Driver Perspective Active Safety System: A Multi-Level Simulation in Virtual World Using Unity for Developing Safe Driving.

Ajay Mannolkar
Mechatronics and Cyberphysical Systems
Deggendorf Institute of Technology
Deggendorf, Germany
ajay.mannolkar@stud.th-deg.de

Ravi Kiran Kosuri
Mechatronics and Cyberphysical Systems
Deggendorf Institute of Technology
Deggendorf, Germany
ravi.kosuri@stud.th-deg.de

Neeraj Cheripally
Mechatronics and Cyberphysical Systems
Deggendorf Institute of Technology
Deggendorf, Germany
neeraj.cheripally@stud.th-deg.de

Shubham Urmode
Mechatronics and Cyberphysical Systems
Deggendorf Institute of Technology
Deggendorf, Germany
shubham.urmode@stud.th-deg.de

Varghesekutty John
Mechatronics and Cyberphysical Systems
Deggendorf Institute of Technology
Deggendorf, Germany
varghesekutty.john@stud.th-deg.de

Vaishak Prakasan Kannittayil
Mechatronics and Cyberphysical Systems
Deggendorf Institute of Technology
Deggendorf, Germany
vaishak.kannittayil@stud.th-deg.de

Nishan Mudavangolan
Mechatronics and Cyberphysical Systems
Deggendorf Institute of Technology
Deggendorf, Germany
nishan.mudavangolan@stud.th-deg.de

***Abstract*—Traditional Driver training usually lacks behind for unexpected road conditions with less preparation for the real-world conditions and exposure. This paper presents a multi-level Driver Perspective Active Safety System developed using the Unity game engine to perform and enhance driver training with realistic simulation in the virtual environment. The virtual environment consists of various weather conditions, like day-night, rain and fog. A natural urban layout with pedestrians and traffic system, Challenging drivers with unexpected surprises to progress the driving skills. Developed Four levels to guide players from basic controls to navigate path by encouraging to achieve rewards through complex scenarios involving passenger pick-up and drop-off. Also, teaching to be aware of obstacles in the path and avoid randomly wandering pedestrians and traffic vehicles. The Simulation integrates VR hardware with steering and pedal input. Results demonstrate the experience of learning and developing VR environment to improve the driver training using the VR Technology and shaping the growth of modern education system in the perspective of Driver.**

***Index Terms*—Unity, virtual reality environment, pedestrian, Simulation, development, driver.**

I. Introduction (Ajay 22402834)

The growth of the Architecture and transportation system enhanced the usage of the vehicles in both Urban and Rural area. Traditional driver training or education often creates the problems like conceptually getting entire knowledge of the traffic system, lack of safety risk and cost. The drivers need to get well trained to face the challenges during the unusual situation face on the roads while driving. The Virtual world has developed the various aspects with making the real-world scenarios experience to provide the alternative way for ensuring the safety of the pedestrian and other living bodies moving on the road. The unity is not just promoting the gaming Industry but simultaneously it is playing the important role in shaping the perfect driver education for ensuring the safety and real-world experience with the virtual reality. [1] [2]. Virtual reality gaming simulation is developing the skills of the driver training to make the driver aware of the traffic rules and get aware to deal with the distractions in the environment. The driver gets more familiar with the real-world scenario with getting trained in the virtual world which provides the driver more realistic experience. This paper represents the enhancement of the driving skills by framing the development of the Driver Perspective Active safety system using the Virtual World created using the Unity Game Engine. The Simulation is designed with various levels to focus more on creating the framework for better understanding and practicing of the driving skills with providing knowledge of unexpected obstacles in the scenarios occurring during the driving. The levels in the simulation will bring the driver closer to understand the traffic rules and navigation system, Even the driver get more confidence about driving. The Simulation is structured in four levels: The Tutorial session for driver to provide information on how to play the game, pick-up and drop the passenger from the house to festival and return, with each level learning to drive safely and avoid getting collision with the target pedestrian, where the trigger is placed at a particular distance to create surprises for the driver to be aware during the simulation. The project focus to enhance the driver awareness, develop decision-making in various traffic conditions, and test the active safety system.

