Standardised Training Simulations: A Case Study of the Water Industry in Australia

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Abstract: This article is a case study which discusses how a realistic game-based simulation training platform may tackle the challenges raised by the requirements for a national competencies certification framework and the requirements of a new generation of trained water operators. The proposed platform aims to 1) enhance training experience with learn by doing and scenario- based learning experience, 2) increase training capacity for the water industry, 3) provide cost effective methods to deliver training in remote areas, and 4) attract young people to join the water industry workforce. The National Water Commission of Australia is currently developing a national competencies framework for certification of water treatment operators. This framework aims to ensure that the water operator role is carried out by qualified staff. In response to the introduction of this new competencies framework, there will be an increase in demand for skills training in the water industry to ensure that employees at water treatment facilities possess the required certifications. Currently, the water industry is facing several challenges to meet the future training demands required by the new competencies framework. The lack of standardised training manuals and assessment criteria make it very difficult to ensure that training is consistent between different water treatment facilities. Australia is an immense country with sparse distribution of population centres and large distances between towns, which create an insurmountable problem for delivery of training. In particular, for rural areas, there is a substantial lack of trainers available to deliver training. Travel expenses and loss of work days for travelling makes training a very expense exercise. Also, the water industry is facing an ageing workforce with an average age over 45. There are less than 5% of trained water operators under 25 years of age. With the ever increasing technological advancements being introduced into the water industry, a new generation of water operator who are technology savvy are required. In response to these problems, a realistic game-based simulation training platform is being developed for water operator training. The pilot training module focuses on the collection of water samples. This particular task was chosen as it is a statutory requirement for the industry to perform water testing at regular intervals and it is a critical factor in the quality assurance process. It is also important as thousands of dollars can be wasted on each contaminated water sample. During the development of this training application, several technical challenges were encountered. The challenges include rendering of realistic water, simulating physics for small objects, and using two handed controls for object manipulation. Future development of this training platform will also be discussed.

Keywords: skill training, serious game, action learning, experience learning

1. Introduction

This article is a case study which discusses how a realistic game-based simulation training platform may tackle the challenges raised by the requirements for a national competencies certification framework and the requirements of a new generation of trained water operators in Australia.

The National Water Commission of Australia is currently developing a national competencies framework for certifying water treatment operators (Peisley, 2011). This framework aims to ensure that the water operator role is carried out by suitably qualified staff. It proposes to address the problem that there are currently no nationally agreed minimum skills and training standards for water treatment operators. The introduction of this new competencies framework will increase the demand for skills training in the water industry.

There are a wide range of skills required by water treatment operators. The water training package provide by the National Industry Skill Council contains over 190 units which includes installing and operating different equipment, monitoring treatment plant operations, and implementing related policies and procedures. The pilot training module to be developed in this training platform focuses on the collection of water samples. This particular task was chosen as it a statutory requirement for councils to perform water testing at regular intervals and it is a critical factor in the quality assurance process. It is also important as thousands of dollars can be wasted on each contaminated water sample.

The following sections outline the development stages of the training platform and highlight the design challenges encountered in the development of this simulation training platform.

2. Project initiation

The water industry is facing several challenges related to training capability, training cost, competency records, and an aging workforce.

- Currently, workplace skills are generally transferred from experienced staff to new staff by demonstration and on-site training. Local supervisors observe the new staff performing the tasks on-site then sign off to accredit them with the competency. The lack of standardised training manuals and assessment criteria make it difficult to ensure that training is consistent between different water treatment facilities. Numerous case studies in the water industry worldwide demonstrate the critical role that water operators play in most failure scenarios. Hence, it is critical to increase the quality and capacity of training provision.
- There is no centralised database and registration system to record and to check the training and competency level of individuals working at a water treatment facility. This information is required when employing new staff or transferring staff from one facility to another.
- Australia is an immense country with sparse distribution of population centres and large distances between towns, which creates an insurmountable problem for delivery of training. In particular, for rural areas, there is a substantial lack of trainers available to deliver training. Either the trainer has to travel to the rural areas to provide training or the water operators must travel to capital cities. Travel expenses and loss of work days for travelling makes training a very expense exercise.
- The water industry is facing an ageing workforce with an average age over 45. There are less than 5% of trained water operators under 25 years of age. With the ever increasing technological advancements being introduced into the water industry, a new generation of water operator who are technology savvy are required (Fergusson, 2011).

