IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 1, March 2025

3D Game Development

Prof. Reena Deshmukh[1], Adarsh Tripathi[2], Ayush Palkar[3], Shantanu Sali[4]
Professor, Department of Computer Engineering[1]
Student, Department of Computer Engineering[2,3,4]
Shivajirao S. Jondhale College of Engineering (SSJCOE), Dombivli East, India
reenadeshmukh58@gmail.com, Adarshtrip1854@gmail.com,
ayush.palkar1@gmail.com, shantanusali20@gmail.com

Abstract: *This project explores the development of a 3D game that integrates immersive environments, interactive gameplay, and real-time rendering, aimed at delivering a unique and engaging experience. The game currently focuses on the journey of a delivery boy who, disillusioned with his job, navigates a dynamic city environment while completing deliveries. Players interact with the environment and take on delivery tasks, with a system that allows NPCs to wander the city. The AI for these NPCs is currently simple, where they randomly choose destinations and travel to them, adding some unpredictability to the environment. Although the game currently centers on the delivery system, future updates aim to introduce chaotic elements, including humorous pranks and unpredictable interactions, contributing to a more dynamic gameplay experience. The city is designed with detailed streets, buildings, and objects, with dynamic lighting, shadow effects, and NPC interactions that enrich the environment. The exaggerated art style emphasizes the game's comedic tone, which will be further enhanced as additional features are implemented. This paper details the design process, technical challenges, and ongoing work to optimize performance across different platforms, demonstrating proficiency in game design, 3D modeling, and real-time mechanics.*

Keywords: 3D game development, Dynamic city environment, Game design, Interactive gameplay, NPC AI, Performance optimization

I. INTRODUCTION

The evolution of video games has seen a dramatic shift from simple two-dimensional graphics to immersive three-dimensional environments. This transition has enhanced the gaming experience, offering players the ability to interact with virtual worlds in more dynamic and engaging ways. Unlike 2D games, 3D games utilize depth, perspective, and detailed modeling to create expansive spaces that players can explore from multiple angles.

This advancement in game development has opened up new possibilities for complex gameplay mechanics, such as physics-based interactions and spatial navigation. Players can now experience more realistic environments where objects behave according to real-world physics, and characters move with greater fluidity and realism. These improvements contribute to a deeper level of immersion and interactivity, allowing for more engaging and varied gameplay.

This paper focuses on the development of a 3D game that takes advantage of these advancements to provide players with an interactive, dynamic city environment. Through innovative character design, gameplay mechanics, and a detailed virtual world, this project demonstrates the potential of 3D game development to create rich and engaging experiences.

II. OBJECTIVE

Many modern games rely on linear progression models, which can limit player agency by imposing strict objectives and pathways. This structure often restricts creativity and personal expression, leading to repetitive gameplay experiences. Additionally, an emphasis on hyper-realism in many contemporary titles tends to overshadow engaging gameplay mechanics, prioritizing lifelike graphics over innovation. This focus on visual fidelity can result in redundant gameplay

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and a lack of originality. Many games also recycle established concepts without introducing fresh ideas or unique narratives, making the gaming landscape feel stagnant and reducing players' emotional investment.

Our project seeks to address these issues by offering a more dynamic, player-driven experience that prioritizes freedom and creativity. We aim to create a world where players have the option to either follow the delivery path or engage in humorous, chaotic antics. By giving players this freedom, we hope to create a game where every playthrough feels distinct, engaging, and unpredictable. Future updates may expand the chaotic elements, adding more pranks and interactions, but for now, we focus on the core delivery system.

Our key objectives are as follows:

- Blend cartoony low-poly graphics with modern design elements for a unique experience.
- Enhance visuals with dynamic lighting, shadow effects, and detailed environments to make the world come alive.
- Design interactive, engaging environments, allowing players to engage meaningfully with their surroundings.
- Create AI-driven NPCs that follow simple behaviors, providing a responsive world, even if currently limited to basic actions.
- Provide players the choice to either complete deliveries or embrace chaotic behavior, ensuring diverse playthroughs and replayability.