II. Literature Survey (Shubham 22408646)

Evolution of interactive and immersive driving simulators has accelerated with the blending of game engines like Unity and AR/VR technologies. Research studies have established the possibility of using such simulators for car personalization, user experience, and safety training. This chapter presents the existing literature related to the use of AR/VR in driving simulations, motion tracking, and system design using Unity.

Virtual Reality (VR) helps researchers test driver behavior and safety systems in a controlled and safe environment [9]. It allows the study of how drivers react in risky situations without putting anyone in danger [1]. VR driving simulators can improve how drivers notice hazards and make decisions on the road [9].

Using VR with tactile feedback, like vibrations, helps drivers steer more accurately without adding stress [7]. VR can simulate distractions and test how drivers react to different warning signals [6]. Research shows that using different types of warnings (visual or sound) in VR can help drivers react faster [6]. VR combined with Augmented Reality (AR) can guide drivers better, especially older drivers, to avoid accidents [2]. Although some users may feel motion sickness, VR still provides reliable data for research [8].

VR tests can also include traffic sign recognition using AI tools, improving driver training [4]. It can simulate heavy traffic, sudden stops, and bad weather to test driver reactions [9]. VR can be used to test how well self-driving cars and human drivers interact safely [1]. It is also cost-effective, reducing the need for expensive real-world testing [5]. Overall, VR provides a realistic, repeatable, and safe way to study and improve driver behavior and road safety systems [9].

III. Hardware and Software Requirements (Varghesekutty John 22405975)

The development of the AR/VR-based Driver Perspective Simulator included focused research into affordable, realistic hardware components suitable for immersive training simulations. The simulation was created in Unity version **6000.0.49f1** that includes enhanced VR rendering support, low-latency input, and wide-ranging hardware compatibility[10][13].

A. Virtual Reality Headset Review

A comparison was made with certain consumer-grade VR headsets already available in Germany. The most critical parameters were resolution, tracking type, refresh rate, and value for money. We choose **Meta Quest 3** based on its colour passthrough, Unity OpenXR support, and standalone/PC VR modes. Its 6DOF inside-out tracking dispenses with external sensors, making it easier to deploy[11][12][14].

B. Pedal vs. Steering Wheel Comparison

Based on German market availability and suitability for education use, the following steering wheel systems in table were researched. The **HORI RWA Racing Wheel** was finally chosen for its low price, simple installation, and sufficient realism for hobbyist simulation environments. It has no force feedback but has responsive pedals and is good enough for speed tests and braking control tests[14][15].array

TABLE I
VR Headset Comparison (Germany-Centric)

Model	Res.	Refresh	Tracking	Price (EUR)
Meta Quest 3	2064×2208	120 Hz	Inside-out	˜550
HTC Vive Pro 2	2448×2448	120 Hz	Ext. Base	˜800
Meta Quest 2	1832×1920	90 Hz	Inside-out	˜350

TABLE II
Steering Wheel Comparison (German Market)

Model	Rot.	Force Feedback	Pedals	Price (EUR)
HORI RWA	270°	None	Gas, Brake	˜100
Logitech G29	900°	Dual-Motor	Gas, Brake, Clutch	˜280
Logitech G923	900°	TRUEFORCE	Full Set	˜340
Thrustmaster TMX 300	270°	Vibration	Gas, Brake	˜90

C. Final Hardware Configuration

The overall simulation arrangement consists of: **Meta Quest 3:** High-resolution, full-colour passthrough VR head-mounted display for visualization. **HORI RWA Racing Wheel and Pedals:** High-quality input hardware at an affordable price. **Playseat Evolution Pro:** Comfortable seat for more immersion and bodily comfort. This configuration provides a pedagogically and economically scalable AR/VR simulation experience, within the Unity **6000.0.49f1** feature set. The hardware chosen provides responsive control, sufficient user presence, and strong compatibility with Unity's render and input platforms[12][14][15].

IV. METHODOLOGY

A. Environment Design and Development in Unity (Neeraj 22401917)

Building an entire virtual world where the player or user can experience realistic and immersive environment is the main objective of this Project. In this environment placing buildings and using other elements to make it looks better with different assets.

