Desktop forklift simulator - DFS

Simulador de montacargas de escritorio - SME

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Abstract

This article presents the design and development of a technological tool that has the function of a forklift simulator, which is an interactive desktop application, and the objective is to train personnel in the use of a forklift car, to prevent accidents and major injuries. reliability in the mobility process when driving in real time: the methodology used is scrum to generate a software product with compliance with the industry requirements, which is carried out through a product backlog, and sprints to carry out the deliverables of the simulator modules, the result obtained was a graphic engine of Unreal Engine 5 and Blender for modeling, where the connection of devices is made, the control with steering wheel, pedals and gear lever is generated.

Goals: Development of a virtual forklift simulator for training in the manufacturing industry, through the use of devices with graphic control.

Findings: Graphic engine, with control of devices for training

Contributions: Development of virtual simulators that facilitates the handling of heavy machinery in companies, reducing training costs and minimizing accidents.

Method: Adquisition; Preprocessing; Model generation; Tester

Forklift, Simulator, Training, Unreal engine, Control

Resumen

Este artículo presenta el diseño y desarrollo de una herramienta tecnológica que tiene la función de un simulador de montacargas,la cual es una aplicación de escritorio interactiva, y el objetivo es poder capacitar personal en el uso de un carro montacargas, para prevenir accidentes y mayor confiabilidad en el proceso de la movilidad al conducir en tiempo real: la metodologia utilizada es scrum para generar un producto de software con el cumplimiento de los requerimientos de la industria, la cual se realiza mediante un product backlog, y sprints para realizar los entregables de los modulos del simulador, el resultado obtenido fue un motor gráfico de Unreal Engine 5 y Blender para el modelado, en donde se realiza la conexión de dispositos se genera el control con volante, pedales y palanca de velocidades.

Objetivo: Desarrollo de un simulador montacargas para la capacitación en la industria, mediante el uso de dispositivos con un control gráfico.

Resultados: Motor gráfico, con el control de

Contribuciones: Desarrollo de simuladores virtuales que facilita el manejo de maquinaria pesada en las empresas reduciendo costos de capacitación y minimizando accidentes.

Análisis de Requisitos; Diseño de la interfaz y funcionamiento; Generación del Modelo; Pruebas; Evaluación del usuario

Montacargas, Simulador, Unreal Enginer Control

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Introduction

In the area of engineering and technollogy as well as innovation It is still transforming the way we aproach industrial challenges. The development of innovative solutions is a key element to power operating efficiency and also to improve security standars in a work environment.

This proyect developed a technollogical solution that uses a simulator in a format of a local desktop application which controls a wheel decive and pedals for videogames.

The use of cutting edge technollogy, is essential in industry in order to train new operators who work in high-risk activities.

Tho technollogy will be also be able to interact with more decives in real time.

This proyect was created by using Blender and Unreal Engine software.

Blender and Unreal Engine allowed us to generate functionality on every device connected to the software all together working to simulate a lift fork.

Manufacturing industry is in charge of creating products which require a high difficult range such as the ability of driving a lift fork in warehouses. Traning forklift drivers might be a risky task when interacting directly with the l forklift car. (Anylogic ,2019).

Therefore by developing this project ,one of its main porpouses is reducing risks by using a virtual forklift simulator it can also help us improve the task of driving a forklift

Background

We count with contributions that use a forklift simulator with the development and the implementation of a virtual forklift simulator to train forklift operators, the study compared traditional training methods with a VR-based training approach, assessing their impact on energy consumption and overall efficiency of forklift operations in airport cargo terminals (Kierzkowski, A, 2024)

In addition several studies have been made that use simulation to optimize automotive assembly lines , highlighting their contribution to improve productivity and cost reduction in automotive industry. The simulation-based optimization is used to find feasible scenarios with least reconfiguration, stochastic, influences such station failures and reactive scheduling decisions can be considered (Rachner et al, 2023)

While some other authors have also been interested in the meta-analysis on the effectiveness of training simulators for crane operators, analyzing the impact on industrial security and skills acquisition by operators, The commercial release of affordable, low-cost, and consumer-ready virtual reality (VR) devices has increased the accessibility for researchers to investigate the benefits of VR technology including those aimed at education and training. VR technology provides several opportunities that may provide benefits over traditional training methods (Song et al, 2021)

Some other projects about safety at work in contruction industry have been made by using Virtual reality simulators , these simulators were able to improve safety an efficency at work o (Ra chner, 2023)

On the other hand there are also outcomes when using Virtual simulators in the teaching-learning process in the different educational instances showing the need of encouraging and appreciating art and culture .

