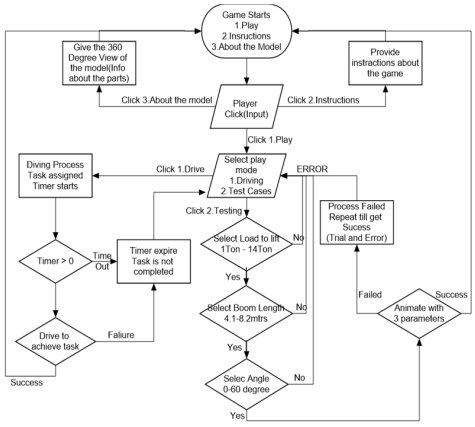

Fig. 1. Flow Chart of crane simulator.

In the survey conducted among crane operators, we learned the various problems faced by operators of the preferred model. Fig. 1 shows the game flow diagram based on this information.

As depicted in Fig. 1, the preferred crane model has 3 main tasks. For a person who does not have any basic knowledge of cranes, he will need to know about its functioning before training on a real crane. Therefore the first step is for the learner to get a comprehensive understanding of the specific crane model in our crane simulator serious game. The "learn about the model" button gives an interactive interface displaying details of the crane model. Learners can rotate 360 degree to get better view of the crane model. When we conducted the survey among crane operators they highlighted that driving process itself was challenging in the following ways:

- To drive using a lever rather than a steering wheel
- The boom is connected in front of the driving cabin, which inhibits visibility
- The left side of the front wheel cannot be seen
- Depending upon traffic conditions, driving can be difficult

In our game development we use the operators' suggestions as criteria for improvement to meet their requirements. We implemented this simulation game using a trial and error method. The learner can try again and again until he understands this module of the game.

The third task in our research game is lifting and dropping operations. Most crane accidents happen at the time of lifting a load. All types of cranes have their own load chart which specifies the amount of the weight that can be lifted under certain conditions. Depending upon the object weight, the boom length and the angle we create test cases. So in the third task, the player or trainee needs to select these 3 parameters logically in order to lift the object effectively. The player can make repeated attempts till he achieves that task. So without the awareness of the trainee we can teach about the various conditions that come with real world scenarios.

V. RESEARCH METHOD

This serious game was developed by using Unity3D game engine, and CSharp and javascript are scripting languages. MAYA is the 3D modeling software. The game was divided into 4 sections: Understanding the Model, Crane Driving, Lifting and Dropping (and other test cases) (under development), and finally assessment (under development). The simulation was modeled after the Ace 14XW driving crane.

After developing the first 2 tasks, a survey was conducted on 25 crane operators in a crane operator training centre called JK cranes, Karunagapally, Kollam, Kerala. As part of the study, we did the first and second tasks (Understanding the model and Driving), the third task was under development at the time of the survey. The 25 participants were either current operators or were going through a training session of the preferred crane model. A set of multiple choice were written for both the pre- and post-game quizzes.

A. Participant Demographics

Participants of the survey consisted of 2 groups. One group was of 5 people of age 35-40 who were the managers of a crane rental firm in Kollam Dist., Kerala and the other group consisted of crane operators and trainees of age 20-30.

B. Methodology

The participants of the test were given a pre-game test via Google forms and they were allowed to fill it prior to playing the game. After the pre game test, we allowed them to try our simulator. They tried this without any guidelines. Then we

provided post game quiz. The post game survey has the similar questions we provided for pre-game test. Both Pre and Post game responses were recorded.

VI. RESULTS

The pre game test result is shown in Fig. 2. It reflected that most of the operators are unaware of serious games. Responses are shown in the Fig. 3. Below mentioned are the inferences obtained from the study.

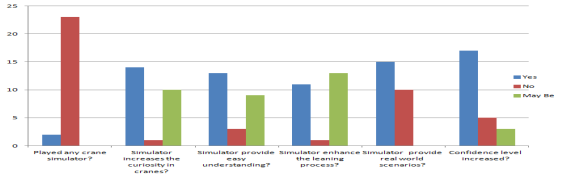

Fig. 2. Pre Game test results.

- In pre-game responses some of them claimed that they had used crane simulators previously. But after playing our game, they realized that they have never played this type of crane simulator.
- Some of the pre-game responses pointed out that they are not confident about the training process done using a game. After playing the game they felt that a serious game can teach or train an operator effectively.
- We can identify that in the pre-game test around 40-50% of people were not aware of the existence of serious game or they do not agree that a game can help them to get better training or learning. However, on our post-game testing, we can see that the number of persons who supports the game based learning is increased to 90-95%.
- It can be noted that the majority of the people, from 45 - 70% to 80- 95% started supporting Game based learning.

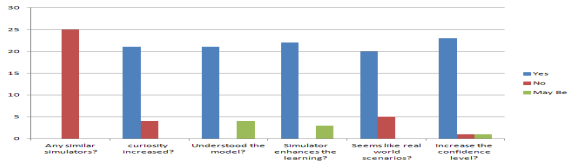

Fig. 3. Post-Game test results.

VII. CONCLUSION AND FUTURE WORK

This research is designed to provide better training for crane operators. The aim is to reduce the rate of crane accidents due to lack of training. As per the motor vehicle departments' records, there are 1,544 cranes registered across Kerala. Out of these, around 70% of them belong to the type of model that is considered in our work. The numbers of training centres are not adequate with respect to the increasing number of cranes. As our proposed method is a serious game, we provide a better understanding about the model and give different test cases so that operators can check again and again until he understands the concepts. Since it is trial and error method, any learner can try as many times until he is satisfied. We wish to implement the third task sooner by including some enhancements based on survey comments on the current game version as given below:

- The entertainment element of the game can be improved and can use 3D models.
- Instead of implementing as a desktop or mobile game, integrate this game with HMD and joysticks. Thus get a more realistic feeling.
- Add more crane models to the simulation.

As our future work we intend to implement this crane simulator using haptic devices such as HMD (Head Mounted Device), Joysticks, vibrator chairs etc. So these devices give more realistic feeling than a desktop game.

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