

DEVELOPMENT OF VIRTUAL REALITY-BASED TRAINING ENVIRONMENT FOR BREAK RELEASE MEASUREMENT OF AN INDUSTRIAL FLOUR MILLING PROCESS

Lawrenze Earl Romaguera¹, Efren Tabuada¹ and Cherry Mae J. Galangque²

¹Department of Electrical Engineering and Technology,
Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines.

²Faculty of Computer Engineering,
Department of Electrical Engineering and Technology,
Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines.

Corresponding Author's Email: ¹lawrenzeearl.romaguera@g.msuiit.edu.ph,
¹efren.tabuada@g.msuiit.edu.ph, ²cherrymae.galangque@g.msuiit.edu.ph

Article History: Received xxxxx; Revised xxxx; Accepted xxxx

ABSTRACT: The fast-growing field of virtual reality is slowly reaching a trend in the field of professional training. With the advent of faster and more powerful Virtual Reality System and their rapidly increasing applications in business sectors are starting to tap into VR to assist them during recruitment, training, and retaining employees with virtual reality simulated environments. By giving new recruits and old hands immersive experiences that seem more like play than work, Virtual Reality System can inject interest and engagement where they may be lacking, helping employees see their jobs in a more positive light. This paper mainly focuses on the development of a virtual-reality based training environment for the break release measurement procedure of an industrialized flour production facility. The methodology is based on the use of flour mill equipment models and virtual reality techniques in order to simulate processes in a safe and immersive virtual environment. The researchers made use of Unity's game engine platform to handle the physical behavior and responses of the game objects to the user's interactions and C# to simulate the virtual environment processes together with an HTC Vive VR hardware setup to connect the user to the virtual world.

KEYWORDS: *Virtual Reality; Roller Mill; First Break Release; Virtual Trainer; Milling Process Simulator.*

1.0 INTRODUCTION

Virtual reality (VR) technology is defined as an advanced system that allows users to

experience computer-mediated environments and simulations through the use of a combination of different technologies and sensors such as head-mounted displays (HMDs), handheld game controllers, haptic feedback, IR tracking system, and many others [1].

The innovative nature of virtual reality makes it very appealing to several business groups and the public sector. Industries that belong to the fields of medicine, engineering, and the physical sciences have been relying more heavily on VR systems in order to provide better training, visualization, and education to both their students and staff [2].

In a Flour Mill industry, flour milling is the process by which wheat grains are ground into flour [3]. In this process, operators are usually exposed to work hazards such as dust, excessive noise, explosions, electrocutions, and injuries from improperly guarded machinery [4]. This is why newly-hired employees, especially machine operators, must be given proper training on safety and standard operating procedures to avoid unwanted accidents and on-site injuries. However, employee training is expensive and time-consuming as evidenced by the fact that teaching new employees on how to operate factory equipment is usually done in groups to save time and resources [12]. For some industrial facilities, training often requires shutting down operations and putting employees and trainees in potentially dangerous situations. Conversely, poor training experience for new employees can have disastrous consequences ranging from low company productivity to major work accidents, possibly resulting in serious injury or loss of life [5]. Because of these, virtual reality training scenarios would be highly beneficial to both new employees and the company, thus, this paper is focused on the development of a virtual reality training environment for the industrial flour milling process, specifically, for the break release measurement procedure of a roller mill.

2.0 METHODOLOGY

2.1 Break Release Measurement

The development of the system comes with the understanding of what is break release measurement in flour milling process. Break release is stated as the percentage of material passing through a specific size testing sieve [6]. The purpose of measuring the break release in flour milling is to ensure consistent distribution of the stock throughout the mill and avoid choking which causes machine malfunction [7].

Before executing the procedure, one must ensure that the mill is operating under regular load [13]. The process starts with collecting samples from specific roller mills. Representative samples must be taken equally from the left side and the right side of the roll, both from the front and the back, to ensure accurate results. The next step is recording the weight of all the samples taken from the mill, just before sifting them. The sifting time and the sifter size used must be uniform all throughout the entire procedure. The break system extraction will then be computed by comparing the amount of stock obtained before and after the sifting process using (1).

$$\text{break_release} = \frac{\text{amount_of_stock_through_the_sifter}}{\text{total_amount)of_stock}} (1)$$

2.2 System Setup

Generally, a VR system that is rendered on a personal computer or laptop needs 3 primary VR hardware components: (1) a head-mounted gear to display the VR content; (2) a pair of base stations to track the position and location of the VR devices; and (3) 3D game controllers to interact with the game objects within the virtual environment. For this study, the researchers used HTC Vive virtual reality hardware setup as shown in Figure 1.

