Simulation of Solar System using Augmented Reality

By

Muhammad Nasiruddin Bin Mohd Kamal

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Technology (Hons)
(Information Systems)

May 2012

UniversitiTeknologi PETRONAS

Bandar Sri Iskandar

31750 Tronoh

Perak DarulRidzuan

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMMAD NASIRUDDIN MOHD KAMAL

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Information & Communication Technology Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
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(INFORMATION & COMMUNICATION TECHNOLOGY)

Approved by,

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(NAZLEENI SAMIHA BT HARON)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2012

ABSTRACT

The use of visual aids in learning process has been proven to be very useful and effective in helping the students understand and memorise the topic that learned. Most of the topics learned by the students in Science subject are most affected by the help of visual aids including the topic about the Solar System. However, the existing learning aids for the Solar System topics has many limitations that hindered the students from understanding the lesson better such as still images, only in 2D visualisations and so on. The main objective of this project is to produce an accurate simulation of the solar system using the augmented technology environment. Augmented reality is used to superimpose digitally a computer generated graphics, images or animations onto the real world environment. With augmented reality technology, the simulation can be projected in 3D visualization and by implementing animations in the simulation, the students can see for themselves the actual movements and rotations of the planets in the solar system. Moreover, the students are able to manipulate the camera position in order to view the simulation from various angles. With the simulation, the student can learn, understand, and memorise the topic easily and interactively.

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Chapter 1: PROJECT BACKGROUND

1.1 Introduction

Science is one of the subjects that are compulsory for students to be learned in their school studies. For primary education purposes, the field of biology, physics, chemistry as well as astronomy, are included in Science subjects. The students will learn about the living things, matters, substances, and also the solar system throughout their years in school via Science subject. The learning of these important facts are usually hard for the students to fully understands the information, thus, many types of learning method have been use in order to help the students. This is because, some of the lesson that the student learn requires them to imagine by themselves as they cannot see the message that been taught to them. One of those topics is the solar system. The students are required to imagine by themselves about as they are no possible way for them to observe the real solar system physically. Therefore, many forms of visual aids have been developed in order to help them understand the solar system much better such as models, graphic images and videos.

However, these visual aids have their limitations. For example, most physical models are usually been built inaccurately in terms of the sizes, colours and their physical positioning. The images provided in the book are still images and only can be shown in 2D. Most animation or videos about the solar system able to project the visual reality of the planets but the students are always to distracted by the images and unable learn the details of about the images as they are always presented in audio. Moreover, as the technology enhanced, the students nowadays becomes easily bored with the available visual aids thus, making it hard for them to learn even with such visual aids.

Figure 1:A model of solar system

With the advancement of today technology, augmented reality offers a new method of learning to all students. With augmented reality, the students will be able to see the 3D images of the lesson that they learned which also includes animation or movement. Augmented technology has the ability to present any images that the usual visual aids can but with much more enhancement. As the implementation of augmented reality in education is not that wide, it still seems to be a new technology to most students. With a simulation using augmented technology, the students will more interest and enjoy learning about the solar system which helps them to understand much better. The eagerness of the students will be triggered not only by the interactive visuals but also the sophistication of the equipment.

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1.2 Problem Statement

In Science syllabus for year 4 students in Malaysia, the students will learn about the solar system. The students will study structure of the solar system including the characteristics of each planet in the system such as earth. Currently, they refer to the textbooks to learn about the solar system. The textbook currently only provide a 2D graphic images and text explanations for the students to understand. The students have a difficult time to fully understand and memorize the topic as they cannot see the actual structure of the solar system in 3D. The current visual aids caused a lot of confusion to the students as they need to imagine on their own about the actual solar system.

1.3 Objectives

- To develop a solar system visual simulation as visual aids in school education.
- To implement augmented reality technology in the simulation.

1.4 Scope of Study

- Augmented Reality

  Augmented reality is a live, direct or indirect, view of computer generated images which appear to be seen among the real-world environment. Augmented reality is viewed as advancement in virtual reality field. With augmented reality a digitally created images will appeared to be existed in real environment. Augmented reality also allows users to enhance the experience of real objects. For example, while browsing a magazine, an augmented reality application can be used to generate a "buy now" button just by capturing the image of the magazine with their phone's camera. Augmented reality allows the users to manipulate these computer generated object in a way that it seems to be in real-world environment or even based on a real-world object.

