Study of Projectile Motion: Augmented Reality

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Abstract

The traditional pedagogical approach to understanding projectile motion often relies on two-dimensional diagrams, chalkboard explanations, or at best, simple practical demonstrations. While these methods provide foundational knowledge, there is increasing need to implement innovative teaching tools that cater to the digital age, ensuring more immersive and intuitive understanding for students. This study explores the efficacy of using Augmented Reality (AR) as a tool for teaching and learning the concepts of projectile motion in physics. Using AR, students are able to project trajectories onto their physical surroundings, change parameters like angle of projection, initial velocity, and observe the effects in real-time. The application also offers instantaneous feedback on calculations, helping students comprehend the underlying mathematical relationships.

Keywords

Augmented Reality, Projectile Motion, Physics Education, Innovative Teaching, Interactive Learning

Introduction

Technological developments in this day and age are growing so rapidly. Including its role in various sectors, such as education, agriculture, health, and others. Augmented Reality at present one of the rapidly developing Technology. Philipp A. Rauschnabel et al.[9] AR is a technology that combines the imaginary world and the actual world where users are able to explore the actual world in a more interactive and interesting way. Slowly but surely AR technology has provided new options that are changing how we interrelate with each other, learn and play in the 21st century. Using AR technology for education is not something new as it has been done it for assembly training or body organ recognition. Therefore, in this research, researchers try to utilize the same technology for learning concepts in Physics subjects. If we study projectile motion, we will always be presented with illustrative vision of the parabola's motion. Currently, parabolic motion experiment equipment is still quite rare in schools. The equipment that are used to demonstrate the projectile motion are quite expensive. This condition conveys that not all schools have adequate equipment, especially parabolic motion experimental equipment. This causes the learning atmosphere to seem monotonous so that feedback is relatively low. And another problem is that the teaching aids provided by the school cannot be taken home by students. Therefore, we want to create an application to visualize parabolic motion using AR as a learning medium for students to learn about parabolic motion. The application used to project a real time projectile concept by receiving the input and calculated using physic formula. And with the help of AR technology, the outline of a parabola can be seen directly in the real world.

The traditional educational props used in teaching projectile motion are limited and cannot be used for accurate calculation. Matt Bower et al.[10] the utilization of AR in educational methods may raise curiosity and provide a unique way of learning projectile motion, as the motion can be seen in three dimensions. The use of smartphones in teaching physics laws be effective in engaging students and helping them learn faster. Philipp A. Rauschnabel et al.[9] AR is a combination of real-world and virtual objects, and it can be used to simulate projectile motion and its velocity more realistically. AR provides a unique way of learning projectile motion and allows students to see it in three dimensions. Joe Yuan Mambu et al. [2] also mentions the using Vuforia SDK to blend real-world and virtual objects. Overall, using AR in teaching projectile motion can raise curiosity and provide a more engaging and interactive learning experience for students. T B Ding et al. [7] emphasizes the importance of providing students with different technique of understanding a topic, especially when it arrives to essential chapters like projectile motion. It suggests that incorporating technology like AR can help switch from teacher-centered to student-centered learning environments and provide a more inclusive learning experience.

Literature Review

Mark Billinghurst et al. [1] discusses how AR should provide a way to for providing the possibilities for learning, teaching, study, or creative investigation. AR uses imaginary objects or data that overlap environment or physical object to create a combine reality in which virtual objects and environments coexist in a meaningful manner to increase learning. Applying AR technology in the education sector can result in having an intelligent campus. AR helps to increase students' content understanding, motivation, interaction, and collaboration. AR will be a successful approach to tackling problems in physics. AR technology tools for education have been evaluated systematically, and teaching based on AR will be effective in technical, creative design courses and software editing courses for students. The utilization of AR in educational methods may raise curiosity and give a unique way of learning projectile motion. Joe Yuan Mambu et al. [2] uses the Vuforia SDK, which can meld the natural world and virtual objects. The virtual objects help a user perform real-world tasks, making them a distinct example of what Fred Brooks terms Intelligence Amplification (IA): using the computer as a gadget to make a task more manageable for a human to perform. Ergi Bufasi et al. [3] have focused on fusing real and virtual images and graphics, but AR could be amplified to include sound. This would give the system a chance to cover up picked authentic sounds from the environment by initiating a masking signal that exactly canceled. Instructions might be easier to understand if they were available as 3-D drawings superposed upon the actual equipment, revealing step-by-step the tasks that need to be done and how to do them. These superposed 3-D drawings can be animated, making the directions even more explicit. Carlo H. Godoy Jr et al. [4] explores current mobile AR solutions like ARKit and ARCore, highlighting their capabilities in surface detection and object pinning on smartphones. Despite the surface detection proficiency of many existing AR systems, there is a notable need for improved object detection and recognition in the real world. Additionally, these systems require increased computational resources to render high-quality elements effectively.