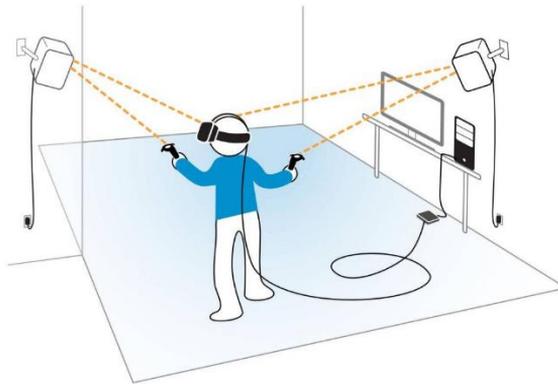


Figure1:HTC Vive Virtual Reality Hardware Setup

Vive's Lighthouse tracking system, pioneered by Alan Yates of Valve, uses Beacons (also known as base stations) which emit well-timed IR pulses and 2D IR laser sweeps [8]. Arrays of IR-filtered photodiodes are embedded within each VR device that needs tracking and the system uses them to calculate the relative position of the devices in 3D space. As the 2D plane of IR laser emitted by the base stations hits the photodiodes (sensors) of each respective devices, the diodes' output is amplified and then sent into an internal circuitry which is programmed with the relative location of the source signals from the base stations [9]. Given that there are enough inputs from the sensors, the internal integrated circuit within each VR device can then locate its relative position and orientation in space.

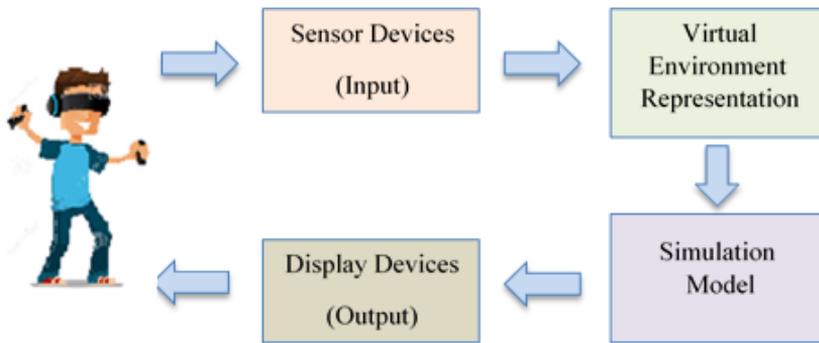


Figure2: System Architecture

Figure 2 shows the overall system architecture. Using IR-based technology, the sensors embedded within each device determines the user’s real-time position and location relative to the ground. The data from the sensors are then used to translate the user’s movements and position from the real world to the Virtual Environment Representation. The user’s interactions as well as the objects’ behavior and response are then processed and computed in the simulation model to emulate real-world interactions. The simulation’s behavior and response to the user’s actions are then rendered to the Display Devices which acts as the window into the virtual world.

2.3 Development Process

Creating the virtual training environment involves the following steps: (1) creating 3D models for the game objects, (2) environment design (3) environment programming and (4) creating tutorial scenes to guide the user throughout the entire training session. The overall system development process of the VR-based training environment is shown in Figure 3.



Figure3:VR System Development Process

2.3.1 3D Modeling

The first part of the development process involved creating 3D models which the user will be interacting with in the virtual world. For this study, the researchers used SketchUp to design all 3D objects needed during simulation.

2.3.2 Environment Design

To implement the designing and programming stage of the virtual environment, the researchers made use of the free version of Unity, a cross-platform game engine developed by Unity Technologies. After creating the 3D models for the objects that will be used in the virtual world, textures can then be added to give an object a material-like finish. Another important thing to consider in designing an immersive virtual environment is the lighting effect. One can choose between the various lighting techniques and light sources available within Unity, each of which has its own corresponding setting for the intensity, direction and color of the light that falls upon it. Unity can also simulate the effect of an audio source that is being emitted by an object. It supports most of the standard audio formats such as MP3, WAV, AIFF, and Ogg formats and can also record audio from any available microphone on the user's computer during runtime. Properly applying these techniques can influence the user's senses into accepting this version of reality by creating effects such as lighting, shadow, sound and tactile feedback.