- Solar System

  In primary education syllabus in Malaysia, the student will learn about the solar system in Science subject during their fourth year or standard 4. In the syllabus, the student will learn the basics knowledge on the topic such as the components of the solar system, the positions of the planets and physical characteristics of each planet. The solar system consist of a star, the Sun, and eight planets that orbiting the Sun. The eight planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. These planets are orbiting around the Sun and rotating on their own axis at different speeds.

Chapter 2: LITERATURE REVIEW

2.1 Visual Aids in Education

Many researcherssuggested that by using visual aids, the learning process become more effective(Chanlin, 1997). The use of visual aids to enhance verbal learning is necessary(Flattley, 1998). This is because the visual literacy, which visual aids stimulates, is precedes the verbal literacy in human development as it is the most basic form of thinking process. In any human child development, the child learns by seeing with the eyes first before learning words (Berger, 1972).

2.2 Augmented Reality and Education

Augmented reality is a visualization technology which extends to beyond the limitations that other visual media have. Augmented reality allows the students to control the visualization of the topics which they can see all the elements from any angle. Although there are already 3D simulations available for educations purposes these simulations are still create a cognitive filter as the manipulations of these 3D objects can only be done via mouse clicks. The possibility of manipulating the objects physically will give a more direct cognitive way of learning the content which helps the students to understand much better(Shelton, 2002).

2.3 Application of Augmented Reality in Education

There are several topics have been researched and developed using augmented reality and create visual simulations for educational purposes. One of them is the visualization of the concepts involving the seasonal changes with the light and temperature also known as “earth-sun relationships”. The simulation works by showing a virtual sun and earth that can be manipulated using a small hand-held platform. The student can view the simulations from any angles so that they can understand better.

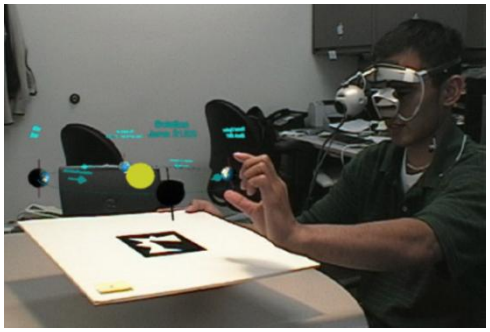


Figure 2: AR simulation of earth-sun relationship.

Other than astronomy, biology is also a field which can benefits from augmented reality technology. The HITLab has initiated a research project which developed a simulation of molecular biology. This project, which is in conjunction with the Scripps Research Institute and the University of Utah, allow the teacher and students to experiment with various kinds of 3D molecular models. Due to the positive feedback received, a high school in Seattle agrees to implement augmented reality in the teaching for biology and chemistry subject(Shelton, 2002). Augmented reality can be used to develop an indoor navigation system by superimposed a 3D image of directional signage (Huey, 2011).Solar system magic book consist of basics information, facts and characteristics of the planets in the solar system(Slijepcevic & Huang, 2012).

Figure 3: Solar System AR Magic Book

2.4 ARtoolkit

ARtoolkit is an open source software library for developing AR applications. It was initially developed by Dr.Hirokazu Kato and the project was supported by several entities such as Human Interface Technology Laboratory (HIT Lab) at University of Washington, Hit Lab NZ at University of Canterbury, New Zealand and ARToolworks, Inc. Seattle (Lamb). The advantage of ARtoolkit is that it is able to real-time track the view point of the user accurately. The software used computer vision techniques to calculate the camera position and orientation relative to the marker orientation so that the virtual object that rendered on top of the marker appears will always be aligned with the marker. The rendering from ARtoolkit provides smooth animation of 3D object. First a frame from the video stream is grabbed from the web cam. The image will be converted into binary image (black and white) based on the threshold value which is the technique of binarization and thresholding(Huey, 2011).

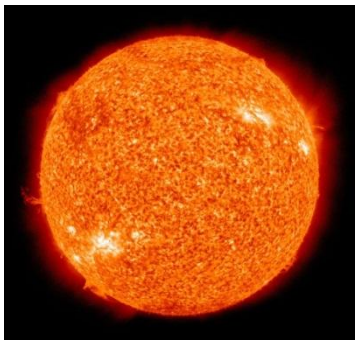
2.5 OpenGL

OpenGL is a cross platform application programming interface that is considered today as an industry standard. OpenGL was developed with the objective of to provide access to the graphics hardware abilities at the lowest level that still not depends on the hardware(Rost, 2004).