It is important to find effective ways to promote experiences releated to art for students in order to develop multiple learning intelligences , especially focused to spaces and enviroments. Therefore virtual tours are a very important tool to appreciate art from any place in the world; this methodology allow us explore places and spaces in a virtual way an so then people can get knowledge by using cultural resources from different institutions and museums. (Calvillo Villicaña, 2024).

Simulation is used to improve material handling in a factory , showing how this tool can improve efficiency and operational cost reduction (Kim, 2021).

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Comparative studies have been made by using different virtual reality simulators used in cranes operators trainning ,assesing effectiveness and impact when trainning.(Lee, 2019).

The researching group Wang et 2018 made a research analysis that use simulation to analyze automatic guided vehicle systems in warehouses, providing an overview of their application and outcomes as well (Wang, 2018).

Another longitudinal field of study examines the long-term effects of virtual reality training for industrial truck drivers, evaluating its impact on job safety and drivers performance (Rodríguez, 2020).

It was also analyzed a case study about optimizing material flow in automotive manufacturing plants by using simulation , highlighting improvements in efficiency and productivity (Chen, 2019).

The Kim and Park working group describe a experimental report where they obtained research results with a variable focused on effectiveness, in the training of forklift operators through virtual reality simulation, assesing its impact on safety and the acquisition of skills by the operators (Kim, S., Park, J., 2017).

A contribution has been obtained from a study case by implementing a training program based on simulation to provide maintenance to industrial equipment improving times reduction and different virtual reality simulation approaches for assembly line balancing (Jones, 2018).

A simulator that uses ultra broadband technollogy with UWB measurements from a real sensor array was used as well. This simulator was used also with a localization algorithm and a physical model of a forklift, position estimates were obtained in different scenarios with different obstacles, a UWB was also modeled and simulated as well , an additional inertial sensor and an optical sensor were also modeled to test their effect in supporting UWB-based location (Kierzkowski, Ryczyński, & Kisiel, 2024).

The other authors conducted a study based on collaborative virtual environments (CVE) that offers a promising avenue for inclusive teamwork training. (Amat et al. 2024) An application was found that presents an experimental concept for developing a realistic human-machine interaction (HMI) for a Virtual context (VE) and a new methodology for assesing the system. This assesment is generated to facilitate the transfer of VE model/knowledge to a Real Environment (RE), where the VE is implemented to activate user behavior similar to that of RE. This analyzes the application of that concept to asses forklift interactions operation in the VE. First, a virtual reality forklift simulator is used. The simulator is developed using motion capture and 3D (J. Y. Chew, 2019).

The autor Preutenborbeck (2024), in their article they show the integration of haptic feedback into virtual assembly systems, providing a comprehensive overview of the current state of research, a systematic literature review.

The review is carried out focusing on applications, study designs, haptic devices and the effectiveness of haptic feedback. The review shows that haptic feedback can increase immersion in virtual environments and thus improve the quality of information and highlights the potential of the systems for future virtual assembly applications.

Methodology

A virtual simulator for desktop application format was developed , in 5 phases , these phases were implemented by the team work to develop a design , the modeling of the forklift , the programing of interactions in Unreal Engine software , the implementation of interactions, verifying the logic of movements and testing on desktop computers and with operators.

Phase 1: Environment Design

The design was made by using Blender software, with this software the physical facilities of the factory were designed were the forklift is located and working. In order to develop this phase of the project a basic model of a warehouse and a fork lift obtained from the store Epic Games , It allowed us no to start from zero at the environment design phase.