1) Environment Planning and Layout: Planning the general arrangement and structure of the environment was the first step. Outline the space by finding the places of objects such as buildings, roads, and other features. This step was necessary to organize it into a virtual environment and designed the base level of the area, and carved all the ground out with Unity's terrain functionality.

2) Road Network Creation : Built the road network with Traffic Lights System SE [1] at Unity asset store. This wasn't just the roads and junctions but also the traffic lights. Proper alignment, scaling, and texture application were carefully managed to ensure visual consistency and realism.

3) Building Placement: The placement of buildings along roads was made with care so as to create the impression of a city plan and used 3d modelled buildings from Unity asset store [1][4][5][6][7]. Also added box colliders to every building to receive the detection. Keeping things real Scale and proportion were kept in mind every step of the way. The intention was to create a city that is essentially improve our gameplay features.

4) Environmental Detailing: Trees and Streetlights: Added lights and trees on the crosswalks and in the empty terrain, to give the scene a sense of place and detail. Trees were selected from [8] and placed in order to obtain visual richness and mimic natural distributions. Streetlights from [10] were placed along the streets at equal distances to guarantee the proper illumination of the scenes at night and closer approximations of urban infrastructure. And also added capsule colliders on these trees and street lights as well. These features helped enrich the environment and create atmosphere.

B. Climatic Scenarios (Ravi 22401580)

This project consists of 6 combinations of climatic scenarios; the player would be able to select the desired scenarios by pressing the mapped buttons on the steering wheel setup.

1) Day and Night mode: The day mode is setup with 9C9583 hexadecimal colour directional light. Soft shadows were used to cast realistic shadows that can be casted by direct sunlight. Similarly, CCC6C6 hexadecimal directional light for night mode.

2) Rain mode: The unity's particle system effect was used for the rain effect and the full opaque rain asset was used to create the ripple effect when the rain drops fall to the ground. The rain settings were adjusted accordingly with the setup environment.[20]

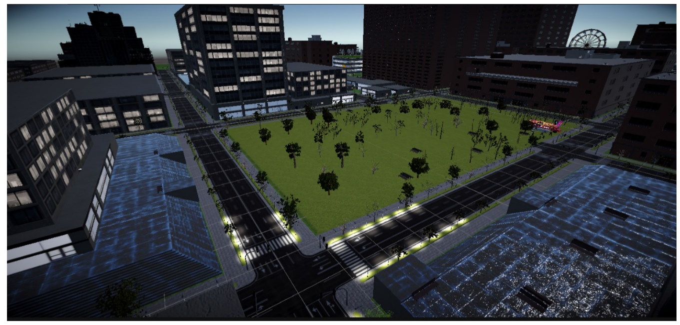

Fig. 1. Environment

Fig. 2. Be post processing

3) Fog mode: Fog effect was created using the lightening window, in the environment light backing the fog was selected with exponential squared mode. The density of the fog is adjusted according to the environment. There were four skyboxes used for these modes. The skyboxes were selected from the "AllSkyFree" asset from the unity asset store. [21]

C. Post Processing (Ravi 22401580)

The post processing work is a requirement for this project; the objective of the paper was to create a real-world environment in the virtual world. Post processing helps the environment to look more realistic in the virtual world. These postprocessing volume profiles were added to the canvas in the "DayNightManager" C sharp script and it were made to activate in the day and night modes only.

D. Street and Fest lightening (Ravi 22401580)

The streetlights and market lights were assigned to turn ON during the night mode only. It is added to the "DayNightManager" C sharp script. All these modes were done make activate in their desirable states using "DayNightManager" C Sharp script.

E. Fest setting (Nishan 22203798

A 3D festival market area was developed as part of the Unity-based group simulation project. The scene was designed to resemble a lively Oktoberfest-style food street, featuring

Fig. 3. After post processing

Fig. 4. Fest

elements like food trucks, grills, sweet carts, and small market stalls. Assets were sourced from public 3D model websites and the Unity Asset Store, then arranged into a compact layout that mimics a real festival setting. Decorative elements such as benches, lights, and hanging props were included to enhance the festive mood [22] [23] [24].