2.6 Solar System

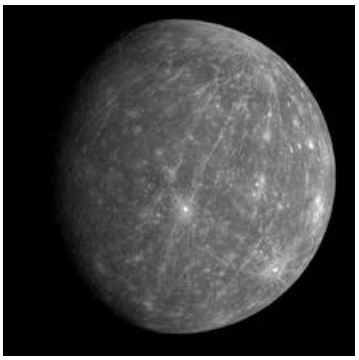
According to NASA website, the solar system consists of the Sun and the some other astronomical objects such as planets and moons that bound by the Sun gravitational force in the orbit around it. The most basic knowledge about solar system is regarding the Sun and the planets in which are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

The Sun



The Sun is the star and the center of the solar system. With 1.392×10^6 km diameter, which is approximately 109 times of Earth's diameter, the sun is the biggest component in the solar system. It rotates at a velocity of 7.189×10^3 km/h.

Mercury



Mercury is the planet closest to the Sun. It has a mean radius that is 0.03829 times the Earth which is equivalent to 2440 km. It is also the smallest planet in the solar system. It takes 88 days to complete one circulation around the Sun. Mercury also takes 59 days to complete one rotation on its axis.

Venus

Venus is the second planet closest to the Sun, after Mercury. It has the closest size to the Earth with mean radius of 6052 km which is 0.9499 times of Earth's mean radius. Venus ranks 6^{th} biggest planet. Venus takes 42 days to make a complete rotation on its axis in clock wise-direction and takes 224.7 days to orbit the Sun.

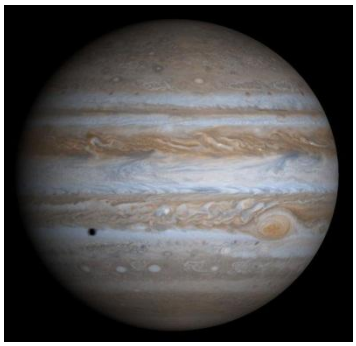
Earth

Earth the third planet from the Sun. It is also the only known planet in the solar system that contains living organics. The Earth's mean radius is 6378 km and circumference of 40.075.017 km which makes it the 5th biggest planets in solar system. The Earth completes a single rotation on its axis in 24 hours or 1 day. Earth takes 365.25 days to complete orbiting the Sun.

Mars

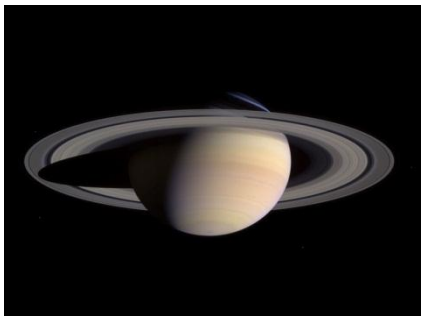
Mars is positioned fourth from the Sun next after Earth. With a mean radius of 3397 km which is 0.533 times the Earth. Mars is the second smallest planet among solar system. Mars takes 24.7 hours to make one rotation on its axis. It surrounds the Sun on its orbit within 687 days.

Jupiter



The Jupiter is the 5th planet in the solar system. It is also the biggest one with a mean radius of 69911 km, 10.961 times the Earth. Jupiter takes only 9 hours and 50 minutes to complete a rotation on its axis which is the fastest one among the planets in the solar system. It also takes 11.86 years to orbit the Sun.

Saturn

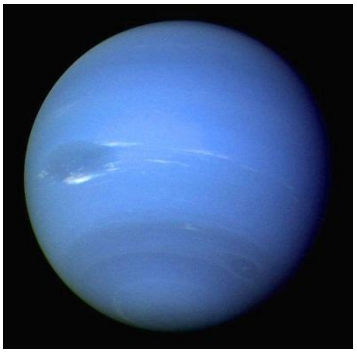


Saturn is the 6th planet from the Sun. It has a mean radius of 60268 km, 9.4492 of the Earth, which makes it the second biggest planet in the solar system. Saturn takes about 10 hours and 39 minutes to complete a single rotation on its axis and takes orbits the sun once every 29 days.

Uranus

This 7th planet from the Sun is also the third largest planets in size. Saturn's mean radius is 4.007 times the Earth which is 25559 km. To complete a rotation on its sides, Uranus takes about 17 hours and 14 minutes. Uranus revolves around the Sun once every 84 years.