III. TECHNOLOGY AND TOOLS

The development of the game relies on various software and hardware tools to achieve its retro PS1-inspired aesthetic while implementing modern game mechanics. The tools and technologies used are as follows:

Software Setup:

- **Blender**: Blender is used for the 3D modeling and animation of characters, objects, and environmental assets. All models are created in a low-poly style to match the retro aesthetic of the game. Materials are applied within Blender to achieve the desired visual effects, with a focus on vibrant color palettes.
- **Godot Engine**: Godot is the primary game development platform. It handles the game mechanics, physics, rendering, and AI scripting. The engine's flexibility allows for seamless integration of both 2D and 3D assets, and its GDScript language is used for scripting interactive elements and character behavior.
- **Mixamo**: Mixamo, a free service from Adobe, is used for rigging characters and applying animations from a large library. The animations are downloaded and then processed in Blender before being exported as GLB files for use in Godot.

Hardware Setup:

Development Systems:

- Intel i5/i7 or AMD Ryzen processors with at least 8 GB of RAM.
- GPU: NVIDIA GTX 1050 or higher (for compatibility with modern 3D rendering techniques).
- Minimum system resolution of 1080p for game development and testing.

Test Platforms:

- Desktop and laptop PCs with varying hardware configurations are used for performance testing, ensuring the game runs smoothly across different systems.
- Testing is also conducted on lower-end hardware with integrated graphics to ensure optimization for a broad audience.

IV. SYSTEM ARCHITECTURE

The system architecture is carefully structured to deliver an immersive 3D open-world experience, integrating exploration, dynamic NPC interactions, and a choice-driven gameplay system. At its core, the architecture is designed

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to handle an urban city environment where players can freely navigate, interact with NPCs, and complete delivery tasks while experiencing the lively surroundings. The system ensures smooth rendering of the game world, managing various elements such as player movement, NPC behaviors, and environmental details to create a responsive and engaging experience.

A key aspect of the architecture is its ability to support AI-driven NPC movement and interactions. NPCs are programmed to traverse the city autonomously, selecting random destinations and moving along predefined navigation paths. While their current functionality is simple, they add a sense of realism to the world, making the city feel more alive. Additionally, the architecture accommodates the player's freedom to either focus on completing deliveries efficiently or explore the environment in their own way. The city layout, designed with modular elements, ensures that each district—residential, industrial, and commercial—feels distinct and logically connected.

To maintain performance, the system is optimized to balance visual quality with efficient resource management. The low-poly art style, combined with optimized collision handling and AI pathfinding, ensures that the game runs smoothly on a range of hardware. The structured implementation of interactive elements, such as player-controlled vehicle mechanics and delivery tasks, allows for seamless gameplay flow. By integrating these elements into a unified system, the architecture provides a stable foundation for a dynamic and engaging gaming experience.

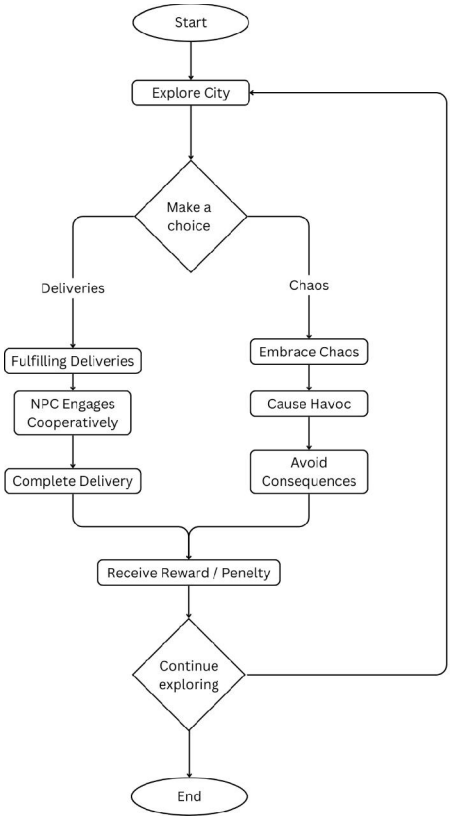

Fig 1: System Architecture

The system architecture of the 3D open-world game is crafted to provide an immersive and dynamic gameplay experience, balancing narrative depth with player agency:

- **Exploration and Interaction:** Players are free to explore a sprawling urban environment, interacting with NPCs, discovering hidden areas, and uncovering story elements. This open-world design encourages curiosity and rewards exploration.
- **Choice-Driven Narrative:** Central to the gameplay is the ability to make meaningful choices that impact the storyline. Players can choose between fulfilling delivery missions or embracing chaotic actions, each path influencing the game world and NPC behaviors.

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- **Dynamic NPC Behavior:** NPCs play a pivotal role in shaping the player's experience. They engage cooperatively during delivery missions, aiding the player, or react dynamically to chaotic actions, creating challenges and consequences.
- **Complex Consequence System:** Player decisions are tied to a consequence system, where actions lead to rewards or penalties. This affects the player's reputation, influencing future interactions and story progression.
- **Replayability and Player Agency:** The branching narrative, influenced by player choices, enhances replayability by offering multiple story outcomes and experiences. This encourages players to explore different paths and playstyles.
- **Semi-Modular World Design:** The game world is structured using a semi-modular approach, where handcrafted environments are combined with modular assets to create distinct city districts. This ensures a well-organized urban layout while allowing flexibility in design. Key locations such as industrial zones, residential areas, and commercial districts are strategically placed to enhance navigation and maintain logical city flow.

V. METHODOLOGY

Our game development process follows a structured approach, combining modern mechanics with low-poly aesthetics, focusing on creating an open-world, interactive environment. Below is a detailed breakdown of the methodologies we have adopted:

1. Asset Creation

We use Blender for 3D modeling, ensuring that all character models, objects, and environmental assets are designed in a low-poly style to match aesthetic. For coloring the characters, we apply different materials in Blender to achieve the desired look. We focus on simple, low-resolution textures to maintain the low-poly style that complements the overall visual aesthetic. For character animation, we employ Mixamo, a free service from Adobe, to rig characters and apply animations from its extensive library. Once animations are downloaded, we process them in Blender and export them as GLB files to be used in Godot.

2. Game Development in Godot

The primary development platform for the game is Godot Engine, which is well-suited for handling both 2D and 3D games with flexibility. We use GDScript to script game mechanics, AI behaviors, and interactions. Physics-based movement is implemented using Godot's physics engine, ensuring that character movements feel realistic, including vehicle driving mechanics. For AI NPCs, we have created a simple system where NPCs randomly choose a point on the NavMesh (navigation mesh) to travel to, then wait before selecting a new point to move toward. Currently, NPCs are designed for aesthetic purposes, with limited interactions, and only the Boss NPC has player interaction for story progression.

3. World Building and Environment Design

The city is designed as a semi-modular open world, where we have handcrafted the layout. Using modular ground tiles, we created distinct districts within the city, such as the airport, industrial zone, residential area, shops, and schools. These districts are strategically placed in four quadrants of the city, ensuring a realistic city layout. For example, parks are located near the mall, and the fire station is near the industrial district, providing logical cohesion to the city design. At the core of the world-building process is creating a dynamic environment where pedestrians and vehicles move around to make the world feel alive.