Additional features like food trucks, rickshaw-style sweet shops, and a giant wheel contributed to a carnival-like atmosphere. To simulate crowd interaction, animated characters from Mixamo were placed throughout the scene as vendors, customers, and passersby. This added movement and life to the environment, making it feel active and engaging[23]. Textures were adjusted where needed to maintain visual consistency, and lighting was set up to create a bright, cheerful daytime feel. The Universal Render Pipeline (URP) was used to optimize materials and performance. Overall, the market scene functions as a central interactive zone, adding energy and a sense of social space within the broader simulation[25][26].

F. Audio System and Scenario-Based Narrative Design Integration (Varghesekutty John 22405975)

A fundamental element of the AR/VR Driver Perspective Simulator is its audio system, both performance- and immersion-focused, specifically created to facilitate realistic driving conditions, contextual feedback, and narrative progression. The engine features dynamic vehicular soundscapes, climatic and time-of-day-dependent atmospheric sound, and

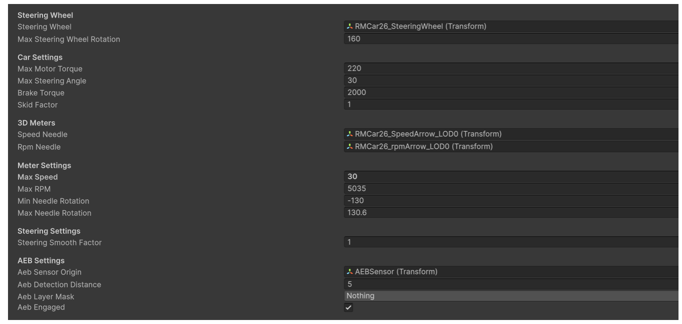

Fig. 5. Car Physics Inspector window.

artificial intelligence-powered vocal guidance aimed at realism and user engagement.

1) Dynamic Vehicle Audio: The main vehicle in the simulator features dynamic pitch adjustment with Unity's AudioSource.pitch, simulating real RPM movement. Horn sounds—mapped to player input—were created from real vehicles and were adjusted for response and clarity. AI NPC cars use movement-based audio loops to simulate road traffic, whereas state-based sound triggers are managed by central scripts that prevent excessive audio load[16].

2) Environment and Weather-Based Sound: Environmental sound responds to scenario changes such as rain, fog, and day-night cycles. Rain sounds, for example, are heard via 2D audio to maintain volume consistency regardless of camera direction. There are ambient drones for fog environments, and day and night cycles have respective market and night ambiance. High-quality pre-mixed audio loops have been used to ensure performance efficiency and avoid the typical overlapping sources of sound in VR simulations[15][17].

3) AI-Based Voice Prompt and Story: Each simulation level is crafted with scenario and story, along with AI-generated voice prompts created using ElevenLabs [19]. They are presented as instructions to users at the start and end of levels. Text overlays using Unity's Canvas system are timed with audio for comprehension, with accessibility still in noisy environments.

4) Optimization and Design Philosophy: The audio design is directed towards perceptual realism and system efficiency. Centralized audio management, pre-rendered ambient spaces (e.g., from Pixabay [18]), and adaptive compression in Unity were used to reduce CPU consumption. Ambient loops simulate complex environments without numerous discrete emitters. The design conforms to current AR/VR audio best practices with a focus on fidelity and real-time responsiveness.

G. Car Physics (Shubham 22408646)

For this research, a free car model from the Unity Asset Store was used, selected for its separate body, wheels, suspension, and interior components. This allowed realistic physics to be added to each part and the vehicle's behavior to be customized in detail. The goal was to create a realistic driving experience so the test driver would feel as if operating a real vehicle in the simulation[26]. Wheel colliders were

Fig. 6. Driver Hands simulation

added to simulate tire-road interaction, allowing dynamic responses to acceleration, braking, and cornering. For example, the front lifts slightly during acceleration and dips forward during braking, combined with natural yaw, pitch, and roll for immersion. The car controller was programmed to allow easy adjustment of torque, steering sensitivity, brake torque, and skid factor directly in Unity's Inspector (Fig. 5). These settings can be modified in real time during testing to refine the car's behavior. To reflect city driving, the car's maximum speed was limited to 60 km/h. A real-time dashboard with a speedometer and RPM meter displayed values calculated from wheel rotation, ensuring accurate feedback for the driver during the simulation [5][9].