Neptune



Neptune is the 8th and farthest planet from the Sun. With a radius of 24764 km, which is 3.883 times the Earth, Neptune is the 4th largest planet in the solar system. Neptune takes 18 hours to rotate once on its axis. It also completes one circulation around the Sun in 164.79 years.

Chapter 3: METHODOLOGY

3.1 Research Methodology

The development of the simulation will be based on the following cycle:

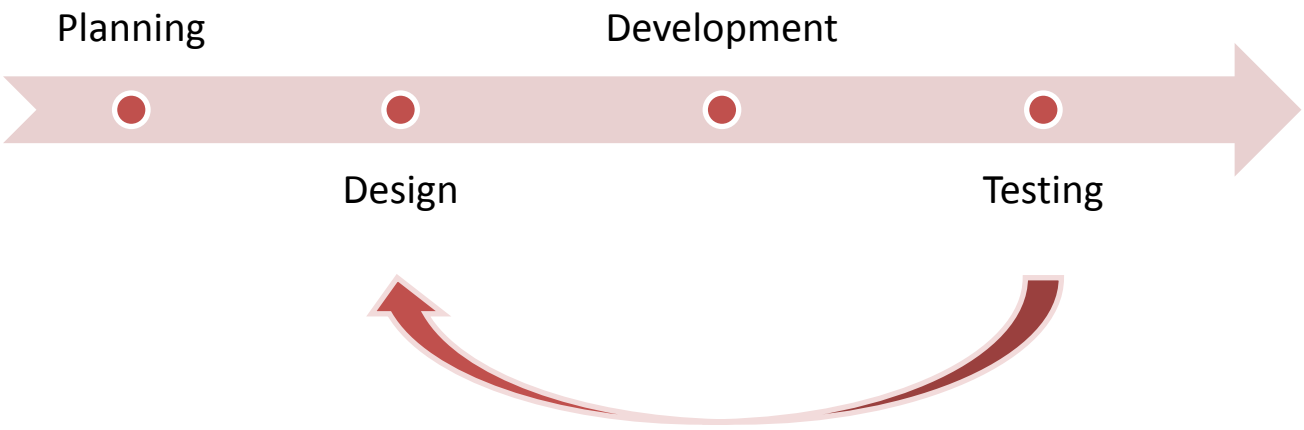


Figure 4: Project Development Cycle

3.1.1 Planning Phase

In the planning phase, a research is conducted on the technology of augmented reality itself in order to determine either the technology is feasible for the project. During researching, various softwares are surveyed and evaluated to find most suitable to be used. The software should be free or opensource software. The advantages and weaknesses of each one is considered during the evaluations. In the end, ARtoolkitis chosen as it is opensource software and one of the simplest augmented reality software to be used by a beginner.

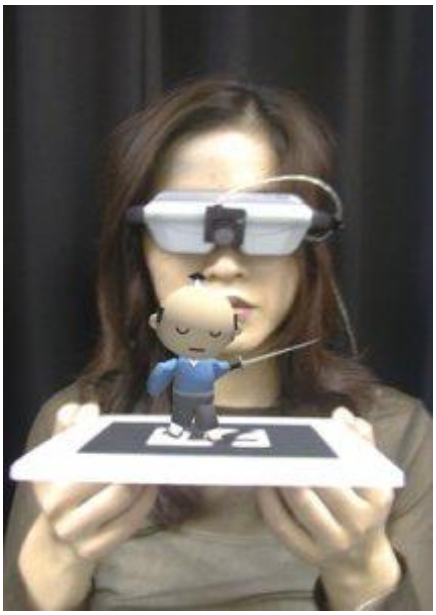


Figure 5: Example of project using ARtoolkit

Besides that, a group of 15 primary schools students are chosen and are given a quiz on solar system topic. The students are given various kinds of learning aids such as models, videos and books to help them learn about the topic. After that, the students are required to answer the quiz given to them where they are required to label several elements of solar system such as the planets. This is done in other to identify the effectiveness of the existent learning aids.