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Once the warehouse was composed and visualized, a search was carried out on the Internet for some models of objects that could be added to the warehouse, such as: containers, shelves, pallets, etc. Some of the sites that were useful for downloading models are:

https://free3d.com/es/modelos-3d/de-madera

https://www.turbosquid.com/es/

https://sketchfab.com/tags/modelos

Creating realistic 3D models of facilities, machines, halls, and obstacles found within the facilities.

Objects were selected, after they were modified in Blender and in the cases necessary for the warehouse. Likewise, the design of the lights, obstacles, platforms, walls, and windows, and they were integrated into the design of the warehouse.

It was necesary to have a general idea of how the warehose was built , hence a resarch was made about industrial warehoses in order to have a first generic draft.

On Figure 1 it is shown the Desktop application for p.c. of the Desktop Forklift Simulator DFS, that allows to acces the application

Box 1

Figure 1
Main menu Desktop Forklift Simulator -DFS.
Source: Own elaboration

Phase 2: Modeling the forklift

Redesigning the forklift 3D model in Blender. Making sure to include details such as the cabin of the driver , forks, wheels, lights, levers, steering wheels, pedals, mirrors and any other necessary components.

Figure 2 shows the design of the forklift integrated with environment objects.

Box 2

Figure 2
Design screen showing the forklift integrated with environment objects
Source: Own elaboration

Figure 3 shows the forklift in a virtual environment with objects and lights that allow realistic interaction.

Box 3

Figure 3
Screenshot with lights in the warehouse and the forklift
Source: Own elaboration

Phase 3 Programming in Unreal Engine

A new project is created in Unreal Engine and the virtual reality settings are set up according to the device specifications. The 3D models and animations created in Blender are imported into the Unreal Engine project.

The game logic is then developed to control movements and interactions of the current forklift and the warehouse using Blueprints, these blueprints can be created from the ground or can be imported from other sources , as can be seen in Figure 4 and Figure 5.

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Box 4

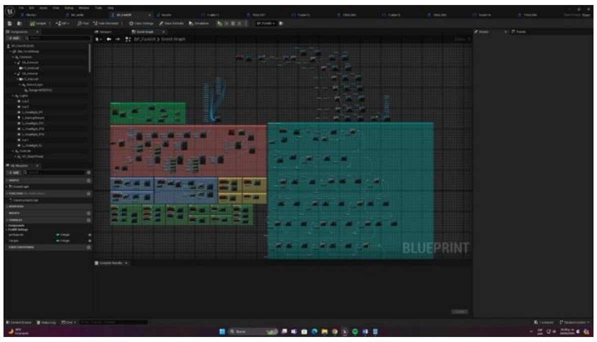

Figure 4
Screenshot showing Blue prints used to create physics , movements and animations for the forklift , and the necessary enviroment
Source: Own elaboration

Box 5

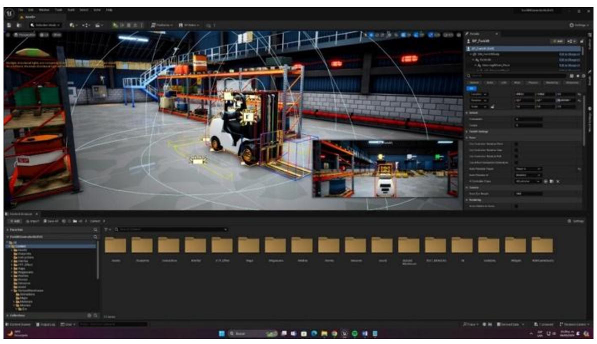

Figure 5
Screenshot showing the DFS in operation
Source: Own elaboration

Phase 4: Implementing interactions

Figure 6 shows how the logic implementation is performed so that the forklift can interact with objects in the environment, such as picking up and dropping pallets, avoiding collisions, etc.

