**Report on Graphics Project: Dynamic 3D Apartment**

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**Objectives**

* To design a dynamic 3D apartment with animated and interactive elements using OpenGL 3.3.
* To implement realistic physics-based motion for objects such as swings and cars.
* To create visually appealing textures for both interior and exterior surfaces.
* To incorporate advanced lighting techniques using Phong shading with multiple light sources.
* To provide user interaction controls for navigating and manipulating the environment.

**Introduction**

This project aims to create a fully interactive 3D apartment in OpenGL 3.3, showcasing dynamic elements and realistic physics-based animations. The apartment features multiple rooms, functional components like lift, doors and windows, and dynamic objects such as a curvy-motioned car and swings. Realistic textures and lighting enhance the visual fidelity, while user input controls enable navigation and interaction. The project demonstrates the potential of OpenGL for building immersive and interactive environments.

**Project Description**

The project involves designing and implementing a dynamic and interactive 3D apartment using OpenGL 3.3. The apartment is composed of two main floors and features a range of dynamically controlled objects, realistic physics-based animations, and visually rich environments enhanced with textures and advanced lighting techniques. Below is a detailed breakdown of the various components and functionalities of the project:

1. **Ground Floor Design**

* Garage: The garage houses a dynamic car designed to follow a curvy motion animation. The animation can only be triggered when the garage door is open, and it can’t be triggered if the door remains closed. The car traverses a textured road that surrounds the apartment.
* Garden: Outside the apartment, a grassy garden is implemented with realistic textures, complemented by a pathway leading to the main entrance.
* Kitchen: Contains decorative cabinets and a functional workspace.
* Drawing Room: Features a TV, sofas, and table, providing a cozy and functional living space.
* Dining Room: Includes a dining table, multiple chairs, and a rack for storing or displaying items as well as a curvy basin designed with Bezier curve and cylinders.
* Toilet: Equipped with curvy objects such as a basin, a bathtub, and a toilet, all created using Bezier curves and cylinders for smooth and realistic shapes.

1. **First Floor Design**

* Bedrooms: Two bedrooms are furnished with beds and tables, offering a realistic representation of living spaces.
* Balcony: A spacious balcony on the first-floor features two swings with dynamic motion. These swings can rotate within a range of -45° to +45°, simulating realistic swinging motions as well as realistic physics implementation like frictions and pushing.
* Lift: A functional lift connects the ground floor to the first floor. The lift operates dynamically and is user-controllable.
* Stairs: A staircase leads to the 2nd and 3rd floor, providing an alternative to the lift for vertical navigation.

1. **Dynamic and Interactive Features**

* Car Animation: The car in the garage is fully animated with curvy motion. It begins its animation sequence only when the garage door is open. The user can control the garage door and car activation.

Logic: Implemented using an if-else ladder based on the translations and rotations of car based on the situations and the control of how much translation and rotation factors need to be considered at that moment.

* Swings: The swings in the balcony are designed with realistic physics. Their motion can be controlled dynamically by the user, with rotational angles ranging from -45° to +45°. It also incorporates realistic physics such as pushing and friction.

Logic: The push button further moves the swing to its current direction based if it is within the (-45, +45) range. The friction comes into effect with every swing as the rotation will be decremented by 2 degrees in every iteration.

* Lift: The lift operates smoothly between the first and second floors. Doors open and close dynamically during operation.

Logic: Translates along y-axis based on the current floor call of the lift.

* Doors and Windows: All doors and windows in the apartment are dynamically controllable by the user, adding interactivity to the environment.

Logic: Rotates the windows and doors by 90 degrees incrementally going up from 0 degrees in case of opening and decrements to 0 degrees while closing. There are also sliding doors that are implemented using translation along an axis.

1. **Textures and Materials**

* All walls, floors, roofs, and most of the objects are textured for added realism.
* Interior and exterior walls have distinct textures to differentiate the indoor and outdoor spaces.
* Curvy objects like basins, bathtubs, and swings are textured to enhance their visual appeal.

1. **Lighting**

* The project uses the Phong shading model to achieve realistic lighting effects.
* Multiple light sources are implemented:
* Two Point Lights: Illuminate specific areas of the apartment.
* Directional Light: Mimics sunlight for consistent ambient illumination.
* Spotlight: Highlights focused regions, adding depth and realism.

1. **Bird’s Eye View**

* A transform system allows the user to toggle into a bird’s eye view mode. This mode offers an overhead perspective, providing a comprehensive view of the entire apartment and its surroundings.

1. **Surroundings**

* The apartment is surrounded by a road textured with realistic asphalt visuals. This road provides the path for the animated car.
* A grassy garden complements the aesthetics, adding a natural touch to the environment.

1. **User Interaction and Controls**

* The project features an extensive set of user controls for navigating the environment, manipulating objects, and toggling animations. Users can interactively control the car animation, swings, lift, doors, windows, and lights, ensuring an immersive experience.

This detailed description highlights the project’s complexity and the integration of multiple advanced features, showcasing the potential of OpenGL 3.3 for creating dynamic and interactive 3D environments.

**Input Controls List**

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| **Key** | **Action** |
| ESC | Close the application. |
| W | Move the camera forward (disabled in Bird's Eye View). |
| S | Move the camera backward (disabled in Bird's Eye View). |
| A | Move the camera left (disabled in Bird's Eye View). |
| D | Move the camera right (disabled in Bird's Eye View). |
| Q | Move the camera up (disabled in Bird's Eye View). |
| E | Move the camera down (disabled in Bird's Eye View). |
| I | Pan up. |
| K | Pan down. |
| L | Pan left. |
| J | Pan right. |
| U | Rotate left. |
| O | Rotate right. |
| G | Toggle fan animation. |
| B | Toggle Bird's Eye View. |
| 1 | Toggle directional light. |
| 2 | Toggle point light 1. |
| 3 | Toggle point light 2. |
| 4 | Toggle spotlight. |
| 5 | Toggle ambient light for point lights. |
| 6 | Toggle diffuse light for point lights. |
| 7 | Toggle specular light for point lights. |
| M | Open the door. |
| N | Close the door. |
| P | Start car animation if the garage door is open. |
| 9 | Open the garage door. |
| 0 | Close the garage door (only if the car animation is inactive). |
| Z | Move the lift to the second floor. |
| X | Move the lift to the first floor. |
| C | Rotate swings dynamically within bounds (-45° to +45°). |

**Discussion**

The project highlights the capabilities of OpenGL 3.3 in creating interactive 3D environments. The use of dynamic elements like a moving car and physics-based swings adds realism. The implementation of user controls for navigation and object manipulation ensures an engaging user experience. Lighting techniques based on the Phong shading model significantly enhance the visual appeal, while texturing adds depth to the environment. Challenges included balancing performance with visual quality and ensuring smooth animations, which were addressed through optimized rendering and physics calculations.

**Conclusion**

This project demonstrates the power of OpenGL 3.3 in developing dynamic and visually rich 3D environments. By integrating interactive elements, realistic physics, and advanced lighting techniques, the apartment serves as a compelling example of modern graphics programming. The project offers a foundation for further exploration into interactive virtual spaces and real-time simulations.

**References**

* Lab provided codes
* Lab and class lecture
* Lab and class slides