2.3.3 Environment Programming

After designing the virtual environment to look and feel realistic, the next step would

be to program the behavior of the machine and the objects used in the VR training environment. To control an object's motion through Unity's physics engine, a rigid body element must be attached to it. By giving it a Rigid body component, an object can then be pulled downward by gravity, react to collisions with other game objects, and be moved to a particular direction by applying forces to it [10].The collider component defines the object's shape and outlines the space of contact with other objects for the purpose of physical collisions [11]. Colliders play a big role in terms of physical interactions with the trainee and the game objects.Unity allows 2 scripting languages in its platform: C# and Java. The researchers used C# as the primary scripting language for this study. The scripts in Unity handle the physical behavior of the objects within the virtual environment.

2.3.4 Tutorial Scene Creation

The next step of the development process is turning the game into a tutorial. This is done by adding scripts or programs to certain game objects within the virtual world, as well as voice commands and arrow pointers for the trainee to follow. The scripts can outline in which part of the tutorial the trainee did wrong by using certain color signals as highlights whenever an incorrect action is executed by the trainee. The arrow pointers and voice commands can help the user determine which step to execute next.

3.0 RESULT AND DISCUSSIONS

This section briefly describes each of the modules produced for this project and the design and development of a VR based training environment for break release. Figure 4 shows the VR-Based Training Environment.

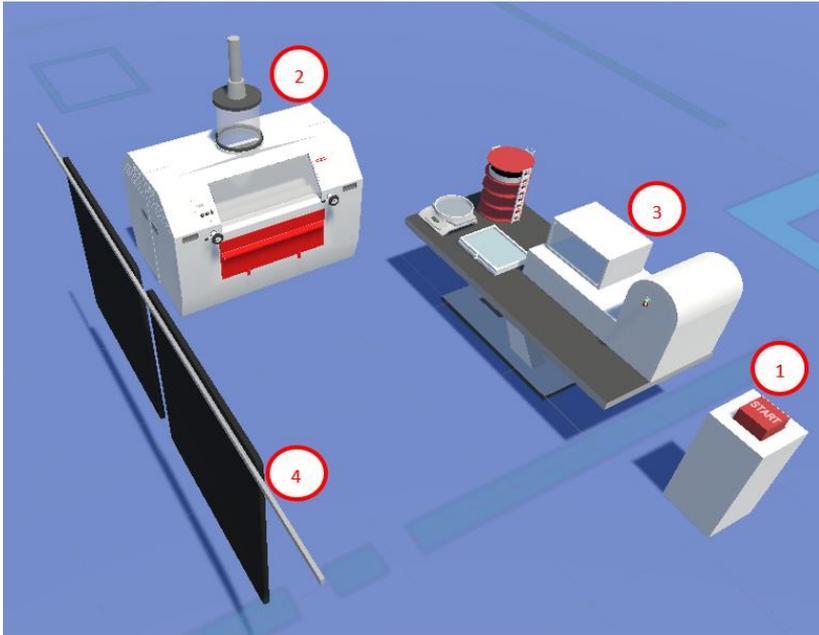


Figure 4: VR-Based Training Environment

The VR-Based Training Environment contains the following:

- i. The start button will have served as a switch for the transition from Free-roam sandbox mode to the guided operation tutorial
- ii. The roller mill houses the rollers which break and grind the input wheat to break flour with the desired yield (component names and functions are further discussed on Figure 5)
- iii. The sample Analysis that contains equipment needed for determining the break release output (component names and functions are further discussed on Figure 6)
- iv. Data display, which displays reference tables and the wheat weights being processed.