4. Gameplay Mechanics

The player has access to basic movement mechanics, including walking, sprinting, jumping, and driving. The player can pick up and drop off packages, load and unload them into the delivery vehicle, and drive the vehicle. However, for now, the chaos and pranks part of the game is not implemented due to time constraints. We have planned for future updates where players will have the option to either complete deliveries or embrace the chaos. The game is designed

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with non-linear objectives, where players can freely explore the city and choose how they interact with the environment.

5. User Interface (UI) and Indicators

The UI is designed to be minimalistic, focusing on simplicity while still conveying essential gameplay information. The player can track their time left and mission objectives using on-screen indicators. We have opted for a simple interface that aligns with the overall aesthetic of the game.

6. Audio

Currently, we have not implemented sound design. However, we recognize that sound is an integral part of game development and plays a crucial role in player immersion. Future iterations will include sound effects for footsteps, vehicle movements, NPC interactions, and environmental sounds to enhance the overall experience.

7. Testing and Iteration

The game is continuously tested to ensure smooth gameplay and optimize performance. Regular playtests help refine mechanics such as NPC pathfinding, player interactions, and vehicle driving. Emphasis is placed on balancing the low-poly visuals with modern mechanics to ensure neither aspect overshadows the other.

VI. DESIGN & DEVELOPMENT

1. Game Design:

1.1 Overall Game Concept:

Core Concept:

- The game is set in a semi-modular open-world city, where players assume the role of a delivery driver. The goal is to transport packages across different locations within the city while managing time, navigating traffic, and completing deliveries to various destinations. The game embraces a retro PS1-inspired aesthetic, with low-poly models and pixelated textures, offering a nostalgic yet modern gameplay experience.

Tone and Theme:

- The game focuses on exploration, light puzzle-solving, and task management within the city's expansive layout. The tone is casual and laid-back, as players traverse through different zones, such as industrial districts, residential areas, and shopping centers, completing deliveries while experiencing the joy of navigating through the lively streets of a retro-styled urban environment.

1.2 Gameplay Mechanics:

Character Interaction:

- Currently, the player can interact with only the boss NPC for story progression. This interaction serves as a key narrative element to drive the player's objectives forward. The boss NPC provides tasks and objectives related to the delivery system, guiding the player throughout the game. Other NPCs in the world are non-interactive and serve to enhance the city's atmosphere and liveliness.

Delivery Mechanics:

- The core gameplay revolves around the delivery system. The player picks up packages from designated areas within the city and drives a vehicle to the drop-off locations. The player must navigate through the city's streets while avoiding obstacles and maintaining an efficient delivery route. Each delivery is timed, adding a layer of challenge. The player's ability to plan and execute deliveries efficiently will determine success and progression in the game.

Player Movement:

- The player character can walk, sprint, and jump. Movement is fluid, and the player can switch between walking and sprinting depending on the situation. Jumping is used for minor navigation or obstacle clearance. The vehicle system allows the player to drive a designated delivery vehicle through the city, using physics-based controls to maneuver around tight corners and obstacles.

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2. Game Development:

2.1 Platform and Engine Choice:

Engine:

- The game is developed using the Godot Engine, which provides an open-source, lightweight, and flexible platform for creating both 2D and 3D games. Godot's easy-to-learn scripting language (GDScript) and intuitive editor make it well-suited for small to medium-scale projects like this one. Its ability to handle 3D assets efficiently, combined with its low-overhead performance, ensures that the game runs smoothly even on lower-end hardware.

Platform Target:

- The game is intended to be playable on desktop platforms, including Windows, Linux, and macOS. Optimization is a key consideration, ensuring that the game runs well on a variety of system configurations, including systems with integrated graphics.

2.2 Asset Creation and Integration:

3D Models and Animation:

- Blender is used to create the low-poly 3D models for characters, vehicles, and environment assets. These models are kept simple to match the retro PS1 aesthetic while maintaining a consistent visual style throughout the game. The characters are rigged using Mixamo, with animations downloaded and processed in Blender before being exported as GLB files for use in Godot. The integration of animated models ensures that the characters move fluidly, and the game world remains visually engaging.