Box 6

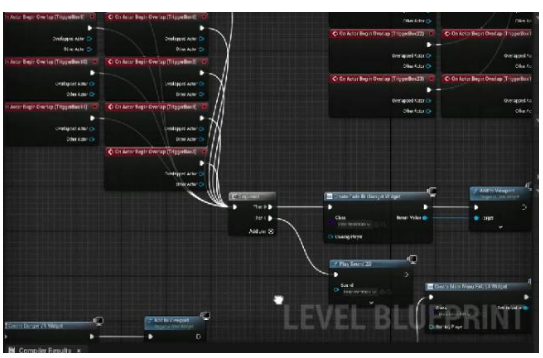

Figure 6
Screenshot showing visual programming by using blue prints used by the forklift to interact with the vrtual enviroment
Source: Own elaboration

Box 7

Figure 7
Screen shot from the warehouse for the DFS
Source: Own elaboration

Figure 7 shows the industrial warehouse environment verifying that interactions are realistic but also respond appropriately to the actions of the player who is known in the game as the operator.

Phase 5: Testing and Optimization

Verification of different simulator movements to identify but also solve errors or performance problems. It is verified that the support software updates are implemented, this is for the maintenance of the simulator, which allows it to maintain good performance.

During the development process of the simulator, different tests were carried out, both by the members of the development team and by the higher education institution as well as by a manufacturing company which helped a lot with feedbacks.

Box 8

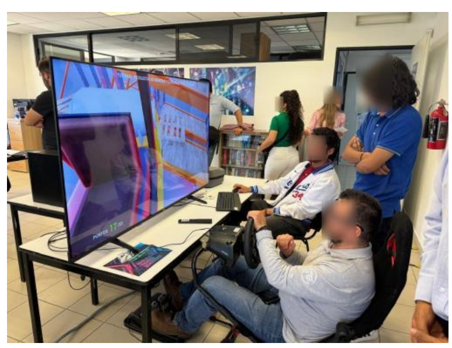

Figure 8
Tests carried by operational staff of a manufacturing company installed in San Juan del Río, Qro.
Source: Own elaboration

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Figure 8 shows oe of some visits of operational personnel to theUniversity where the software was developed and at this stage feedbaks of the simulator were obtained, where it was verified by the operators that the experience is perceived as a very realistic for handling and somewhat revolutionary in virtual learning about real actions.

It is also importan to mention that a comparison was made with the course that was recieved to simulator developers by the manufacturing , where real experience of driving and using a real forklift in the factory was obtained, where it was perceived that the vision and the teaching method taught in the virtual simulator are similar, and therefore it provides many benefits, such as that the operator candidate starts with more confidence and security, the ease of adaptation and the faster learning process, as can be seen in figure 9, the software developers handling forklifts in the maneuvering yard.

Box 9

Figure 9
A member of the team developers using a real forklift to obtain real experiences to take them to a programming environment
Source: Own elaboration

Results

From the variables analyzed to verify the outcomes of the implementation of a virtual forklift simulator, a satisfaction level survey was desined and prepared, where the outcomes are presented in graph 1. A graph where the weighting is from 0 to 10, identifying the level of effectiveness of each essential aspect of the simulator, as it can be seen the level of realism and effectiveness of the simulator is acceptable. The universe is made up of 10 forklift operators from a company.

The forklift operators used the application in order to make an evaluation of the 7 variables that were chosen, which are: 1. Accessibility 2. Satisfaction 3. Playability 4. Realism 5. Sound 6. Reaction 7. Environment.

Box 10

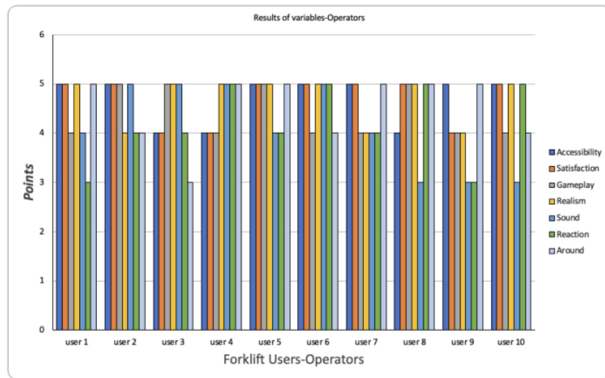

Figure 10
Graphic results showing assesments from forklift operators considering the 7 variables
Source: Own elaboration

Figure 10 shows the outome of the lowest score obtained by forklift operators , which was 3/5; the highest score obtained was 5/5, in which 50% of users rated at least one variable with 3; 100% of users rated at least one variable with 5. While ratings obtained from the variables: the maximum rating is 5 and the minimum 0.

