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# Interactive Solar System Simulation in Unity 3D


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## ABSTRACT:

This paper presents an **interactive solar system** simulation developed in **Unity 3D**, aimed at providing an immersive educational experience for users to explore celestial bodies and learn about their fundamental characteristics. The simulation includes detailed models of the planets and their main moons, allowing users to navigate through the solar system and examine each object individually. Key features of the simulation include the ability for users to learn about the **tilt of the Earth's axis** and its impact on the **occurrence of seasons**. Through interactive exploration and informative overlays, users gain a deeper understanding of celestial phenomena and their underlying mechanisms. The simulation's educational value is evaluated through user studies, demonstrating its effectiveness as a tool for teaching astronomy concepts. Challenges encountered during development are discussed, along with potential future enhancements to further enrich the educational experience. Overall, this project contributes to the advancement of interactive learning environments for astronomy education.



**Index Terms:** Unity 3D, Augmented reality (AR), Virtual Reality (VR), Solar system, Planets and Moons, Feedback


## I. INTRODUCTION:

In an era where digital technology continues to revolutionize education, the importance of immersive and interactive learning experiences cannot be overstated. Our project endeavours to harness the power of Unity 3D to create an engaging and educational tool: an interactive solar system simulation.

The motivation behind our project lies in the recognition of the profound educational value in visualizing celestial phenomena. By bringing the vastness of the cosmos to life in a virtual environment, we aim to provide users with a unique opportunity to explore and comprehend the intricate workings of our solar system.

This paper serves as a comprehensive exploration of our interactive solar system simulation, developed using Unity 3D. Throughout this paper, we will detail the methodology employed in creating our simulation, including the modelling of celestial bodies and the implementation of interactive features. Additionally, we will discuss the educational objectives of our project, highlighting key concepts users can learn through interaction with the simulation.

The core focus of our simulation is to create a model of the solar system with meticulous attention to detail. Each planet, along with its main moons, is meticulously recreated to provide users with an immersive experience. Users are empowered to explore each celestial body individually, gaining insights into their basic characteristics and behaviours.

Our approach to creating this simulation involves utilizing Unity elements to construct the celestial bodies, with textures and sound effects enhancing the immersive experience. The "rotate around" script facilitates the realistic movement of planets, allowing them to orbit the sun at specified speeds.

In the subsequent sections of this paper, we will delve deeper into the technical aspects of our simulation, discussing the design choices, challenges encountered, and the results of user evaluations. Through this exploration, we aim to demonstrate the efficacy of our simulation as an educational tool and outline potential avenues for future development and enhancement.

## II. MOTIVATION AND BACKGROUND:

Understanding the solar system is a core part of science education from an early age. However, standard textbook diagrams and models can make it difficult for students to fully grasp the true scale, orbits, and characteristics of the planets, and their moons. An interactive augmented reality (AR) or virtual reality (VR) experience that allows users to virtually explore and manoeuvre around a 3D model of the solar system has the potential to greatly enhance comprehension and engagement with this important topic. By providing an immersive, visually engaging environment, students can develop a more intuitive and lasting understanding of fundamental concepts like planetary orbits, relative sizes, tilts, moons, and other celestial phenomena. Rather than passively viewing static images, they can navigate the virtual solar system themselves, zoom in on objects of interest, and even simulate the effects of axial tilts in the context of this project’s scope while it could be extended further to showcase a large number of events. This hands-on, self-guided approach aligns with modern pedagogical theories emphasizing active learning and knowledge construction. Furthermore, AR/VR experiences are highly versatile and can be used independently by students, integrated into classroom lessons by teachers, or even adapted into educational videos or installations for enriching science exhibits and informal learning environments. Their inherent novelty and interactivity have strong potential to engage and inspire the next generation of scientists, astronomers, and space explorers. The proposed interactive solar system experience will be built using the Unity 3D game engine, widely used for developing AR/VR applications across multiple platforms and devices. It will feature detailed 3D models of the Sun, all 8 planets, and the major moons of each planet. Users will be able to freely navigate around the solar system, zoom in or out, and click/touch on celestial bodies to view informative overlays about their key characteristics like size, mass, orbital parameters, and any noteworthy moons. The experience aims to strike a balance between educational rigor and engaging visualizations, drawing inspiration from past virtual planetariums and space simulators. However, its self-contained, portable, and highly interactive nature enabled by AR/VR technologies provides a new paradigm for delivering immersive astronomy education. With further development, there is potential to expand with more advanced concepts, multimedia assets, and even multi-user collaboration for shared exploration.