3.1.2 Design Phase

During the design phase, an extensive research on the solar system is conducted. All the information about each planet in the solar system such as sizes, physical looks, rotations, position, and so on are gathered as these details are important in order to ensure the outcome of the simulation will be an accurate representation of the real solar system. The simulation must be able to show the position of all planets in the solar system, the rotation of each planet, how the planets circulates the sun on their orbit and the different in sizes, colour and textures of each planets. Besides that, a sketch of each planetis drawn as the outlines for the simulation. The sketch shows the images of the planets, their position on their axis and also their rotations direction.

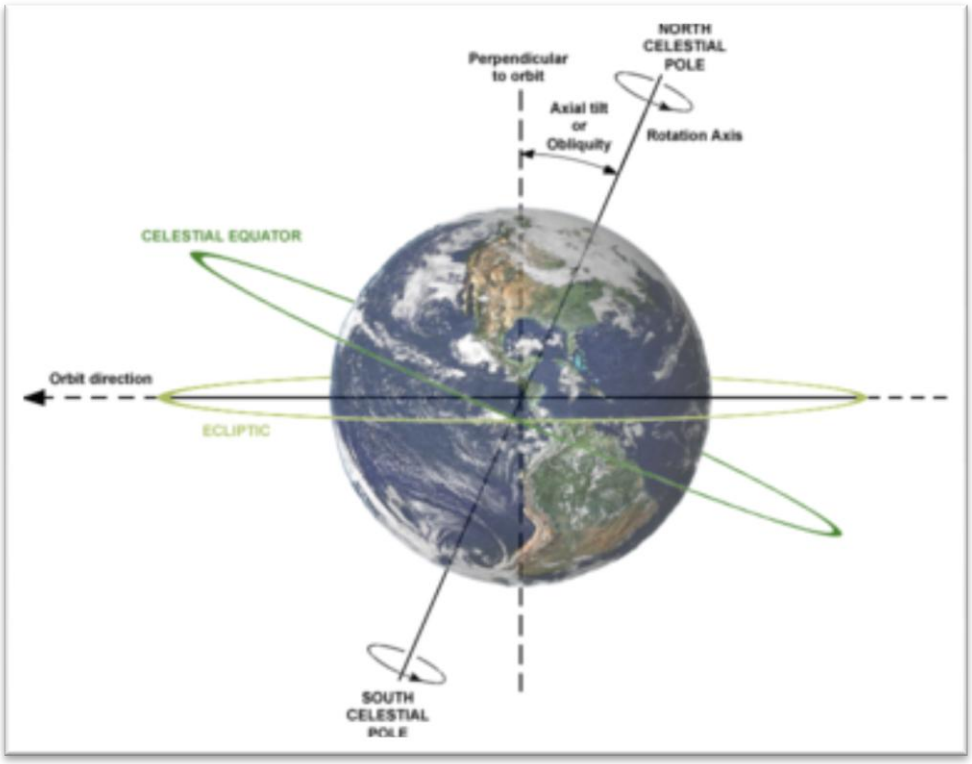


Figure 6: The sketch for the simulation oh Earth

The position of all the components in the solar system in order to determine the position of markers involved. The sketch shows the positions of the planets and also the shape and size of their orbits.