3. Requirement gathering

3.1 Prototype prompting and meeting with mangers

To clarify the objectives of the training platform and to elicit requirements, a face-to-face meeting was organized with the program managers from the local government and the development team. The general infrastructure and features available in the virtual world platform developed by the authors' software development team was demonstrated to the clients. An initial scope for Stage 1 of the project was established (with a duration of 17 weeks), which aimed to provide a virtual world environment. This included the minimal 3D models required for the water facilities to illustrate the complete water cycle, incorporating water pickup points from river, water tanks, and water taps in various locations. Full interactivity of these facilities was not expect in Stage 1, but will be developed in later stages.

The project team decide that the pilot training module should focus on the collection of water samples. This particular task was chosen as it is a statutory requirement for councils to perform water testing at regular intervals and it is a critical factor in the quality assurance process. It is also important as thousands of dollars can be wasted on retesting for each contaminated water sample.

3.2 Site visits, demonstration and meeting with operation staff

Several site visits were organised by the water industry staff to show the development team the operations of water facilities, which included the water pickup point, water treatment plant, waste water treatment plant, and water testing laboratory. On-site staff provided guided tours to explain the operation of the facilities and their roles in the water cycle. Photos and videos were used to record the visits. These are used as a reference for 3D models of the facilities in the virtual world as well as determining the required interactions with the objects. Demonstrations for the appropriate procedures of water sampling were presented by operational staff and recorded by the development team. Follow up meetings with the operational staff revealed more details of the water sampling procedures, including an explanation of the use of paper forms related to water sample requests, labelling of the water samples, uses of different types of bottles and jars for different types of tests, and precautions required for transporting water samples from the field to the test laboratory.

4. Features and implementation challenges

The training platform was developed in a virtual world with the landscape modelled after a small Australian outback town, which included water facilities to allow the trainees to carry out the water sampling procedures. Several challenges where encountered when developing the functionality for the training application.

4.1 Rendering realistic water

Rendering of realistic water is a difficult problem because of the visual complexity related to the physical properties of water, such as transparency, reflectivity, refractiveness, and fluid dynamics. Although there are a number of methods such as Fast Fourier Transforms (Tessendorf, 2001) and those based on fluid dynamics (Enright, Marschner & Fedkiw, 2002), these methods unfortunately require substantial amounts of computation, making them unsuitable for an interactive simulation application.

For rendering water on-screen, a two-pass rendering approach was developed. The first pass captures the environment geometry followed by the objects using the water shader prior to rendering the transparent geometry. The water has a customised shader that does not save any colour information to the frame buffer besides an alpha value of zero. It will not write to the ZBuffer, so no transparent geometry is occluded. The rendered environment (with the alpha zero holes) is stored and fed back into the rendering process for a second pass. This second pass uses a technique called Shader Replacement to render only the water meshes with a new refractive shader. The pre-rendered environment texture is used in conjunction with a tiling normal map and the objects' UVs to simulate a transparent refraction effect behind the actually-opaque object. Only pixels on the environment texture with an alpha of zero will be refracted, eliminating artefacts caused by lack of depth during refraction. Figure 1 shows the realistic water surface of a river in the virtual environment.

Figure 1: Realistic water simulation

One of the features required by this training platform, which is not usually require in other simulations or games, is the ability to fill different containers with water in the water sampling procedure. To simulate the filling of containers, a segment based approach is used to generate a stream of water from taps and other fittings, as well as to simulate water stored inside of a container. Segment locations and thicknesses are specified in the water attributes, which the water simulator will use to fill a cylindrical stream along the segments based on the volume required. The water will respect collisions and is designed to handle sharp bends in the flow. It will procedurally generate a mesh with the correct UV and triangle set to be rendered on-screen. Figure 2 illustrates the segmented water generator and the rendered segmented water.