Awelani V et al. [5] said about common misconceptions about projectile motion, such as the belief that the direction of acceleration or force follows the direction of motion. Various material available for students to explore the effects of varying the velocity and angle of projection. Teachers can design their lesson plans based on these materials and provoke discussions of projectile motion in a various context. Chester Ian S. Pineda et al. [6] talks about projectile motion being used in a variety of real-world applications, such as ballistics, sports, and space travel.

The motion of a projectile can be modeled using mathematical equations, such as the equations of motion and the kinematic equations. Ergi Bufasi et al. [3] explains the computational of projectile motion involves using computer simulations to model the movement of a particles that is thrown or launched into the air. Refik Dilber et al.[8] by using computational modeling, students can gain a profound understanding of the physics behind projectile motion and how different factors, such as mass and velocity, can affect the movement of an object.

Implementation

The study of projectile motion using augmented reality (AR) involves combining real-world physics principles with digital simulations to provide an interactive and immersive learning experience.

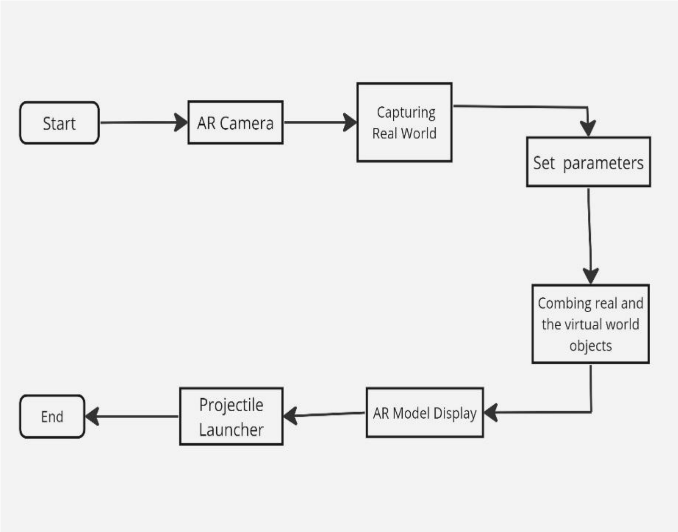

Fig: System Framework Diagram

Simulation Development: Our team developed an AR application using platforms like Unity and ARCore/ARKit. This involved in creation a virtual environment where users can observe and interact with projectile motion scenarios.

The simulation requires the user to input the initial velocity, angle, and rate of motion for the object to move. The simulation then calculates the horizontal and vertical components of the object's momentum, which influence its acceleration as it travels through the air showing parabolic movement. The simulation also shows how the object's velocity changes over time, with the horizontal velocity remaining constant and the vertical velocity decreasing due to the force of gravity. The simulation can be used to visually understand the properties of projectile motion, such as why a projectile fall after reaching a certain height.

Physics Engine Integration: We integrated a physics engine into the AR application to accurately simulate projectile motion based on real-world physics principles. Unity's physics engine or external libraries like Box2D were used for this purpose.

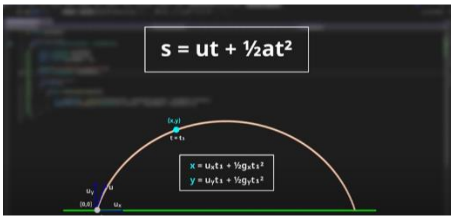

Fig: demonstration of projectile motion

Vertical Projectile Motion

- Vertical position:
  The vertical position y of the object at any time t can be calculated using the equation:
  $$y = y_0 + v_0 t - \frac{1}{2} g t^2$$
  Where:
  y is the vertical position at time t
  y_0 is the initial vertical position
  v_0 is the initial vertical velocity
  g is the acceleration due to gravity
  t is the elapsed time

- Vertical velocity
  The vertical velocity v_y of the object at any time t can be calculate using the equation:
  $$v_y = v_0 - gt$$
  Where:
  v_y is the vertical velocity at time t
  v_0 is the initial vertical velocity
  g is the acceleration due to gravity
  t is the time elapsed

- Vertical acceleration
  The vertical acceleration a_y is a constant and equal to the acceleration due to gravity (g).

Horizontal Projectile Motion

- Horizontal Position:
  The horizontal position x of the object at any time t can be calculated using the equation:
  $$x = x_0 + v_0 t$$
  Where:
  x is the horizontal position at time t
  x_0 is the initial horizontal position
  v_0 is the initial horizontal velocity

- Horizontal Velocity:
  The horizontal velocity v_x of the object remains constant throughout the motion and is equal to the initial horizontal velocity:
  $$v_x = v_0$$
  Where:
  v_x is the horizontal velocity
  v_0 is the initial horizontal velocity

- Horizontal Acceleration:
  There is no horizontal acceleration (a_x = 0) acting on the object, assuming negligible air resistance.