## III. DESIGN:

In this section, the development cycle of the project is presented, from Ideation to User Feedback. It is designed specifically to create an immersive learning environment focused on exploring our Solar System.

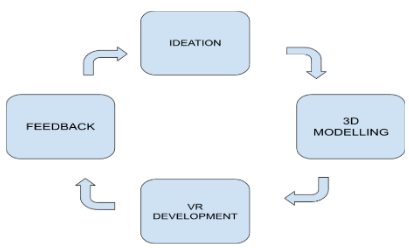


FIGURE: Shows the steps involved in designing the virtual environment of the solar system.

**Ideation:**

The exploration of the solar system is crafted with a learner-centred approach. The paramount focus is placed on empowering students to navigate the complexities of our near-cosmic neighbourhood with ease. Taking note of learner anatomy, which focuses on kids and adults alike, this model fosters a dynamic learning environment.

The design of the project is guided by the fundamentals of astrodynamics. It keeps the learning more authentic to the cosmic universe. The fidelity and quality of these 3D models are paramount, as they directly correlate with students' motivation and engagement levels. This should also instil confidence and proficiency in initiating learning about the intricacies of the subject.

The idea is to not only show the solar system but also educate the learners about it. The information baskets have been strategically placed to refine the knowledge of the users. It will equip users with the requisite understanding of each planet and its moons. The synergy between the visual graphics and information would create a meticulously tailored environment for learning.

**VR Development:**

Virtual Reality (VR) development for the solar system simulation involved a meticulous process aimed at achieving both accuracy and immersion. The development encompassed several key aspects, including:

**1. Conceptualization and Planning:** The initial phase of development focused on conceptualizing the VR environment and outlining its features. This involved determining the simulation scope, defining user interactions, and setting objectives for educational content.

**2. Data Acquisition and Research:** Accurate representation of the solar system required comprehensive research and data acquisition. Astronomical data, including planetary orbits, sizes, distances, and axial tilts, served as the foundation for the simulation. Additionally, information about the major moons of each planet was gathered to provide users with educational insights.

**3. Design and User Interface (UI):** The design phase involved creating a visually appealing and user-friendly interface for navigating the VR environment. Intuitive controls were implemented to facilitate seamless interaction with the simulation. Visual elements and user interface components, were carefully used to depict correct information.

**4. 3D Modelling and Texturing:** The creation of 3D models for planets and moons was a crucial aspect of VR development. Using software tools such as Unity, high-fidelity models were constructed.

**5. Programming and Simulation Logic:** Implementing simulation logic to replicate the dynamics of the solar system was a significant technical challenge. Programming scripts were developed to simulate planetary orbits, and axial tilts.

**6. Integration of Educational Content:** Educational content was seamlessly integrated into the VR experience to provide users with informative insights into the solar system. Interactive modelling of the solar system, and text descriptions were utilized to convey relevant information about each planet, its major moons, and the phenomena observed within the simulation.

**7. Testing and Optimization:** Extensive testing and optimization were conducted to ensure the stability, performance, and accuracy of the VR environment. Feedback from users was gathered to identify and address any issues or areas for improvement.

Overall, the development of the VR environment for the solar system involved a multidisciplinary approach combining astronomy, computer graphics, user interface design, and educational content creation. The result is an immersive and educational experience that allows users to explore the wonders of our cosmic neighbourhood firsthand.

**User Feedback and Revisions:**

Throughout the development process, frequent user testing and feedback gathering was conducted with the target audience of students and educators. This iterative process proved invaluable for identifying areas of improvement and refining the interactive experience.