1) Driver Character Using Mixamo and Steering Wheel animation: To create a realistic driving experience, the simulation replicates what a driver sees while sitting in a car. A Mixamo character was animated using Inverse Kinematics (IK) and Unity's Animation Rigging system (Fig. 6). The character's hands were linked to the target points on the steering wheel, and as the wheel rotates, these targets move, causing the arms, elbows, and wrists to move naturally and in sync with the steering [27]. A virtual camera was attached at the character's eye level and tilted downward by about 15 degrees to match a real driver's view. Before starting the simulation, users can enter their height, and the camera position adjusts automatically to ensure the view feels accurate for each driver, regardless of height [5] [9].

2) Implementation of AEB and ABS: Two safety features, Autonomous Emergency Braking (AEB) and Anti-lock Braking System (ABS), were added Fig. 2. Driver Hands simulation. to test driver and vehicle responses in different conditions. The AEB's detection range, adjustable in Unity's Inspector, allowed simulation of various obstacle warning distances. Waypoints were added along the route, with dashboard indicators blinking for turns, helping the driver follow directions and enhancing the simulation's realism.

3) Crash Detection and Warning System: A collision warning system using a mesh collider was added to detect impacts. When a collision occurs, a screen warning and audio alert notify the driver immediately, improving awareness and safety. Collision data is automatically recorded for later analysis of driver performance and reaction time.

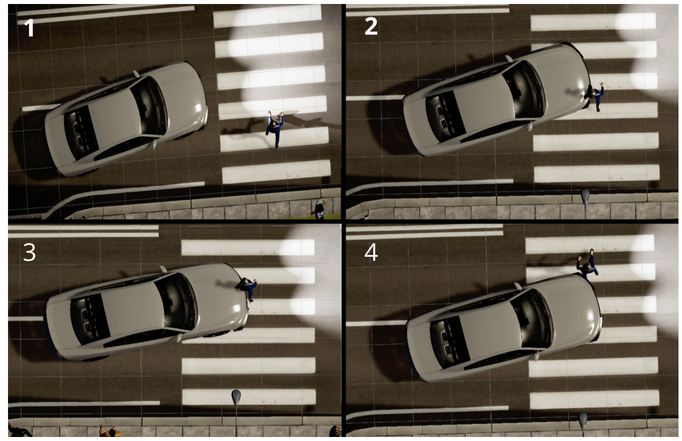

Fig. 7. AEB and ABS scenarios.

4) AEB and ABS tests: Fig. 7 shows the four different scenarios tested along with their results:

In the first scenario, both AEB and ABS were active. Here, the vehicle stopped automatically without the driver having to apply the brakes.

In the second scenario, AEB was active while ABS was turned off. In this case, the skid factor increased by 50 percent, and the vehicle collided with the pedestrian.

In the third scenario, both AEB and ABS were turned off. Despite rapid steering to avoid the obstacle, a collision still occurred.

In the fourth scenario, AEB was off while ABS was active. In this case, the driver was sometimes able to avoid a collision, but in some trials, a crash still occurred.

H. Implementation of Pedestrians and Traffic system(Ajay 22402834)

The process of learning to import the character is carried out through open source Mixamo website. The characters are organised with the various animations like walking, running, and jogging. Aim of importing the humanoid characters in the simulation is to create distractions for the driver and to enhance the experience of driving like a real-world scenario. The Pedestrians are assigned to be walkable on only the Baked area, which is done using the NavMesh Surface, NavMesh Modifier for the Footpath zone where we want to make the humanoid agents to walk[3]. The logic behind importing the thousands of pedestrians all over the city is AI Spawner. This Ai Spawner is applied to create the clone of the prefabs of pedestrians to spread them across the city with the given animation.