Ratings are obtained with the arithmetic mean, for example "Accessibility" has 4.7 since 7 users assigned 5 points 7 * 5 = 35; 3 users assigned 4 points 3 * 4 = 12 total points obtained 35 + 12 = 47 Dividing the total points between the 10 users 47/10 = 4.7; Accessibility rating 4.7, Satisfaction rating 4.7; Playability rating 4.4; Realism rating 4.7; Sound rating 4.1; Reaction rating 3.8; Environment rating 4.5.

As it can be observed 7 out of 10 users rated accessibility, satisfaction and realism with a maximum score; likewise, 7 out of 10 users assigned at least 4 variables with a maximum score.

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Box 11

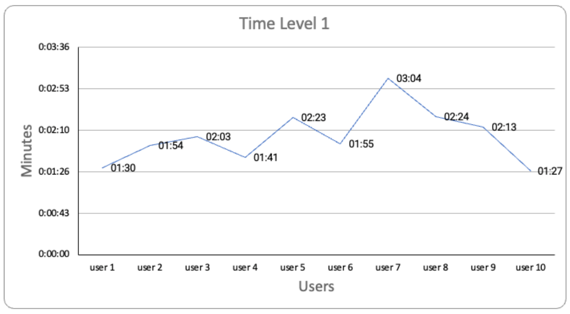

Figure 11
Graphic results of time used for level 1
Source: Own elaboration

Figure 11 shows the outcomes of the times when using the software in the time taken to interact and get into level 1. Arithmetic mean X̅: 02:03 minutes; Minimum time: 01:27 minutes; Maximum time: 03:34 minutes, with a difference of 01:31 minutes.score.

Box 12

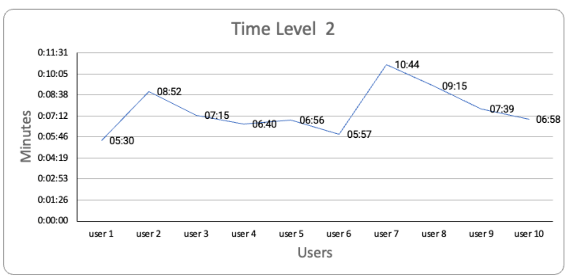

Figure 12
Graphic outcomes to show time used to get into level 2
Source: Own elaboration

Figure 12 shows the outcome for level 2, the following times were achieved: Arithmetic mean X̅: 07:35 minutes; Minimum time: 05:30 minutes; Maximum time: 10:44 minutes.

Box 13

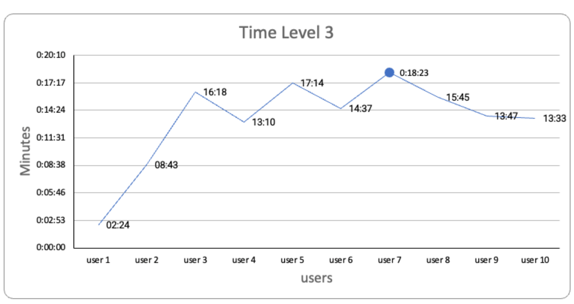

Figure 13
Graphic results of time used for level 3
Source: Own elaboration

Figure 13 showing the outcome for level 3; For level 3 the following times were achieved: Arithmetic mean X̅ : 13:23 minutes; Minimum time: 18:23 minutes; Maximum time: 02:24 minutes.