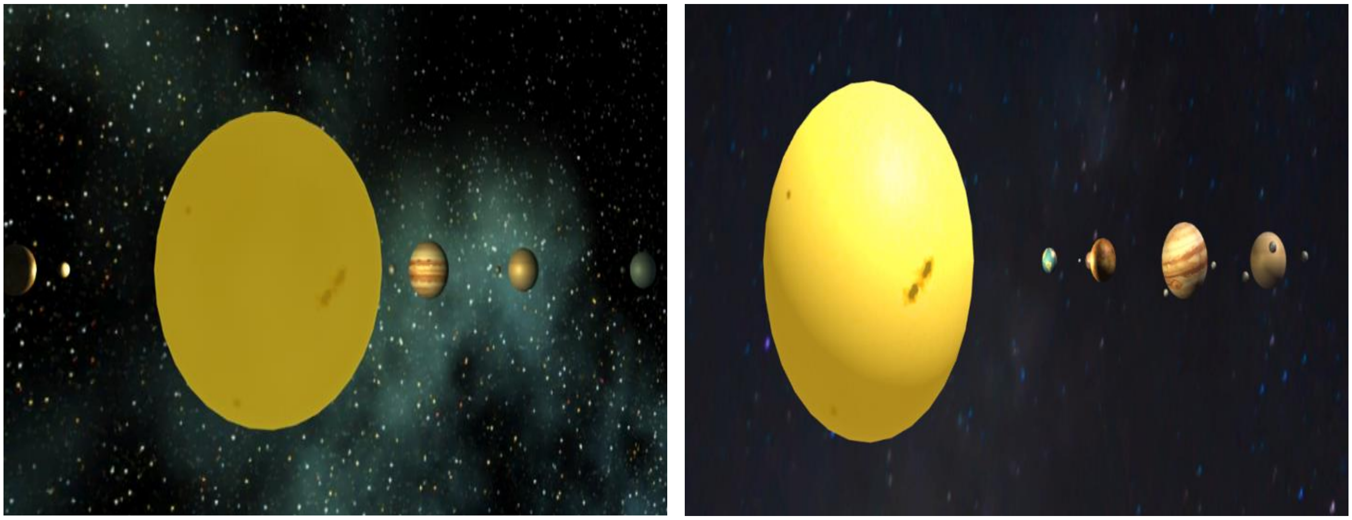

FIGURE: The image on the left shows the model before scaling the terrestrial planets, with the previously chosen background showing too many stars creating a problematic experience for the users. Problems relating to the tilt of all the planets, their textures and the light effects were also found. The following were corrected and the image of the latest model is shown in the right image

1. Initial feedback from users indicated that the plain black background of the virtual space environment felt too empty and made it difficult to establish a sense of scale and depth perception. To address this, a realistic starry backdrop was added, giving spatial context while avoiding concealment of the sun and planetary bodies.
2. Camera controls were also adjusted based on user input. The original free orbital camera mode was cited as confusing and nauseating for some participants. A revised hybrid camera system was implemented, allowing free rotation around a point of focus, while avoiding drastic changes in perceived velocity that can cause discomfort in VR.
3. For the planetary models themselves, two significant revisions were made in response to user feedback. Firstly, **the initial scale representation of the terrestrial planets** (Mercury, Venus, Earth, Mars) **was seen as too small** and made it difficult to discern surface details and interact with them meaningfully. Their scales were increased slightly to allow better visibility while preserving relative size differences.

   **Secondly, while the mechanics for demonstrating effects like the Earth's axial tilt and progression of seasons were functional**, users indicated it was difficult to intuitively observe and understand the connection. A seasonal visualization mode was added, projecting seasonal orientation indicators around the Earth's orbit to better convey the relationship between axial tilt and seasonal transitions over the year.

4. For objects like moons, feedback was received that information panels became cluttered when multiple bodies were present. To streamline this, a toggle system was created to only focus on the user's currently selected point.

Looking ahead, additional user feedback has highlighted interest in more advanced capabilities like:

- Simulation of theoretical future events (e.g. Andromeda galactic collision)
- Multi-user collaborative exploration mode
- Zoom levels extending into deep space objects
- Curriculum-aligned educational programming and assessment tools

Continuously evolving the experience based on real user needs and feedback remains a top priority for maximizing engagement and educational efficacy across formal and informal learning environments. The flexible, expandable architecture of the Unity 3D platform positions this interactive solar system experience for ongoing growth and improvement.


FIGURE: Shows the Seasonal Change Scene specifically designed to enhance the users experience for understanding the seasons of Earth in a separate scene.

**Solar System Virtual Environment as a Learning Tool:**

**Development of the VR Environment:** The solar system VR environment developed for educational purposes aims to offer users an immersive journey through our celestial neighbourhood. The environment consists of three distinct scenes, each tailored to enhance understanding and engagement.

FIGURE: Shows the spaceship view of our project when the focus was on Jupiter. This spaceship view enhances the user experience and makes our project more interactive. Also, this spaceship mode can be toggled out of, if the user requires to get an expanded view of the solar system.

