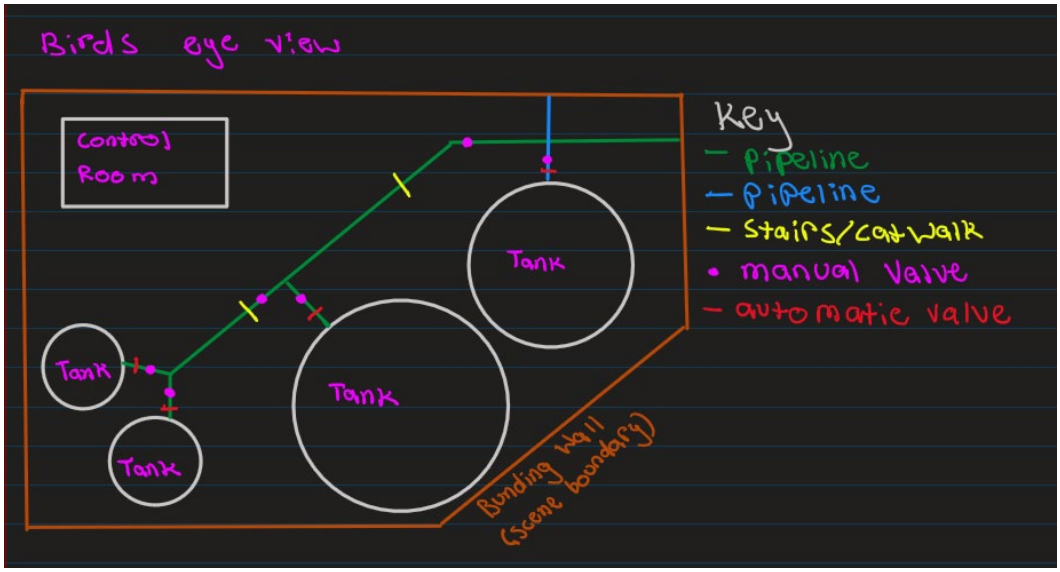
Assignment 4 Group 10

Introduction / overview



The Tank Operations and Advanced Safety Training v2 (TOAST2) application allows companies operating tank farms to train new pipeline operators with ease. It reduces the costs associated with ordinary training methods and improves accessibility of training, while being undertaken in a hazard-free environment. This access to training will reduce the risk to global infrastructure and the developed/developing nations that rely upon it.

Description of the application

Hydrocarbon based fuels remain essential to powering the modern world. However, managing these resources is a complex and hazardous operation, with improper operation resulting in disastrous effects to the environments and economies of all parties running and relying on these resources. These fuels are stored in tank farms, which subsequently are critical infrastructure for any developed nation.