In the character inspector window, the NavMesh Agent component must assign to all the prefab of the characters with the script of Wander.cs which will assign the random points for the pedestrian to walk on the Footpath randomly without walking on the road. The Script of pedestrian manager will create clone of the prefabs in assigned radius. The Driver need to also avoid the traffic vehicles on the road, so the script of waypoints is used to the car prefab. and imported the Car

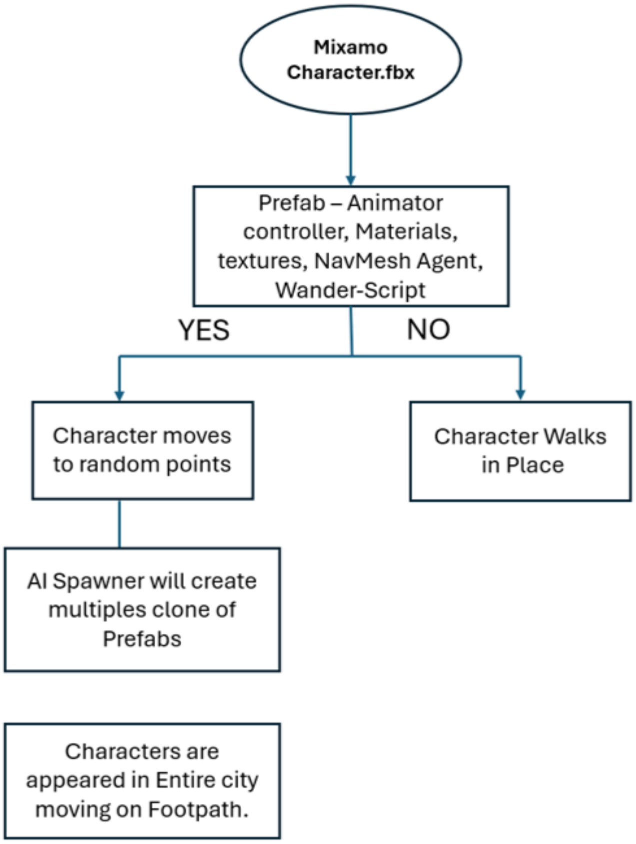

Fig. 8. Flow chart of character inspector

TABLE III
CHARACTERISTICS OF CHARACTERS USED FROM MIXAMO

Character	Speed	Angular Speed	Obstacle Avoidance Radius	Area Mask
1	1.3	120	0.5	Walkable
2	2.5	120	0.6	Walkable
3	3.0	120	0.3	Walkable
4	2.0	120	0.5	Walkable
5	1.1	120	0.5	Walkable

prefabs from the assets and assigned them with the rigid body and wheel collider to follow the waypoints given on the route of the destination.

I. Target Pedestrian with Trigger and UI (Vaishak 12300527)

Target pedestrian with trigger help in evaluating. Autonomous emergency braking system. The response of AEB system to sudden pedestrian appearance can be analyzed.Time to collision, vehicle speed and position can be determined by the implementation of target pedestrian with trigger. Target pedestrian implementation with trigger also helps to under-

Fig. 9. Target pedestrian

stand driver behaviour and system response in VR. The main component of the test set up include

(i)Pedestrian-model
(ii)Trigger-collider
(iii)Vehicleplayerobject
(iv)Game-manager

The pedestrian model is taken from mixamo. Collider, Rigid body and animation are given to the pedestrian model. A separate box collider is used as the trigger in this set up and pedestrian trigger script is added to the trigger component such that when vehicle enters the trigger zone the pedestrian starts walking. The vehicle player object is tagged is tagged as "player" such that the player controls the vehicle with rigid body. An empty game object is set up and its renamed as game manager. The script attached to the game manager helps in managing the game and controlling. Trigger Activation Logic-When the vehicle passes through the box collider set up as the trigger. The pedestrian movement get activated and the pedestrian approaches the vehicle unexpectedly making it difficult for the driver to apply brake. The Time to collision, vehicle speed and position can be determined by this set up. The user interface includes a canvas and a game over panel. In the canvas panel Text is added like Game over. Script attached to the target pedestrian (Pedestrian collision handler) helps to stop the game when the pedestrian is hit by the vehicle and the game is initiated back to the starting point.