1. **Default Scene:** The default scene serves as the starting point for users, presenting an overview of the solar system with the person being able to see the view as being inside a spaceship. Here, users are greeted with a panoramic view of the sun, the eight planets, and their major moons, all rendered in stunning detail. Interactivity is a key feature of this scene, allowing users to select individual planets for further exploration. Upon interaction, users are seamlessly transitioned to a detailed information scene dedicated to the chosen planet.
2. **Planet Information Scenes:** Upon selecting a planet from the default scene, users are transported to a dedicated information scene providing comprehensive details about the selected celestial body. Information is presented through a combination of visuals and text to accommodate different learning styles.
3. **Seasonal Change Scene:** The final scene of the VR environment simulates the change of seasons, a fundamental concept in understanding Earth's orbit around the sun. Users witness firsthand how the tilt of Earth's axis relative to its orbital plane results in the varying lengths of daylight and the changing seasons. This scene provides a dynamic visualization of astronomical phenomena, helping users grasp abstract concepts in a tangible way.

**Educational Benefits:** The solar system VR environment offers several educational benefits:

- **Engagement and Immersion:** By providing an immersive experience, VR captivates learners' attention and enhances retention of information.
- **Interactivity:** Interactive elements promote active learning, allowing users to explore at their own pace and delve deeper into topics of interest.
- **Visual Learning:** Visualizations aid comprehension of complex concepts, making abstract astronomical phenomena more accessible and tangible.
- **Personalized Learning:** The multi-scene structure accommodates diverse learning styles and preferences, allowing users to tailor their learning experience.
- **Real-World Application:** By simulating real-world astronomical phenomena such as seasonal changes, the VR environment fosters a deeper understanding of Earth's place in the solar system.

## IV. RELATED WORK:

In reviewing existing solar system simulations and educational software, it's evident that many prior projects have laid the groundwork for interactive learning tools in astronomy. However, these simulations often lack certain features that enhance user engagement and educational value. Let's delve into how our project addresses these gaps and builds upon previous work.

**Seasonal Variation:** While some existing simulations offer basic representations of planetary orbits, few delve into the nuances of seasonal variation and its relation to Earth's axial tilt. Our simulation stands out by incorporating a portrayal of seasonal changes, allowing users to observe the effects of Earth's tilt on the prevalence of seasons and to gain a deeper understanding of the Earth's relationship with the sun and its impact on our climate.

**Dynamic Camera Angles:** Many existing simulations may offer static camera views or limited control over the user's perspective. In contrast, our simulation prioritizes user feedback by dynamically adjusting camera angles based on user interactions. This feature enhances the user experience by allowing for more personalized exploration of the solar system, ensuring that users can focus on areas of interest and view it from various perspectives.

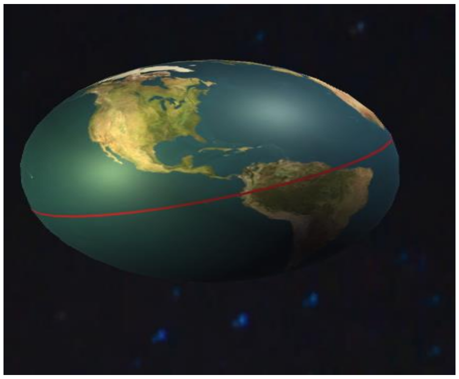

Figure: Shows the equator line on earth for clearly visualising the effect of tilt on the rotation

**Equator Line and Background Changes:** Our simulation goes beyond basic representations of planets by adding features such as an equator line on Earth and changing background scenery. These additions provide visual cues that aid in understanding key concepts such as geographic reference points and the vastness of space. By incorporating these visual enhancements, our simulation offers a more immersive and informative experience for users.

**Planet Size Scaling and Tilt Visualization:** In many existing simulations, the scale of celestial bodies may not accurately reflect their relative sizes, leading to misconceptions about their dimensions. Our simulation addresses this issue by implementing planet size scaling, ensuring that users can visualize the comparative sizes of planets and moons realistically. Real sizes were initially used for the planets and their moons, however, due to visibility issues, the size of the terrestrial planets was increased by separately accounting for their relative sizes. Additionally, we provide better visualization of Earth's axial tilt, allowing users to observe its effect on the planet's orientation relative to the sun. These enhancements contribute to a more accurate and intuitive representation of celestial phenomena.