User Interaction: In our project, we have successfully integrated intuitive user interfaces into the augmented reality (AR) application, facilitating user interaction and customization of parameters essential for the simulation of projectile motion. Users are empowered to manipulate critical variables such as initial velocity, launch angle, and gravitational acceleration, thereby enhancing their engagement and understanding of the underlying physics principles.

To ensure accessibility and ease of use, our team implemented a variety of intuitive input methods inside the AR interface. Users can use the application through touch-based controls, enabling them to directly input values or adjust parameters using familiar gestures such as tapping, swiping, and pinching. Additionally, we have incorporated gesture recognition capabilities, allowing users to intuitively manipulate virtual objects and adjust settings through natural hand movements or gestures.

This intuitive user interface design not only enhances the user's experience but also promotes active learning and experimentation. By providing users with the potential to dynamically modify parameters and observe real-time effects on projectile motion simulations, our AR application fosters deeper engagement and comprehension of physics concepts in an immersive and interactive learning environment.

Real-time Visualization: In our implementation, augmented reality (AR) technology serves as the backbone for overlaying dynamic virtual elements onto the physical environment, offering users an immersive and interactive experience. Through AR, we seamlessly integrate virtual representations of projectiles, launch trajectories, and impact points into the user's surroundings in real-time.

This approach enables users to visualize and interact with simulated projectile motion directly within their physical environment. As users adjust parameters such as initial velocity, launch angle, and gravitational acceleration, they receive instant visual feedback through the AR interface. Virtual representations of projectiles accurately reflect changes in trajectory and velocity, while impact points dynamically update to reflect the projected landing location.

By leveraging AR technology, our application enhances the learning experience by facilitating users with tangible, real-time visualizations of projectile motion principles. Users can observe the effects of parameter adjustments firsthand, gaining a deeper understanding of the relationship between input variables and resulting motion trajectories. This real-time feedback mechanism fosters active experimentation and exploration, allowing users to engage with physics concepts in a hands-on and intuitive manner.

Overall, the combination of AR technology into our application transforms the learning process, offering a dynamic and immersive platform for exploring and understanding projectile motion in the physical world.

Educational Content Integration: In addition to the dynamic visualizations of projectile motion, our AR application incorporates educational content aimed at enhancing users' understanding of the underlying physics concepts. Through the integration of explanatory text, diagrams, and animations, we provide users with comprehensive support materials that elucidate the principles governing projectile motion.

Explanatory text is strategically embedded within the AR interface, offering concise explanations of key concepts such as velocity, acceleration, and trajectory. This textual guidance serves as a valuable reference for users, providing contextual information and reinforcing their understanding of the physics principles at play.

Diagrams are utilized to supplement textual explanations, visually illustrating the relationships between various parameters and their effects on projectile motion. Users can work alongside with these diagrams within the AR environment, gaining insights into the geometric and mathematical aspects of projectile motion through dynamic visualizations.

Furthermore, animations bring physics concepts to life, showcasing dynamic simulations of projectile motion phenomena. Users can observe the interplay between different variables in action, gaining a deeper appreciation for the complex dynamics underlying projectile motion.

By integrating educational content into the AR experience, our application transcends traditional teaching methods, offering a multi-modal learning environment that caters to diverse learning styles and preferences. Users are empowered to explore concepts at their own pace, engaging with educational materials in a highly immersive and interactive manner. This integral approach not only facilitates comprehension but also fosters a deeper appreciation for the beauty with complexity of physics principles governing projectile motion.

Experimentation and Exploration: Our AR application fosters a culture of exploration and experimentation by encouraging users to manipulate various launch conditions and scenarios. Through this hands-on approach, users gain firsthand experience in observing how changes in parameters such as initial velocity, launch angle, and gravitational acceleration impact the path of the projectile.

By actively engaging with the simulation and observing the resulting effects on projectile motion, users develop critical thinking skills and deepen their understanding of the underlying physics principles. This interactive learning experience empowers users to form hypotheses, test different scenarios, and draw conclusions based on their observations, fostering a sense of discovery and inquiry.

Furthermore, the ability to experiment with different launch conditions promotes self-directed learning, allowing users to explore concepts at their own pace and tailor their experience to their individual interests and learning objectives. Through this dynamic and interactive approach, our AR application facilitates active learning and cultivates a deeper appreciation for the complexities of projectile motion.