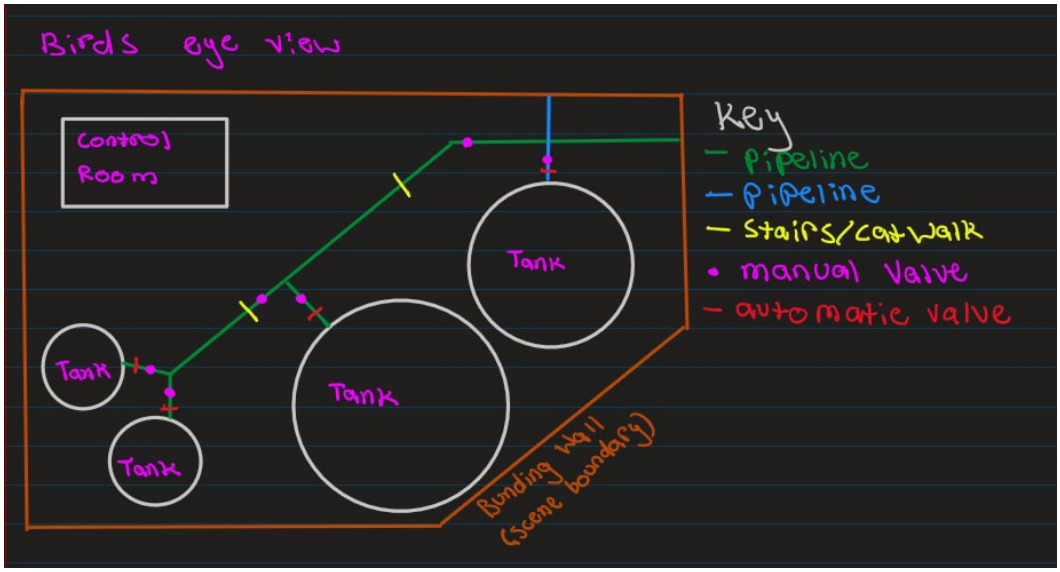


Figure 1: Storyboard of scene layout as seen from a bird's eye view.

Figure 1 is the preliminary design of the application's scene layout, reflective of a typical small scale tank farm a trainee would begin in.

Although there is little data on the frequency of tank farm accidents, one paper found the average cost of accidents to be $205,191,298 (a substantial sum) [1]. This application is designed to reduce the risks and cost associated with safely operating a tank farm through simulation. The application simulates day-to-day tank farm operations alongside response training to dangerous situations. This allows users to practice operations in a safe environment and build good practices before operating the real thing.

Description of the interface solution

Ordinarily to train new pipeline operators (those working on the tank farm) in a hazard-free environment either a tank farm needs to be temporarily shut down or an expensive simulator would be needed. With the huge volume of fuel processed by a tank farm, the cost of temporarily pausing operations would be exceedingly costly to the business. A dedicated simulator would be the better option, but there would also be large costs associated with this and would likely only be accessible to staff in dedicated training sessions. Virtual Reality (VR) is the ideal environment for this application, as it gives the required immersion demanded by a real-life simulation without the cost of either shutting down a tank farm or investing in an expensive simulator. This low cost means that the tank farm could have many VR headsets running the training application, increasing accessibility for pipeline operators at any time. Unlike Augmented Reality or a standard computer training experience, VR enables the user to take the physical motions of opening large valves that require two hands and may take time and effort to open rather than being as simple as clicking a button. VR is the deal interface to reduce cost and improve accessibility while retaining the 'realism' needed to train a pipeline operator to work in a hazardous environment.

Interaction Design

The interactions present in TOAST are critical for training, as these interactions in real life are typically physically involved. Training presented through visual feedback via a video or 2D like game often cannot convey the motions one must take to quickly open a valve or interact with controls in the event of an emergency.

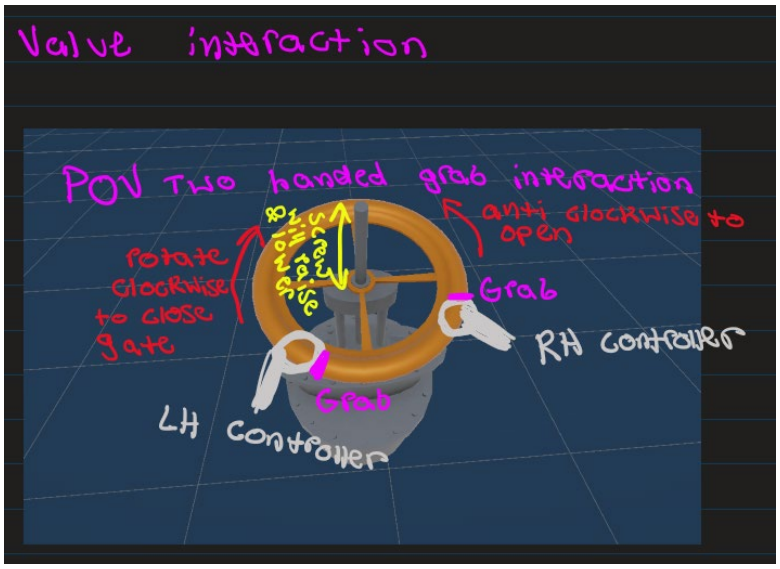


Figure 2: Storyboard of valve interaction from the point of view of the user.