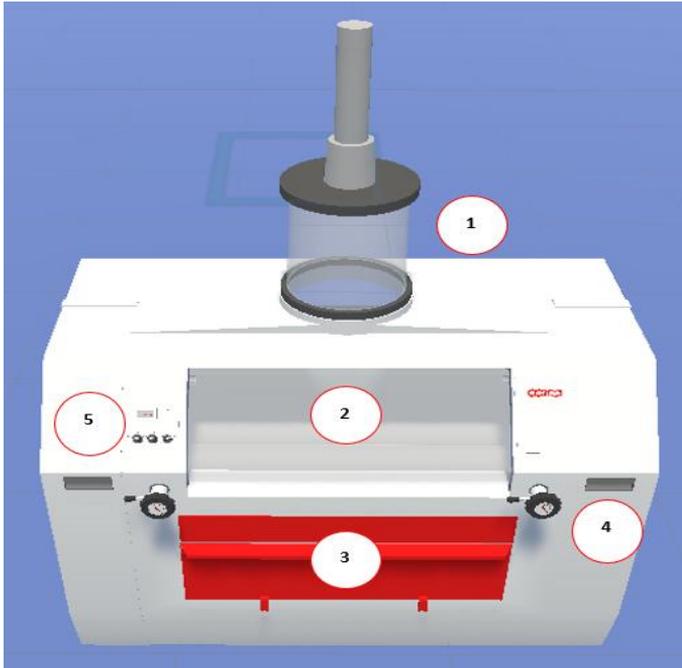


Figure 5: The Roller Mill

Figure 5 shows the components of the roller mill. It contains the following:

- i. A tank that acts as a window to the input wheat, which gives the operator visuals on the wheat's flow rate
- ii. A wheat viewing window, used as a viewing window which gives the operator access to the incoming wheat, for acquiring input wheat samples positioned above the grinding zone
- iii. A window that gives the operator access to the sampling zone to collect discharged wheat for break release sampling, situated below the Grinding zone
- iv. A grinding clearance adjustment knob that adjusts the grinding clearance between rollers to achieve the optimal yield expected for specific break release levels and roller mill to bring the roller mill to operation or stop its processes.

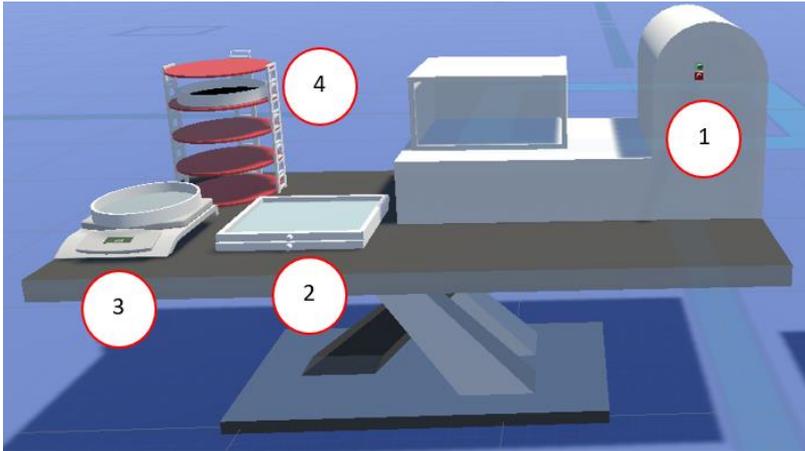


Figure 6: Work Table for Sample Analysis

Figure 6 shows the work table for sampling analysis. It contains the following:

- i. A vibrating sifter that vibrates to separate the break flour from other wheat components not needed for the final flour and are subject to more grinding
- ii. A sieve and bottom frame that strains the break flour from other wheat components by way of separating finer flour particles with much coarser wheat components. The separated flour is then collected at the bottom frame, which is to be weighed as the final output to compute yield
- iii. A weighing scale for measuring the weight of the acquired initial break flour sample and the strained flour to compute the break release yield
- iv. A sampler container and tray for a more organized stacking and transport.

4.0 CONCLUSION

The researchers were able to design a virtual reality training environment for break release measurement of an industrial-grade flour manufacturing facility with the use of a game engine platform and 3D modeling software. In the system architecture of this paper, the basic working principle of a VR environment was presented. The steps needed to design the VR training environment were also discussed as part of the development process. The results showed the appearance of the finished VR training environment as well as some description of each object in the virtual world and their respective functionalities and uses.

For the future direction of this study, the researchers plan on coordinating with local industrial production plants to introduce the application and benefits of virtual reality training for the company and its employees. Possible future applications of this research include: virtual tour of the entire manufacturing plant, virtual training for proper safety procedures in the factory, guided multi-person training session, machine maintenance training, and many others.

ACKNOWLEDGMENTS

The paper would like to acknowledge the Mindanao State University–Iligan Institute of Technology and partnered Flour and Feed Mill Foods Corporation. Special acknowledgment is given to the people who helped in the project conceptualization and provided us the premises and facilities which were necessary in the development of the project.