Integration with Curriculum: By aligning the analysis of projectile motion using AR with educational curricula in informal learning environments, we ensure that learners benefit from a cohesive and relevant educational experience. This strategic integration bridges the gap between formal educational standards and the dynamic learning environments found in museums, science centers, and other informal settings. By incorporating AR technology into these contexts, we provide learners with engaging and interactive opportunities to explore physics concepts in a hands-on manner. This approach enhances retention and comprehension but also encourages learners to make connections between conceptual knowledge and real-world applications. By seamlessly integrating AR-enhanced experiences into informal learning environments, we empower learners to develop critical thinking skills, foster a deeper appreciation for science, and cultivate a lifelong love of learning.

By employing these methods, the study of projectile motion using augmented reality can offer an engaging and effective way for learners to explore and understand fundamental physics concepts in a real-world context.

Results

Augmented reality (AR) has the potential to enhance the study of projectile motion in various ways:

Visualization: Augmented reality (AR) offers students an immersive learning experience by providing realistic 3D visualizations of projectile motion. With AR, students can observe the trajectory of the projectile in real-time and from various angles, enhancing their understanding of fundamental concepts such as launch angle, initial velocity, and range.

By interacting with virtual representations of projectiles within their physical environment, students gain precious insights into the dynamics of motion. They can test with different launch conditions and observe how changes in parameters affect the trajectory, fostering a deeper comprehension of the underlying physics principles.

Furthermore, the interactive nature of AR allows students to engage actively with the material, promoting hands-on learning and critical thinking skills. By incorporating AR technology into educational settings, educators can provide students with dynamic and engaging experiences that facilitate deeper learning and retention of concepts related to projectile motion.

Interactive Simulations: Augmented reality (AR) applications offer students a dynamic learning experience by enabling interaction with virtual objects representing projectiles. Through these applications, students can actively manipulate parameters such as initial velocity and launch angle, witnessing firsthand the impact of these adjustments on the trajectory of the projectile.

This active approach fosters deeper engagement and understanding of the underlying physics principles governing projectile motion. By experimenting with different launch conditions and observing the resulting changes in trajectory, students gain precious insights into concepts such as velocity, acceleration, and projectile motion equations.

Furthermore, the interactive nature of AR applications encourages exploration and experimentation, promoting critical thinking and problem-solving skills. Students are empowered to explore physics concepts in a tangible and intuitive manner, facilitating a deeper level of comprehension and retention.

Overall, AR applications provide an immersive and interactive platform for students to explore and understand projectile motion, paving the way for enriched learning experiences in physics education.

Real-world Context: Augmented reality (AR) technology revolutionizes the study of projectile motion by overlaying virtual objects onto familiar real-world environments. Students can immerse themselves in scenarios such as throwing a ball in a park or launching a rocket in a classroom, creating an engaging and relatable learning experience.

By simulating projectile motion within their immediate surroundings, students can better grasp the concepts and principals involved. They can observe the trajectory of virtual projectiles as they interact with the physical environment, gaining a deeper understanding of factors such as launch angle, initial velocity, and trajectory.

This experiential approach not only enhances comprehension but also fosters a sense of connection between theoretical knowledge and real-world applications. By contextualizing the study of projectile motion within familiar settings, AR technology makes learning more accessible and meaningful for students of all backgrounds and learning styles. Ultimately, AR empowers students to explore and understand physics concepts in a dynamic and immersive manner, paving the way for enriched educational experiences.

Experimental Exploration: Augmented reality (AR) offers students the opportunity to conduct virtual experiments related to projectile motion, providing a safe and accessible environment for exploration and learning. With AR, students can simulate experiments that may be challenging or risky to perform in real life, such as launching projectiles at extreme angles or velocities.

By immersing one-another in these virtual environments, students can observe the behavior of virtual projectiles and analyze the resulting data to draw conclusions and make predictions. They can manipulate parameters such as launch angle, initial velocity, and projectile mass, observing how these factors affect the trajectory and range of the projectile.

This hands-on approach to experimentation fosters critical thinking and problem-solving skills, allowing students to explore physics concepts in a dynamic and interactive manner. Furthermore, by interacting with virtual experiments, students can gain a deeper understanding of projectile motion principles while minimizing safety concerns and logistical constraints related with traditional laboratory settings.

Collaborative Learning: AR applications can support collaborative learning experiences by allowing multiple users to interact with virtual objects simultaneously. Students can work jointly to explore and analyze projectile motion scenarios, fostering teamwork and peer-to-peer learning.

Conclusion

Using augmented reality (AR) in teaching projectile motion has shown promising results. AR provides a unique and interactive way of learning, allowing students to see the motion in three dimensions and associate with virtual objects. One study used the Vuforia SDK to simulate projectile motion and its velocity more realistically, allows students to input parameters and see the results. Overall, AR can revolutionize the way we teach and learn projectile motion, providing new opportunities for interactive and immersive learning experiences. However, there are numerous challenges to overcome, some of them are cost of AR technology and the proper training given to the teachers to use AR in the education effectively.

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