The inclusion of a valve interaction demonstrates to a trainee how a large gate valve works through visual and physical feedback. When a user grabs onto the handwheel with both hands (controllers) and rotates it clockwise, the screw begins to lower, obviously shutting the valve and stopping the flow of product. Once fully closed, the valve can no longer be rotated clockwise as the gate has bottomed out. The opposite is true for when rotating the handwheel anticlockwise to open the valve.

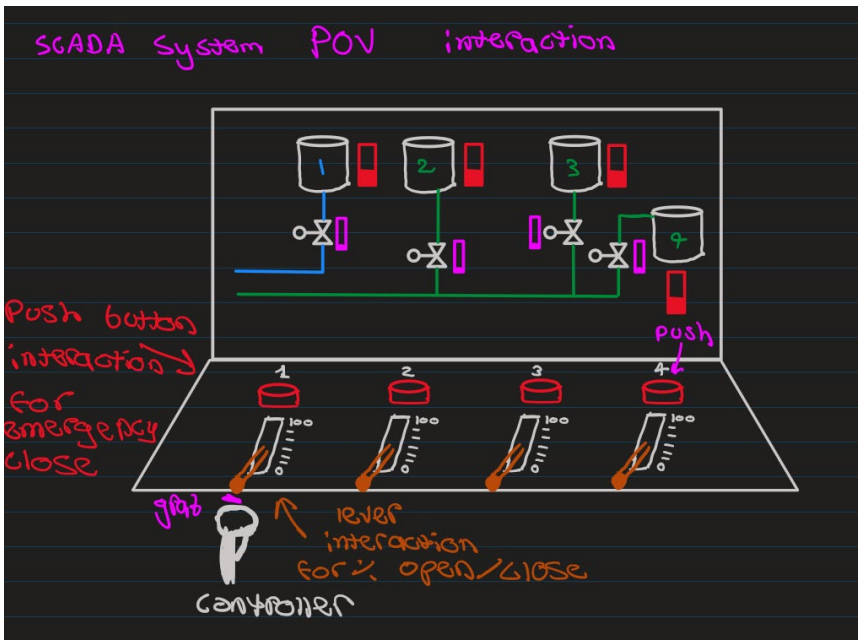


Figure 3: SCADA system with interactable push buttons and control levers.

As general operations of a tank farm include familiarity with a SCADA system for controlling automatic valves, inclusion of “control room” interactions were considered highly important. Simply grabbing a lever and moving it to the indicated percentage on the gauge located next to it would allow the automatic valves to be controlled with precision, changing the rate of flow into a tank. The push buttons would serve as an emergency stop, shutting the automatic valves as quickly as possible. While push buttons and lever use are less physical than other interactions such as valve operation, it is equally as important for it to become muscle memory for emergency situations. While SCADA simulators exist, they are typically expensive to build and will not represent the working environment. Additionally, conducting SCADA control system training away from a real operational environment permits the occurrence of user error, which would normally be catastrophic for the environment and personnel.

Technical Development Planning

This application will be developed in Unity using the Meta XR SDK for both the Meta Quest 2 and 3. Basic interactions like turning off a valve and spraying water on a fire have been implemented in AT3, which this application will build upon [2]. This application will extend the initial concepts developed and provide multiple valves and levers, along with automatic controls in a central control room (as shown in figure 1).

The major changes from AT3 will be automatic valves that are controlled from a central control room, a simulation mode for general tank farm operation (not just emergencies) and text prompts instructing the user on tasks to complete. The emergency scenarios will also occur at random tanks, requiring a different response each time. Emergency situations will need to be dealt with promptly to complete the tasks. To navigate around the new larger environment, we will utilise Meta XR locomotion interactions to teleport the user.