J. Gamification Simulation (Neeraj 22401917)

In the Mission mode, the player needs to complete the given tasks. The game proceeds to the next consecutive level when the task is completed in the preceding level. In every level certain target pedestrian are deployed as obstacles to test the driver, if the car is collided with pedestrian, then it is considered as mission is failed. The player has a navigation map to show the location of the mission. The Simulation is designed in three levels for testing the driving skills and developing the performance of the driver.

K. Level Tutorial

To get familiar with the surroundings, there is tutorial level to adjust the player to environment by briefly introducing about the games rules and driving instructions. The UI panel will also display the instructions on the screen of virtual world.

Testing: The driver follow the instructions and start playing the game with the help of tutorial guidance and then the tutorial gets over the driver have completed the initial tutorial and reached to next level.

L. Level 1

After the completion ofLlevel Tutorial the driver is now familiar with the game rules and levels, so the driver needs to follow the map and reach a house to pickup player friend and go to the Fest.

Testing: The simulation carried out to test the driving skills where driver need to reach the passenger house without colliding anyone and escaping from the target pedestrian and the completion of this level will take the driver to next level.

M. Level 2

The passenger is now inside the car and the driver have to take the passenger to the festival where his/her friends are waiting and now its driver responsibility to drop the passenger safely to the destination on time.

Testing: The timer start once the passenger is inside the car and then the driver will drive car without colliding anyone and safely take the passenger to the festival and then the level gets complete if the driver drives faster within the time and safely drop the passenger.

N. Level 3

This is final level and bit of complicated to complete because now the driver need to take the passenger back to his house within 2 minutes because the passenger parents are waiting for him in home.

Testing: The driver will safely take the passenger within the given time and accomplished the levels but if the driver collide with target pedestrian while playing in any level then again driver need to start from beginning.

V. HARDWARE SETUP AND INTEGRATION (RAVI 22401580)

The driving simulator game was developed on unity application (version 6000.0.49f1). It was connected to the Meta Quest 3 Vr headset and also to a driving simulator which consists of a physical steering wheel and pedals for acceleration and braking. For setting up VR with the game it requires several software components working together, those are available in unity package manager just need to import packages into the project. The required software are :

1. XR Plugin
2. XR Interaction Toolkit
3. Oculus XR

After setting up the XR settings, the ordinary camera is replaced with XR origin camera rig. All the 2D UI canvas in the project were replaced with the XR Canvas for it to visible in VR headset. The Hori Steering wheel setup includes separate input action controls for game control. After assigning the steering button to their respective actions were edited in the car controller script.

VI. FUTURE WORK

The Simulation is performed by testing the driver experience with the inputs from the keyboard in the virtual environment, but further the simulation need to be conduct with the hardware integration in the unity game. In future, The Game will be conducted with the different age of people to collect the data of their reaction time and response time while driving in the virtual environment with the hardware steering, brake and acceleration system. The data will be used to increase the performance of the driving skills and provide a better result for the drivers to know about the traffic system and obstacles on the road in virtual world and then implement them in real world situations.

VII. CONCLUSION

Immersive virtual reality systems are common in today's world. Offered like a gaming mode or as a simulation of the interactive and more realistic environment further it would help to develop the training. Simulation environments structures were modelled and implemented in unity to achieve real-world scenarios. Since this is a virtual gaming simulation, the obstacle collisions rates can be avoided to give the chance for the beginners to make errors and learn from the experience of driving in the virtual environment Thus, the proposed is to create a comfortable, safe and realism environment to bring a successful simulation game for beginners at a low budget. The game improves the self-confidence of the drivers in the real-world after learning through the virtual game. The actual performance of the driver perspective achieved with the simulation of the game by playing it in various levels and change in the atmospheric conditions to experience the virtual world scenario to be more realistic. The development of the game enhanced the learning outcomes of the individual capabilities to acquire the knowledge of the creating virtual environment, changing the climatic conditions like Day, Night, Fog and rain during the gamification, making the virtual characters to get animate. The project mainly focused to provide the smooth gaming environment simulation and successfully able to create the 4 levels of game.

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Fig. 10. QR code for Video presentation