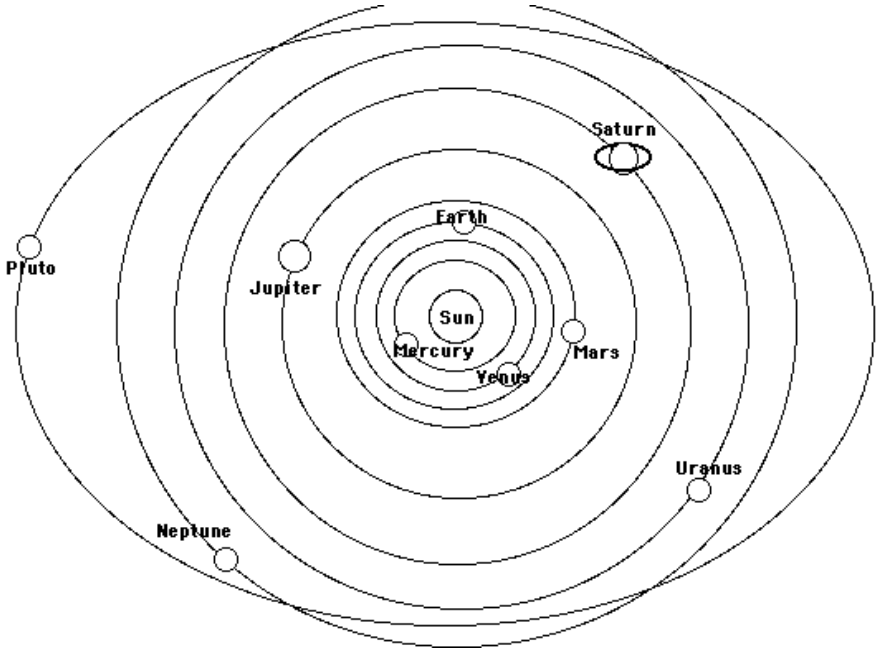


Figure 7:Basic sketch of Solar System

3.1.3 Development Phase

In the development phase, the images of the planes and the Sun are created using OpenGL technology. The images represent the actual physical visual of all the planets in terms of the colours, the shapes, the textures and also other physical characteristics. Then, the animations of the rotations and movements of the planets is added into the graphics. After creating the animations, the markers for each component of the solar system are produced for the implementation of augmented reality in the testing phase. Each planet and also the Sun will have their own markers for the moment in order to ensure that the animations can be seen when the augmented reality projection is used. During this phase, any bugs and problems for the animation itself are identified and fixes before proceeding with the implementation of augmented reality in testing phase.

Figure 8: Example of images and markers for the simulation

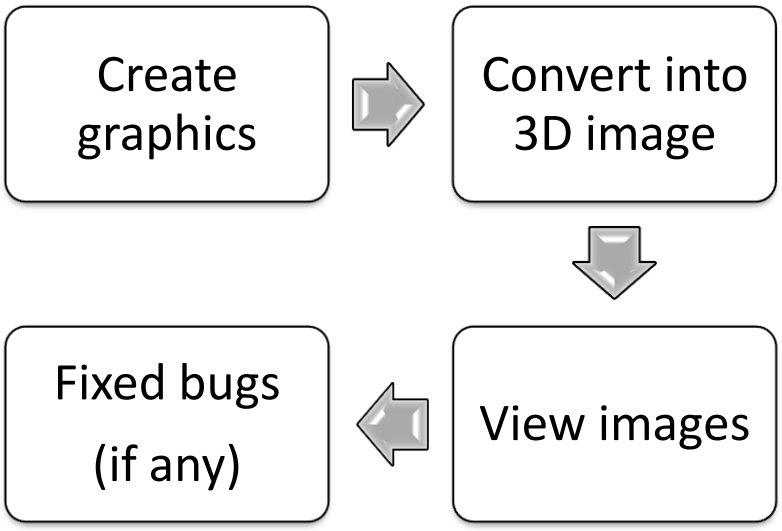


Figure 9: Framework for development phase

3.1.4 Testing Phase

In testing phase, the augmented reality simulations will be created using the graphics, animations and markers generated in the development phase. In this phase, all of those components will be assemble and view into the augmented reality environment using a video capturing tool such as a webcam and rendered in a computer to be viewed as an augmented reality simulations. The simulations also will be test to ensure that the outcome is an accurate representation of the real Solar System. The positions of the planets and the Sun, the rotation of the planets on their axis, and also the movement of the planets around the Sun will be viewed and corrected if wrong. Any bug or problems for the augmented reality implementation process and viewing will be identified and fixed in the testing phase so that the final output will be an accurate and interactive simulation of the Solar System.

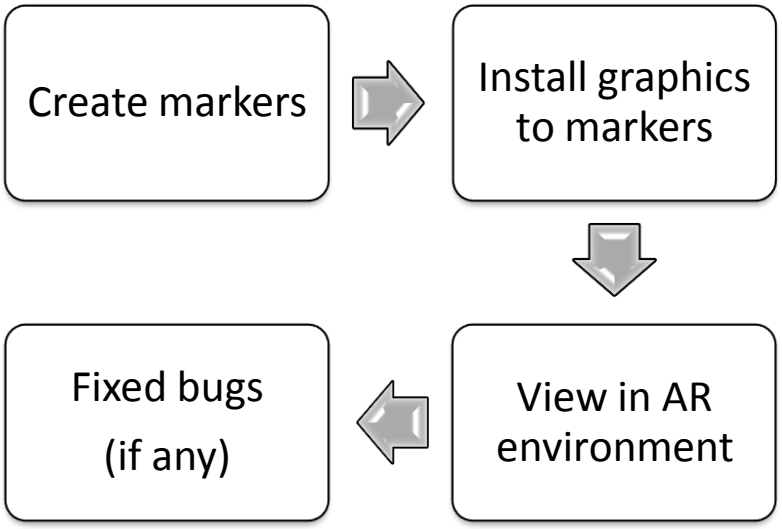


Figure 10: Framework for Testing Phase

3.2 Key Milestones

Final Year Project 1 (May 2012)

