Augmented Reality Simulation for Physics Experiment using Unity and Vuforia Engine

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***Abstract*—This report presents the development of an augmented reality (AR) simulation of a constrained pulley system using the Unity application and Vuforia Engine. The project aims to provide an immersive and interactive learning experience for engineering students by visualizing and analyzing the motion of objects in a pulley system. The report outlines the implementation of the AR system, defines key terms, and explains their application within the Unity framework. The significance of AR for engineering students is discussed, highlighting the benefits of hands-on learning and the integration of AR technology into the educational curriculum.**

I. Introduction

This report describes the development of an AR simulation of a constrained pulley system using Unity, a popular game development platform, and Vuforia Engine, a marker-based AR technology. The constrained pulley system is a key topic in physics education that helps students comprehend concepts related to force, motion, and energy. Augmented reality (AR) technology offers a unique approach to enhancing the learning experience by merging virtual elements with the real world. The objective is to create an interactive and engaging environment for engineering students to explore and understand the dynamics of a pulley system.

II. Methodology

A. Unity Application

Unity is a powerful and widely-used game development engine that offers extensive support for creating AR and virtual reality (VR) experiences. It allows for the integration of 3D models, physics simulations, and user interactions, making it an ideal platform for creating the AR simulation of the pulley system. It is a versatile cross-platform game engine widely used for developing interactive and immersive applications. Unity gives users the ability to create games and experiences in both 2D and 3D, and the engine offers a primary scripting API in `C#` using Mono, for both the Unity editor in the form of plugins, and games themselves, as well as drag and drop functionality.

Unity 2020 LTS officially supports the following platforms : 1) Mobile platforms
2) Desktop platforms
3) Console platforms
4) Virtual/Extended reality platforms.

Unity provides a built-in physics engine that accurately simulates the behavior of objects based on Newtonian physics principles. By integrating the physics engine into the AR simulation, we can realistically depict the motion of the objects in the pulley system, including their interactions, forces, and accelerations. This integration allows students to observe and analyze the simulated motion in a manner consistent with real-world physics.

B. Vuforia Engine

Vuforia Engine is an AR development platform that offers marker-based tracking capabilities. By utilizing Vuforia, we can track physical markers placed in the real world and map virtual objects onto them, enabling a realistic and immersive AR experience. It is basically a software development kit (SDK) for creating Augmented Reality apps. With the SDK, you add advanced computer vision functionality to your application, allowing it to recognize images, objects, and spaces with intuitive options to configure your app to interact with the real world. Vuforia Engine offers tracking a variety of objects and spaces that can be categorized as Images, Objects, and Environments.

C. Augmented Reality (AR):

Augmented reality (AR) is an enhanced version of the real physical world that is achieved through the use of digital visual elements, sound, or other sensory stimuli and delivered via technology. Augmented reality is concept which combines virtual objects with the real-world environment in real-time, providing users with an interactive and immersive experience. key measure of AR systems is how realistically they integrate augmentations with the real world. The software must derive real world coordinates, independent of camera, and camera images. In the context of this project, AR is utilized to overlay virtual pulley systems and objects onto the physical surroundings, allowing students to observe and interact with the simulated physics experiment.

D. Marker-based Tracking

Marker-based tracking is a popular AR technique that relies on physical markers placed in the real world to determine the position and orientation of virtual objects. For our pulley system simulation, we can use markers to represent the pulley and the objects tied to it. By tracking the markers' positions in the real world, we can accurately render and manipulate the virtual representations in the AR environment.

E. Pulley System

A pulley is a machine made up of metal or wood which uses a wheel and a rope for lifting heavy objects by applying small force. The restrictions on the motion of any object caused by different factors which reduce its free movement are called constraints. The pulley and constraints relation is given by the equation $2T_p = T+T = 2T$. In order to calculate the acceleration or tension in two blocks connected to a pulley, first use the formula of tension and then use the pulley constraint relation. On further solving, the acceleration and tension of the two blocks can be calculated.

III. System Design and Implementation

A. Simulation Description

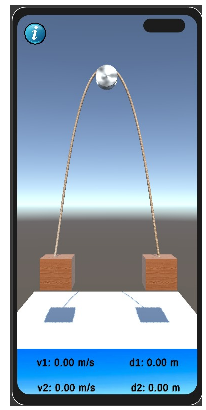
Upon launching the simulation, the user can interact with the virtual objects by adjusting the mass values, initiating the motion, and pausing at any desired time. As the objects move, the simulation tracks their positions and displays real-time information such as distance, speed, and acceleration, allowing students to observe and analyze the experiment. In the AR simulation, users can view a virtual representation of a constrained pulley system projected onto a real-world environment through their device's camera. The simulation consists of a massless pulley, objects of different masses tied with a massless rope, and a statstical representation of the motion data.

B. Physics Engine Integration

The virtual objects connected to the pulley system undergo realistic motion based on the laws of physics. Gravitaitonal force, tension in the rope affect the motion of the objects in the system. The Unity physics engine simulates the gravitational forces acting on the objects, ensuring accurate representation of their movements. Students can observe the motion in real-time and gather data for analysis.