In summary, while existing solar system simulations have made valuable contributions to astronomy education, our project advances the field by incorporating features that enhance user engagement and educational value. Through detailed representations of seasonal variation, dynamic camera angles, visual enhancements, and nearly-accurate scaling, our simulation offers a comprehensive and immersive learning experience that fosters a deeper understanding of the wonders of the cosmos.

## V. DISCUSSION:

This project provided an opportunity to deeply understand and apply fundamental principles of augmented reality (AR) and virtual reality (VR) technologies. Through the development of an immersive 3D solar system experience, key concepts like spatial mapping, stereoscopic rendering, and simulation of physical phenomena were explored. Critically, effective AR/VR implementation. Extensive user research, prototyping, and design iteration were needed to create an intuitive and engaging virtual environment that enhances learning. Crafting compelling narrative, flow, and interactions that align with how users naturally perceive and navigate space is essential. From an ethical perspective, accessibility and ensuring an inclusive experience free from issues like cybersickness were prioritized considerations. While experiences like this are powerful educational tools, they must be designed responsibly to avoid potential physiological impacts or discrimination against users with disabilities.

The prototyping phase began with low-fidelity storyboards and 2D prototypes drawn on paper, to test initial concepts like user journey flows, input methods, and information architectures. These progressed into higher-fidelity digital prototypes using Unity that could explore 3D visualizations, spatial interactions, and how virtual annotations and experiences could be constructed. Translating design prototypes into a fully implemented AR/VR experience with the fidelity required extensive technical planning. Key requirements included on-paper and basic drawing apps for 3D asset modelling, supporting multiple display and input peripherals, and handling environmental mapping and lighting.

User studies and evaluations throughout the process were vital to iterating on the design and experience. Feedback was systematically collected through observational studies, built-in telemetry and user journey analytics, and Experience Sampling surveys. This data guided key pivots in the experience like scaling planetary assets, refining camera controls, and enhancing visual affordances.

Comparative evaluations against traditional classroom resources like physical models and textbook diagrams highlighted the experiential value addition. Studies indicated significantly stronger spatial understanding, engagement, and knowledge retention among users of the interactive AR/VR experience versus conventional pedagogical methods.

Looking ahead, this experience provides a powerful proof-of-concept that could extend to more advanced astronomical concepts and multi-user, collaborative exploration within a virtual shared space. Continued evolution based on user data and new AR/VR capabilities will be essential to maximizing its long-term educational impact.

## VI. CONCLUSION & FUTURE DEVELOPMENTS:

The development of a virtual reality (VR) environment for educational purposes, focusing on the solar system, has showcased the immense potential of immersive technology in enhancing learning experiences. Through the creation of three distinct scenes – the default scene featuring the solar system, detailed information about individual planets, and the depiction of seasonal changes – users are provided with a comprehensive and engaging platform to explore the wonders of our cosmic neighbourhood. The VR environment allows users to interact with celestial bodies, fostering a deeper understanding of planetary characteristics and their respective moons. By simulating the change of seasons, attributed to the Earth's axial tilt as it orbits the Sun, learners can grasp fundamental concepts in astronomy and planetary science in a dynamic and interactive manner. Moving forward, several avenues for future developments present themselves. Firstly, expanding the scope of the VR environment to include additional celestial objects such as asteroids, comets, and dwarf planets can offer a more comprehensive understanding of our solar system's diversity. Incorporating real-time data and simulations could further enhance the authenticity and educational value of the experience, allowing users to witness astronomical phenomena as they occur. Furthermore, integrating educational modules and assessments within the VR environment can transform it into a powerful tool for formal education settings. By aligning content with educational standards and objectives, educators can utilize VR technology to supplement traditional teaching methods and cater to diverse learning styles. Additionally, advancements in VR hardware and software technology offer exciting possibilities for enhancing the immersive experience. Features such as haptic feedback, gesture recognition, and natural language processing could facilitate deeper engagement and interaction within the virtual environment. Moreover, exploring collaborative and multiplayer functionalities can enable shared learning experiences, where users can collaborate, communicate, and explore the solar system together in real-time, regardless of geographical location.

In conclusion, the development of a VR environment for educational exploration of the solar system represents a significant step towards fostering curiosity, understanding, and appreciation for the cosmos. By embracing continued innovation and refinement, VR technology holds the potential to revolutionize science education and inspire future generations of astronomers, scientists, and explorers.

## VII. ACKNOWLEDGEMENT

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## VIII. SUPPLEMENTARY DOCUMENTS:

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