Planned unity functions:

- Locomotion interactions (teleporting the user)
- Hand grab interactions (two and single handed for valves and levers respectively)
- Button press interactions
- Particle effects to represent water, oil and fire
- Text prompt overlays
- Updating SCADA system monitor

Initial 3D Models

The Auto-valve will be used to open and close fuel-flow in the system remotely from the control room. This gives a physical representation of the valves and distinguishes between those the user cannot interact with.

Figure 4: Auto-valve 3D model made in Unity (not directly interactable).

There will be interactable push buttons used to control the simulation from within the headset, either activating systems (e.g. fire suppression) or selecting the desired simulation mode.

Figure 5: Interactable Push Button 3D model made in Unity.

The interactable levers will be used to control the auto-valves from the control room. They will enable users to physically control the percentage that a valve is opened, also providing a visual representation.

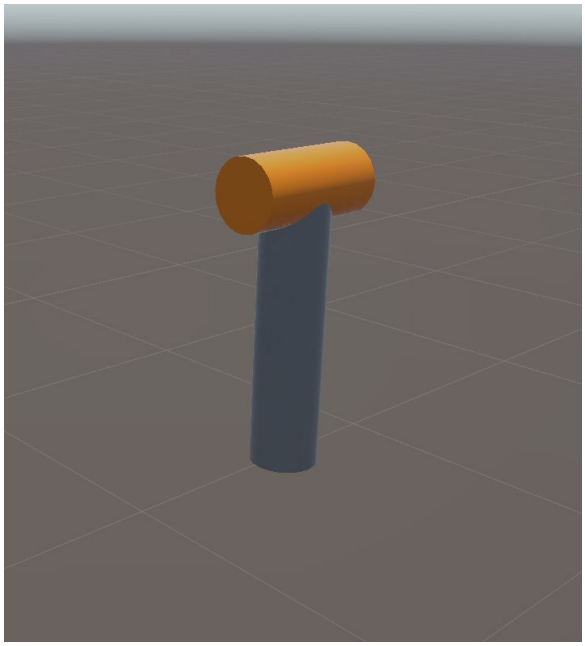


Figure 6: Interactable Pull Lever 3D model made in Unity.

The sprinklers will be used in the fire scenario, visually representing the effects of adding water to the fire.

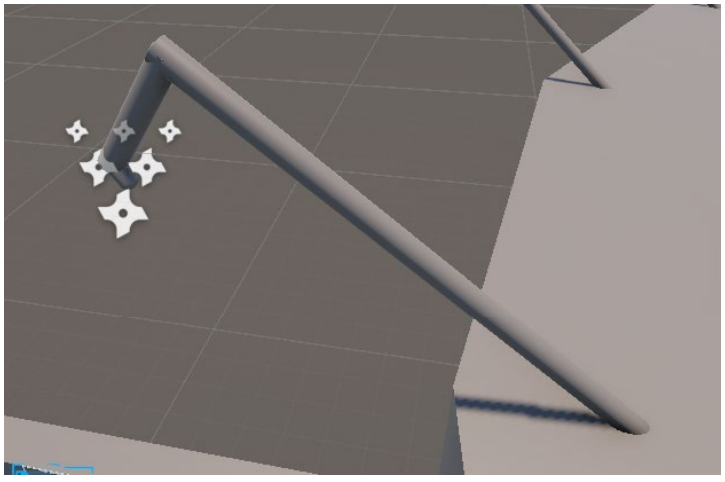


Figure 7: Sprinkler with particle effect 3D model made in Unity (non-interactable).

The tanks will be various sizes and used to contain the fuel that the user needs to manage throughout the simulations. It represents the fuel assets that the pipeline operator must maintain to run the tank farm optimally.