Textures and Materials:

- To maintain the pixelated, low-resolution look, textures are applied to the 3D models within Blender. The use of flat colors and simple textures ensures that the game's visuals remain true to the low-poly style while still offering enough detail to make the world feel vibrant and immersive.

2.3 Game Mechanics Implementation:

Character Movement and Physics:

- The player's movement, including walking, sprinting, and jumping, is implemented through Godot's physics engine, with controls mapped to intuitive input devices. The game uses Godot's physics process function to handle vehicle physics, ensuring that the driving mechanics feel responsive and realistic. The delivery vehicle is controlled through physics-based interactions, making navigation through the city an essential skill for the player.

AI and NPC Behavior:

- The NPCs in the game are scripted to follow specific paths around the city, using Godot's navigation mesh system. NPCs select random destinations within their defined paths and travel towards them, stopping at random intervals. The NPCs, while not interactive in terms of gameplay, add to the city's dynamic atmosphere, making the environment feel alive.

3. World Design and City Layout:

3.1 City Layout and Navigation:

- The game's city is semi-modular, created using modular tiles that define the roads, grass fields, and other terrains. The city is split into four quadrants, each featuring distinct zones such as residential, industrial, shopping, and recreational areas. Locations like parks, bus stops, and a mall are strategically placed to encourage exploration and make the city feel real and lived-in. A minimap is used to help players navigate the expansive city, ensuring that they can find their way to their objectives efficiently.

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3.2 Dynamic Environment:

- The world features pedestrians and vehicles that move throughout the city, adding to the immersion. Vehicles follow predetermined paths and drive through the city streets, while pedestrians wander around specific locations like bus stops or parks. Though the environment itself is not destructible, the dynamic nature of traffic and pedestrian movement creates a sense of life within the city.

3.3 Navigation and Landmarks:

- To assist exploration, important locations like bus stops, malls, and fire stations are placed near relevant districts. A minimap and visual indicators help guide players to objectives.

3.4 Traffic and Pedestrian Simulation:

- The city feels alive with AI-controlled vehicles and NPCs moving throughout designated routes.

4. User Interface (UI) and User Experience (UX)

4.1 Minimalist UI:

- The interface is kept simple and non-intrusive. Players receive only necessary information to maintain immersion.

4.2 On-Screen Elements Include:

- Minimap to navigate the city.
- Timer to track delivery deadlines.
- Mission Objective Display showing current tasks.
- Subtle visual indicators guiding the player without excessive markers.

4.3 Pause Menu:

A simple menu with options for:

- Settings
- Controls
- Quitting the game

VII. RESULT & ANALYSIS

This section presents the key results of the 3D game development project, showcasing the implementation of core gameplay mechanics, dynamic city environment, NPC AI behavior, user interface design, and performance optimization. The images and descriptions provide visual evidence of the game's features, demonstrating the effectiveness of the design choices and technical solutions applied.

Gameplay Mechanics: The game offers an immersive experience through intuitive movement mechanics and interactive gameplay. Players can walk, sprint, jump, and drive delivery vehicles, navigating the city to complete tasks. The player can drive delivery vehicles using physics-based controls, navigating through traffic and obstacles. This mechanic adds a layer of challenge and strategic planning, enriching the gameplay dynamics. The following images showcase the fluidity of character movement and vehicle driving mechanics:

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Fig 2: Vehicle Driving Mechanics

Dynamic City Environment: The game world is a semi-open, modular city with vibrant, low-poly aesthetics. Dynamic lighting and detailed environmental elements enhance the visual appeal and atmospheric immersion. The city's layout encourages exploration and interaction, supporting both delivery tasks and player-driven chaos.