Box 14

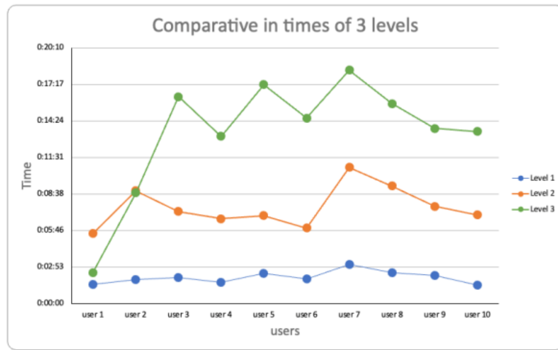

Figure 14
Graphic outcomes showing the comparison of time at the 3 levels of play
Source: Own elaboration

Figure 14 shows the time taken for each level of play, where the longest time is found at level 3 with a duration of 17:17 minutes and the shortest time at level 3 is 02:53 minutes, user 1 was the one who generated the shortest time at his level and user 7 was the one who had the longest time, this is because of the experience of using video games.

Box 15

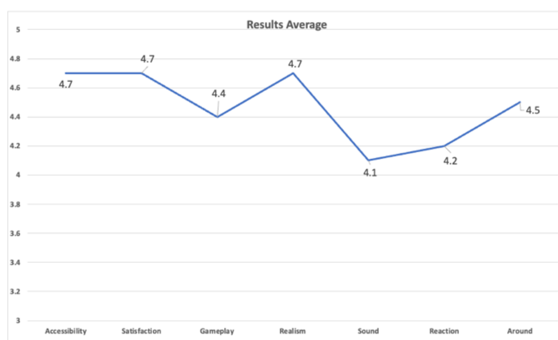

Figure 15
Graphic outcomes showing averages with variables evaluated by forklift operators
Source: Own elaboration

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Figure 15 shows how all variables that were evaluated when using the forklift operations behave, where the average of satisfaction and realism had the highest average 4.7, by the operators, which indicates that for them the use of the software is satisfactory and very realistic allowing them to advance in their interaction and knowledge of handling when interacting with the software, while the sound with an average of 4.1 and the reaction with 4.2, were the lowest evaluated, this indicates that even when the software is in a virtual environment, there was still a complication to react in locating objects, and the sound was not efficient since a good audio message was not perceived.

Conclusions

By developing the software program for a desktop application format, it allowed to work with visual programming and block design through objects that were first tested individually, and then integrated into a industrial warehouse, all togheter with the virtual forklift, this allowed to have a virtual environment, to be used by the forklift operators that collaborated with the software developers, in which operators showed that a training strategy through technology is very supportive, and with the virtual environment, this indicates that this type of applications will be necessary mainly for the manufacturing industry, which is a support for their training, it is also an aid to reduce accidents and fuel costs, with this type of specialized software it is recognized that the benefit is of high impact for companies where forklifts are used.

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Authors' Contribution

The contribution of each researcher in each of the points developed in this research, was defined based on:

Juárez Santiago Brenda: Contributed to the project idea, research method and technique and background. She carried out the data analysis and systematization of results, as well as writing the article.

Mendoza Hernandez Guillermo: Contributed to the project idea, research method and technique. She carried out the data analysis and systematization of results, as well as writing the article.

Ledesma Uribe Norma Alejandra: contributed to the research design, the type of research, the approach, the method and the writing of the article.

Santos Osorio Rene: worked on the application of the field instrument, data collection and systematization of the results. He also worked on the writing of the paper.

Availability of data and materials

In order to create de 3d models the team used Unreal Engine. version 5.1 and. Blender Version 3.x free software and for image editing. the team used the software Photos installed. By default within the operating system Windowss 11.

Funding

The economic resources for developing the simulator were obtained from SEDESU (Secretaria de desarrollo. sustentable) in Querétaro Sate within a government program called PEDETI (Programa Estatal para el Desarrollo de Tecnología e Innovación) , the resources allowed us to get computers, pedals, wheels. levers and cars for vidogames.

Abbreviations

DFS	Deskstop Forklift Simulator
RE	Real Enviroment
VE	Virtual Context
VR	Virtual Reality
HMI	Human-Machine Interaction
UWB	Ultra-Wideband

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