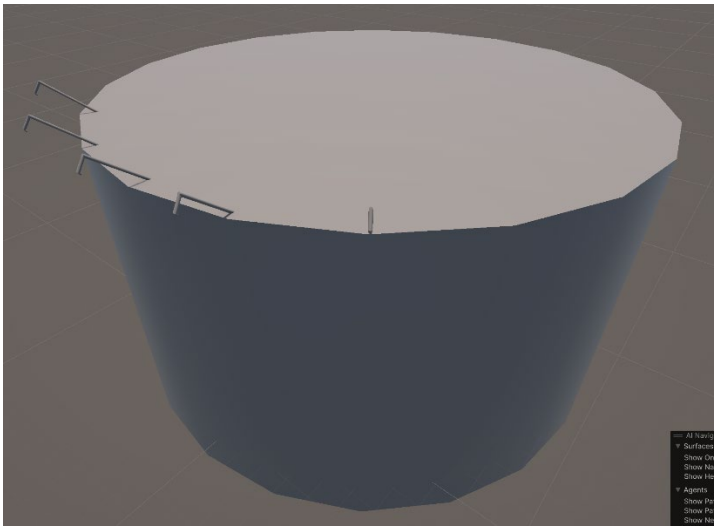


Figure 8: Tank 3D model made in Unity (non-interactable).

The manual valve will represent a physical valve option that the player can use to cut off fuel. This will be physically challenging to close to represent the physical difficulties faced in the real world.

Figure 9: Interactable Two Hand Grab Valve 3D Model made in Unity.

The model below is a prototype of the SCADA system that can be used to monitor the tank farm from the control room. This will only allow users to access the auto-valves, not the physical ones. This shows the clear separation in a real tank farm between electronic and manual measures to control fuel-flow.

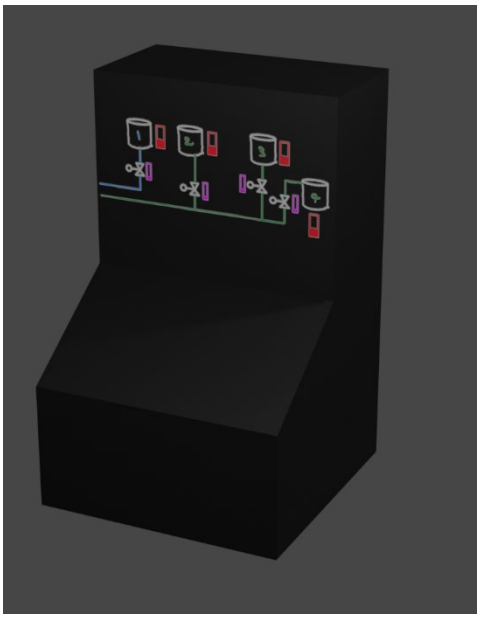


Figure 10: Interactable prototype of the SCADA control panel (missing buttons and levers)

Conclusion

TOAST2 is a VR application intended to assist pipeline operators in safely operating a tank farm. It allows them to train in a low-risk environment, while still undertaking the physical interactions required to do their job. This should result in less tank farm emergencies, which are a huge cost to every industry that relies on fuel for their operations (most companies worldwide).

References

[1] O. Ahmadi, S. B. Mortazavi, and Hasan Asilian Mahabadi, “Review of Atmospheric Storage Tank Fire Scenarios: Costs and Causes,” *Journal of Failure Analysis and Prevention*, vol. 20, no. 2, pp. 384–405, Feb. 2020, doi: https://doi.org/10.1007/s11668-020-00846-5. Available: https://www.researchgate.net/publication/339394946_Review_of_Atmospheric_Storage_Tank_Fire_Scenarios_Costs_and_Causes. [Accessed: Oct. 20, 2024]

[2] *Noah West*, "TOAST," Unity Application, version 6000.0.5f1, Oct. 2024.

No AI was used in the creation of this report.