REFERENCES

- [1] M. Nasser and N. Ali, “Review of virtual trends (previous, current, and future directions), and their applications, technologies and technical issues,” *ARPJ Journal of Engineering and Applied Sciences*, vol. 12, no. 3, pp. 783-789, 2017.
- [2] A. Cirulis and E. Ginters, “Training Scenario Operations Realization in Virtual Reality,” Sociotechnical Systems Engineering Institute Vidzeme University of Applied Sciences, Valmiera, Latvia, 2011.
- [3] L. Popper, W. Schafer, and W. Freund, *Future of flour : a compendium of flour improvement*. Germany: Mühlenchemie GmbH & Co. KG, 2006.
- [4] W. Wachira, “Status of occupational safety and health in flour milling companies in Nairobi Kenya,” M.S. thesis, Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya, 2016.
- [5] R. Li, “Virtual Reality and Construction Safety,” in *An Economic Analysis on Automated Construction Safety: Internet of Things, Artificial Intelligence and 3D Printing*. Singapore: Springer Nature Singapore, 2018, ch. 6, pp 117-136.
- [6] M. Fowler, “Adjusting the Break System,” *World Grain*, vol. 32, no. 4, pp. 114-118, 2014.
- [7] M. Fowler, “Optimizing Break Release,” *World Grain*, pp. 30-34, 2012.
- [8] M. Borges, A. Symington, B. Coltin, T. Smith, and R. Ventura, “HTC Vive: Analysis and Accuracy Improvement,” *IEEE/RSJ International Conference on Intelligent Robot and Systems (IROS)*, pp. 2610-2615, 2018.

- [9] D. Neihorster, L. Li, and M. Lappe, "The Accuracy and Precision of Position and Orientation Tracking in the HTC Vive Virtual Reality System for Scientific Research," *Sage Journal*, pp. 3-4, 2017.
- [10] A. Cano, "Design and Implementation of a Virtual Reality Laboratory for Mechanical Maintenance," M.S. thesis, College of Business and Technology, Morehead State University, Kentucky, USA 2018.
- [11] A. Alqahtani, L. Daghestani, and L. Ibrahim, "Environments and System Types of Virtual Reality Technology in STEM: A Survey," *International Journal of Advanced Computer Science and Applications*, vol. 8, no. 6, pp. 77-89, 2017.
- [12] S. Zahra, A. Iram, and H. Naeem, "Employee Training and Its Effect on Employees' Job Motivation and Commitment: Developing and Proposing a Conceptual Model," *IOSR Journal of Business and Management*, vol. 16, no. 9, pp. 60-68. 10.9790/487x-16916068, 2014.
- [13] J. T. Bell and S. H. Fogler, "The Application of Virtual Reality to Chemical Engineering and Education," *IEEE Virtual Reality 2014*, 217-218, 2004.
- [14] M. Oxenburgh, P. Marlow, and A. Oxenburgh, "Increasing productivity and profit through health and safety. The financial returns from a safe working environment," *Boca Raton, FL: CRC Press*, 2005.
- [15] L. Valente, E. Clua, A. Silva, and B. Feijo, "Live-action virtual reality games," *ArXiv, abs*, 1601.01645, 2016.
- [16] F. Caputo, G. Di Gironimo, and A. Marzano, "Ergonomic Optimization of a Manufacturing System Work Cell in a Virtual Environment," *ActaPolytechnica*, vol. 46, no. 5, pp. 21-27. 2006.
- [17] J. Cecil, A. Gupta, B. R. Kumar, M. Pirela-Cruz, E. Chan-Tin, and J. Yu, "Development of a Virtual Reality Based Simulation Environment for Orthopedic Surgical Training," *Springer International Publishing AG*, vol. 8842, pp. 275-285. 2014.
- [18] A. Cheok, K. Goh, W. Liu, F. Fabriz, S. Fong, and S. Teo, "Human Pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing" *Personal and Ubiquitous Computing*, vol. 8, pp. 71-81. 2004.

- [19] S. M. LaValle, *Virtual Reality*. Oulu, Finland: Cambridge University Press, 2018.
- [20] L. Twiname, H. Samujh, and S. Rae, "Accounting for the costs of recruitment and training," *Association for Business and Economics Research (ABER)*, 2011.