4.2 Physics for small objects

Another challenge was the simulation of realistic physics for small objects. In this application, there are various types of jars and bottles for collecting different water samples as shown in Figure 3. One of the smallest bottles is about 2 centimetres in diameter by 5 centimetres tall.

Figure 2: (a) Segmented water generator and (b) rendered segmented water

Figure 3: (a) Jars and bottles and (b) rendered jars and bottles

In most game engines, physics of objects are simulated by defining the virtual object as a rigid body and allowing it to be affected by gravity in the virtual environment. The collisions between virtual objects are determined by different types of colliders associated with each object. In this application, it was found that the computational requirements and response time for small object collisions cannot be simulated with default primitives or the mesh colliders available in the physics engine. The physics engine did not response fast enough and caused objects to become stuck inside each other as shown in Figure 4, or for small objects to past through surfaces when dropped. To remedy this, raycasting was added to each interactive virtual object to allow detection of collisions in advance to deal with the physics engine response time issue.

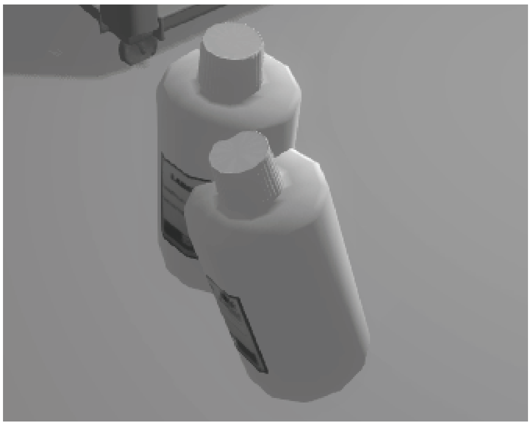

Figure 4: Objects penetrated each other.

4.3 Two handed controls for objects manipulation

The need to use two hands to manipulate objects was required to emulate the way that people interact with objects in the physical world. In the physical world, tasks are usually performed with both hands acting at the same time, but not necessarily doing symmetric actions. For example, the water sampler may pick up a jar with left hand, hold it, and then remove the lid of the jar with their right hand. The water sampler may then decide to put down the lid of the jar.

Researchers have explored uses for two hands in a number of virtual reality environments (Hinckley, Pausch, Proffitt & Kassell, 1998). For example, the Videodesk system (Krueger, 1991) uses video cameras and image processing to track 2D hand position and to detect image features such as finger and thumb orientation. Simple and self-revealing gestures can also be used for object manipulation in virtual environments. Another method is to use virtual reality gloves (Ishiguro & Oshita, 2008), which are based on a six-degree-of-freedom magnetic tracking technology to grab and manipulate virtual objects. However, these two solutions are too costly and require setups that may not be feasible for deployment in remote regions; hence they are not valid options for the current training application. As a result, the simulation was restricted to using the standard mouse and keyboard controls. Using this basic system, the graphical user interface (GUI) was designed with a two-handed conceptual model for the control mechanism. This required the trainee to make explicit decisions to switch control between the left-hand and right-hand in the virtual environment with a context menu to select the action to be performed on the virtual object.

5. Current implementation and future features

5.1 Current implementation

The training platform is being developed using the Unity3d Game Engine (http://unity3d.com). The virtual environment has been created with a virtual town containing residential houses, a school, a hospital, parks, and related water facilities. The virtual town is fully navigable by the users via walking or teleport. Several training features have been implemented and tested by the end users. Figure 5 shows the bird-eye view of the virtual town.

Figure 5: Bird-eye view of the virtual town

Interactions for the objects required for collecting water samples have also been implemented. Examples of these objects included various types of bottles and jars, torch, spray bottle, esky box, ice pack, and water tap. Users can control these virtual objects to complete water sampling procedures.