Fig 3: Vibrant Low-poly Environment

NPC AI and Interactions: The city is populated with AI-driven NPCs that navigate the environment, adding a sense of life and realism.This showcases an **AI-driven NPC** navigating and interacting within the game environment, contributing to a sense of realism. The character is not just a static figure but is actively engaging with the player through dynamic dialogue. This enhances the immersion and narrative depth of the game world.

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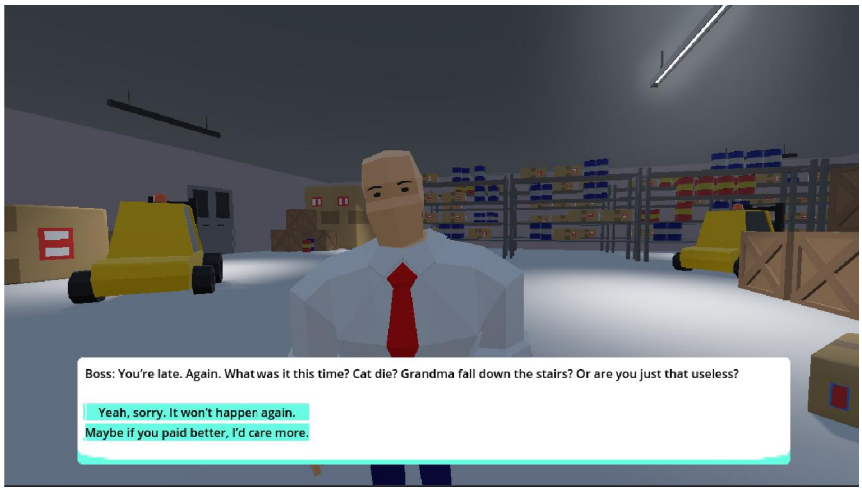

Fig 4: NPC AI-driven interaction showcasing dynamic dialogue choices

Performance and Optimization

Performance optimization was a key focus to ensure smooth gameplay across a range of hardware configurations. The game demonstrates efficient rendering, maintaining stable frame rates even in densely populated city areas.

During testing on a low-end PC with an **Intel i3-8130U processor**, the game achieved frame rates between **20-30 FPS**. Although the goal was to achieve **60 FPS** on such systems, this proved challenging within the time constraints of a single academic year. However, we are optimistic about further optimizing the game to enhance performance in future iterations.

Fig 5: Performance Benchmarks

On systems equipped with dedicated GPUs, the performance is as follows:

NVIDIA 20-series or 30-series GPUs paired with a capable CPU like the **Intel i5 (10th to 12th gen)** achieve frame rates around **40-60 FPS**, providing a smoother experience.

On modern hardware, such as the **NVIDIA 40-series GPUs**, the game runs at an impressive **180+ FPS**, showcasing its scalability and potential for high-performance gameplay.

These results highlight the game's adaptability across different hardware configurations, demonstrating its scalability from low-end systems to high-performance setups. We are committed to continuing optimization and development to fully realize the project's vision.

VIII. CHALLENGES & SOLUTIONS

The development of the game faced several challenges, particularly when working with the unique constraints of the retro PS1-style aesthetic, a large open-world design, and the performance demands of Godot. The following sections outline the key challenges encountered during the design and development phases, along with the corresponding solutions that were implemented.

1. Asset Creation and Consistency

Maintaining a consistent low-poly, retro PS1 aesthetic across a range of assets was challenging.

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Solution:
Reference images and online tutorials guided the asset creation process. Blender was used for 3D modeling, with materials applied directly within the software to achieve vibrant, consistent color palettes across assets.

2. Collision Handling
The use of static body trimesh for collision detection resulted in performance issues, especially with large city structures.
Solution:
Collision handling was optimized by replacing static body trimesh with simplified collision shapes, improving both performance and reducing lag in the editor and during gameplay.

3. File Management and Dependency Errors
Collaborating across multiple developers led to file synchronization issues and dependency errors.
Solution:
A structured file management system within Godot and version control was implemented to streamline collaboration and resolve conflicts efficiently.