- Proposed Project Title : Week 2
- Submission of Extended Proposal : Week 6
- Proposal Defence : Week 8 and 9
- Submission of Interim Report : Week 11

Final Year Project 2 (Sept 2012)

- Progress Report Submission : Week 4
- Dissertation Submission : Week 11
- Pre-EDX Presentation : Week 11
- Viva Presentation : Week 12
- Final Dissertation Submission : Week 14

3.3 Gantt Chart

Month	May 2012	Jun 2012	Jul 2012	Aug 2012	Sept 2012	Oct 2012	Nov 2012	Dec 2012
Title Selection								
Title Proposal Submission		6 Jun						
Extended Proposal Submission		27 Jun						
Proposal Defense			18 Jul					
Interim Report Submission				1 Aug				
Progress Report Submission						10 Oct		
Dissertation Submission							26 Nov	
Pre-EDX Presentation							28 Nov	
Viva Presentation								5 Dec
Final Dissertation Submission								19 Dec
Planning								
Design								
Development								
Testing								

Table 1: Gantt Chart for Final Year Project

3.4 Tools Required

- ARToolkit
- OpenGL
- AR Markers
- Webcam
- BuildAR Viewer

Chapter 4: RESULTS

A group of 15 primary school students are asked to answer a quiz which they need to names some of the elements in solar system and name the learning aids that are involve during the learning process. The following table shows the results of the survey:

Learning Aids	Average Marks (/8)	Highest Marks (/8)
Teacher	4	5
Text Book	3	4
Picture Book	5	5
Models	4	5
Videos	6	6

Table 2: Initial Questionnaire Results

Based on the results, the learning aids that existed currently are not able to help the students to fully understand and memorise about the Solar System. As

After the prototype of the simulation is completed, the same groups of 15 students that are chosen for during the initial survey were asked to use the simulations and then answer the similar questionnaire. The following table shows the outcomes of the questionnaire compared to the initial results.

Learning Aids	Average Marks (/8)	Highest Marks (/8)
Teacher	4	5
Text Book	3	4
Picture Book	5	5
Models	4	5
Videos	6	6
AR Simulation	7	8

Table 3: Final Questionnaire Results

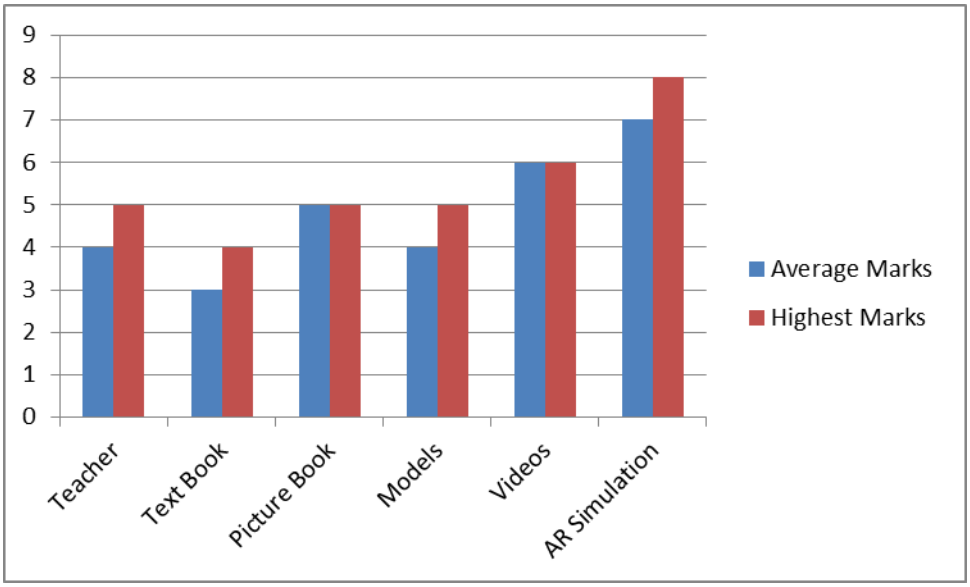


Figure 11: Graph of the Questionnaire Results

Based on the results, the students the highest marks that the students are able to obtain is 8 marks which is the full marks. They are able to answer all questions correctly after viewing the AR simulation prototype. This shows that the AR simulation is an effective learning aid that helps the students to understand and memorise the topic better than the other learning aids.