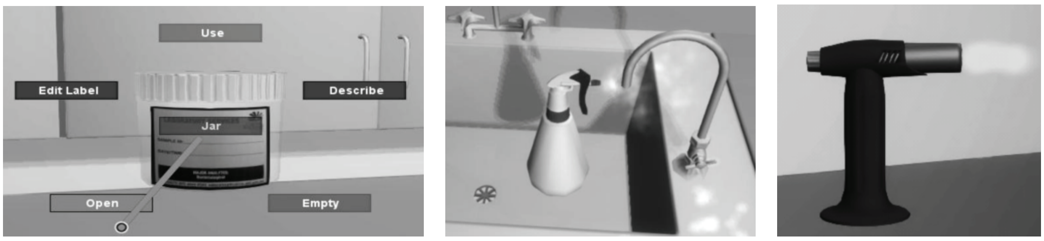

Figure 6: Interactive virtual objects including (a) a jar, (b) a spray bottle, and (c) a torch

5.2 Future features

Many virtual reality systems use only computer graphics to produce immersive virtual environments. In virtual reality research the main emphasis has been on 3D graphics. However, sound, as an important part of our everyday life and must be included in the creation of an immersive virtual environment (Hahn, Fouad, Gritz & Lee, 1998). In virtual reality applications, sound can either be environmental or background, or relate directly to the context. Background sound in a virtual environment can be used to create a certain mood for the user, e.g., background sound can be used for noise in a factory environment or for traffic noise in urban simulations. Sound sources are often attached to corresponding graphic objects and a realistic 3D soundscape should surround the user. For an immersive virtual reality experience, a three-dimensional soundscape needs to be created with sound control software capable of positioning sound sources anywhere in the 3D space according to the spatial and acoustic requirements and with the best level of fidelity.

Future stages of this project will investigate methodologies to enhance the soundscape to provide detailed information about the environment. This will involve developing a sound control software application to manipulate sound sources according to specific parameters. For example, the sound source needs to be manipulated to render the acoustical environmental based on the physical properties of the virtual space (Naef, Staade, & Gross, 2002). Furthermore, sound must render according the physical properties of the virtual environment such as the shape and surface materials of objects, as well as the movement of objects (Tsingos, Gallo & Drettak, 2004).

In addition, future development of this project will investigate the use of eye movement as a supplementary control method for users to interact with virtual objects in virtual space (Olsen, Schmidt, Marshall & Sundstedt, 2011). This is in response to the requirement for an easy to use control method for non-technological users. This is important as there are demands for e-training solutions for skill based training in workplaces where many of the employees have little or no computer experience. For instance, over 90% of water sampling employees are aged over 50 and seldom use a computer. Natural interfaces, such as eye movement and gestures can provide innovative solutions to accommodate a wide range of users when using virtual worlds for education and training.

6. Conclusions

The first stage of this training platform will provide a pilot to seek future funding to develop a virtual training package aligned with the national certification framework of the water industry in Australia. The deliverable of the first stage will assist the managers and other decision makers to recognise and envision several benefits that virtual training can bring to the water industry.

The main motivation for this project is to increase the training capacity for the water industry. This application will reduce travel costs and work-days lost by both the trainers and trainees. Trainees can use the application for self-paced learning to complete different scenarios. Log files recording how the trainees perform the tasks can then be sent to the trainers for reflections and assessments.

The learn-by-doing and situated learning approaches provided by this training platform are believed to be the best way to learn procedural knowledge; that is knowledge of performing a task, such as collecting water samples. The rules, skills, actions, and sequences of actions required to accomplish the tasks that are usually learnt through hands on activities on site, can now be learnt and practiced in the virtual training environment. The application not only ensures that all trainees encounter the same set of standardised scenarios, but it will also provide the trainee with a risk-free environment to practise and polish their skills.

The recorded playback and log files which store actions performed by the trainees in the virtual training environment will allow auditing of the training and assessment by independent assessors to ensure that standardised criteria are adhered to. The archived log files and records can be used to discover the most common mistakes and other hidden issues involved in performing the tasks. This information will then be used as feedback to improve the training package.

It is also believed that this interactive and game-based virtual training platform can not only make training more enjoyable, but also raise the interest of young people to learn more about water management and to consider working in the industry.

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