C. Motion and Mechanics

Distance, Velocity, and Acceleration Calculation: By tracking the position of the objects at different time intervals, the AR application can calculate the distance travelled, speed, and acceleration of the objects. These parameters are crucial for understanding the motion and dynamics of the pulley system. The calculations are performed based on the measured positions and time values, providing students with quantitative data for analysis.



IV. Experimetnal Setup

A. Requirements

To use an Augmented Reality (AR) application on an Android phone, user will need the following requirements:

1) Android Phone with Camera: User needs an Android device, preferably a smartphone, with a recent version of the Android operating system, a functioning camera is essential.
2) API Level: The Android API level should be 25 or higher to support the necessary features and functions for AR app.
3) General Access: This app should have permission to access the camera, file manager as well as other necessary sensors on the device, to provide an immersive AR experience.
4) Target Image: The app should be able to detect and track these target images accurately.
5) Storage Space: AR apps can occupy a considerable amount of storage space, especially if they include high-quality 3D models and textures.

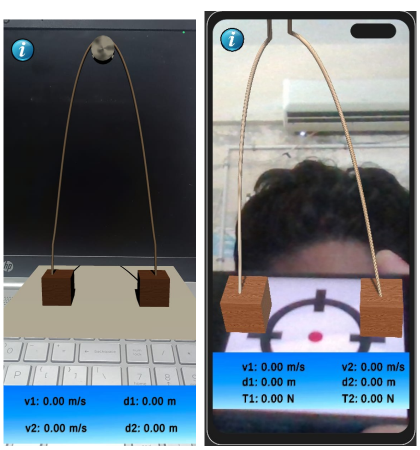
B. Procedure

1) Install the App: Download and install the AR application from a reliable source.
2) Allow Permissions: When user launches the app for the first time, it may request permission to access device's camera and file manager. Allow the app to access the camera so that it can track the target image, and allow access to the file manager to store any data related to the AR simulation.
3) Start the App: Open the AR application on Android phone.

4) Set Values: The app may have a user interface that allows user to set values for different objects in the AR simulation using sliders or other controls.
5) Track the Target Image: Hold the Android phone's camera in front of the target image that the app is designed to recognize and track. The app should detect the target image through the camera and overlay the AR simulation on top of it.
6) Observe the AR Simulation: Once the target image is recognized, user can see the AR simulation appear on your device's screen. Explore the AR experience by moving the phone around and interacting with the virtual objects.
7) Note Down Parameter Values: While interacting with the AR simulation, User can take note of the values of the parameters you previously set using sliders or other controls.
8) Analysis : After finishing the AR simulation, you can analyze the data you noted down and observe how changing the values of the parameters affected the AR experience. Student can experiment with different values and configurations to create unique AR experiences.

V. Experiment Analysis

The AR simulation provides a valuable tool for analyzing the motion of the objects in the constrained pulley system. By observing the motion and collecting data at various time intervals, students can calculate important parameters such as distance, speed, and acceleration. This analysis helps them grasp the relationship between these variables and gain a deeper understanding of the underlying physics principles governing the pulley system.



VI. Result and Discussion

The AR simulation of the constrained pulley system presents a realistic virtual environment where engineering students can observe and analyze the motion of objects. The simulation consists of a massless pulley, objects of different masses tied with a massless rope, and a graphical representation of motion data. By manipulating the virtual objects and initiating their motion, students can observe the effects of various factors on the system's behavior. The significance of the project lies in offering engineering students a hands-on learning experience and visualizing complex systems. The ability to gather quantitative data for analysis enhances their understanding of the system's dynamics.
However, the project has some drawbacks. It is currently not compatible for real-time value analysis and remains a work in progress. The prototype model is ready, but further improvements are needed for real-time analysis. Difficulties with the elasticity of the rope using the Obi Rope asset require attention. Despite these challenges, the project holds promise for the future. With ongoing development and enhancements, this AR simulation can become a valuable tool for engineering students, facilitating their learning and analytical skills.

VII. Future Work

The future work for the AR simulation project involves implementing workable assets to address the elasticity issues with the rope, ensuring an efficient working pulley system with realistic physics. By addressing the current limitations, implementing workable assets, enabling real-time parameter analysis, and expanding the pulley constraint system, the simulation will provide students with a more immersive and comprehensive learning experience. Additionally, new pulley constraint systems will be added to expand the learning scenarios. The user interface and interaction mechanisms will be enhanced for a more user-friendly experience, while curriculum integration will be considered to align the simulation with engineering educational objectives.

VIII. Conclusion

The integration of augmented reality into physics education offers significant benefits for engineering students. The AR simulation of a constrained pulley system provides a hands-on learning experience that enhances engagement and understanding. By visualizing complex concepts and allowing students to interact with virtual objects, AR bridges the gap between theoretical knowledge and practical application. This application enables the development of immersive and interactive simulations that promote active learning and critical thinking among students and also enhances students' understanding of physics concepts while providing them with a flexible and interactive learning environment.

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