4. Large City Map Optimization
Optimizing a large open-world city for performance was crucial, especially for lower-end systems.
Solution:
A quad system was employed for world design, allowing efficient placement of buildings and assets. Modular tiles for roads and ground textures ensured optimized performance without sacrificing visual quality.

5. Animation and Rigging
Creating smooth animations for low-poly models while preserving the retro aesthetic was a challenge.
Solution:
Mixamo was used for rigging and animating characters, with animations processed in Blender and exported as GLB files for integration into Godot.

6. Physics and Vehicle Mechanics
Implementing smooth, physics-based vehicle mechanics in the open world was demanding.
Solution:
Godot's built-in physics system was used to create realistic vehicle interactions, ensuring stable performance during gameplay.

7. AI Pathfinding
Effective NPC pathfinding in the large city environment was a significant challenge.
Solution:
Godot's navigation mesh system enabled NPCs to autonomously navigate the city, providing efficient pathfinding without heavy computational demands.

8. Testing and Debugging
Testing the game's mechanics and ensuring stability was an ongoing challenge.
Solution:
A recursive testing approach was adopted, where each mechanic was developed, tested, and integrated incrementally, minimizing bugs and improving stability.

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IX. CONCLUSION

This 3D game development project successfully combines a low-poly visual style with modern gameplay mechanics, delivering an engaging and immersive experience. By utilizing Blender for asset creation and Godot for game development, the project demonstrates expertise in 3D modeling, real-time rendering, and interactive gameplay mechanics. The focus on player freedom, dynamic environments, and AI-driven NPC interactions allows for an open-ended experience where players can either follow structured delivery tasks or engage in chaotic, unpredictable antics. This dual-path approach ensures replayability, making each session unique and entertaining.

Throughout the iterative design and development process, this project closely follows the Software Development Life Cycle (SDLC), covering all essential phases—from initial concept and planning to design, implementation, testing, and deployment. By adhering to a structured approach, the project ensures quality assurance at every stage, enabling continuous refinement and performance optimization. Each development phase contributes to a stable, scalable game system, ensuring that the game remains playable across various hardware configurations, from lower-end machines to high-performance systems.

Additionally, the game showcases proficiency in 3D modeling, physics-based mechanics, AI-driven NPC behavior, and environmental interactivity. The use of a low-poly aesthetic strikes a balance between minimalist art direction and modern gameplay standards, maintaining a visually distinct yet optimized experience. The semi-modular city layout, carefully placed landmarks, and traffic simulation contribute to a lively, immersive world, reinforcing the game's exploration and task-based mechanics.

In conclusion, this project not only highlights technical expertise but also showcases a deep understanding of structured game development methodologies. By blending artistic simplicity with structured development processes, the game contributes to the ongoing evolution of indie 3D game design. With a strong foundation in game mechanics, AI interaction, and open-world exploration, this project sets the stage for future expansions and refinements, offering both an enjoyable player experience and a valuable learning process in game development.

ACKNOWLEDGEMENT

We would like to express our deepest gratitude to our guide, **Prof. Reena Deshmukh**, for her unwavering guidance and support throughout this project. Her invaluable insights and constant encouragement were pivotal in bringing our research to fruition, from the initial stages to the final draft of this article.

Our heartfelt thanks also go to our Project Coordinator, **Prof. Reena Deshmukh**, and Head of Department, **Dr. Uttara Gogate**, for their exceptional support and leadership. Their effective management provided us with the opportunity to showcase our knowledge, teamwork, and communication skills within the academic community.

We would also like to extend our sincere appreciation to our Principal, **Dr. P. R. Rodge**, for his visionary leadership. His encouragement has allowed us **Tripathi Adarsh Neelkanth**, **Palkar Ayush Sandip**, and **Sali Shantanu Ravindra**—to further develop our technical and problem-solving skills, which were essential in completing this project successfully.

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