CONCLUSIONS

The simulation of solar system using augmented reality technology cab helps the students of science subject to understand the topic much more effective. The simulations conveyed the information in an interactive and entertaining way which will trigger the interest of the students to learn. The students will be able to understand and memorise the information through the simulation as they enjoyed the learning process. The proposed simulation will be a very useful visual aid for teaching purposes that not only to help the students learn, but also to keep their interests and attentions. There are still room of improvements for the simulations in terms of developing a more affordable and simple devices to be used in schools. For future enhancement, the simulation can be improved by including more information besides only the elements of solar system. Other information may be included in the simulation such as regarding the seasonal changes, the eclipses and moon phase.

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APPENDICES

Questionnaire

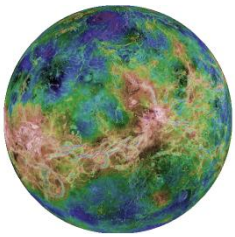
Name:

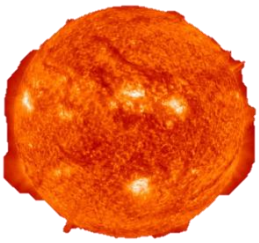
Standard:

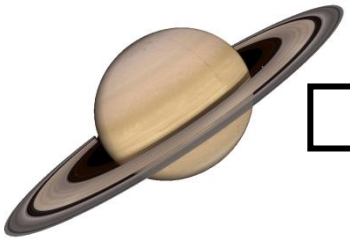
Which learning aids did you used (choose one)?

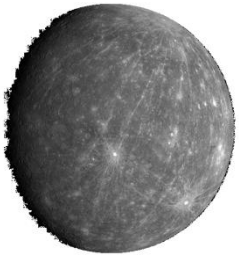
a) Teacher
b) Text book
c) Picture book
d) Models
e) Videos
f) AR simulations

Name these elements of solar system correctly:

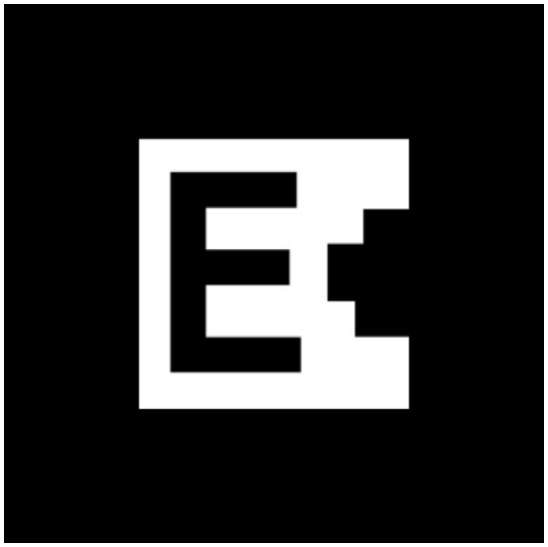


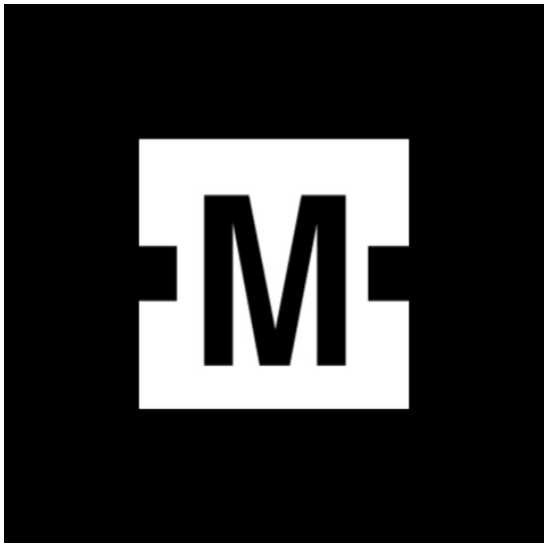






Markers



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Images

Figure 12: Earth simulation image

Figure 13: Jupiter Simulation Images

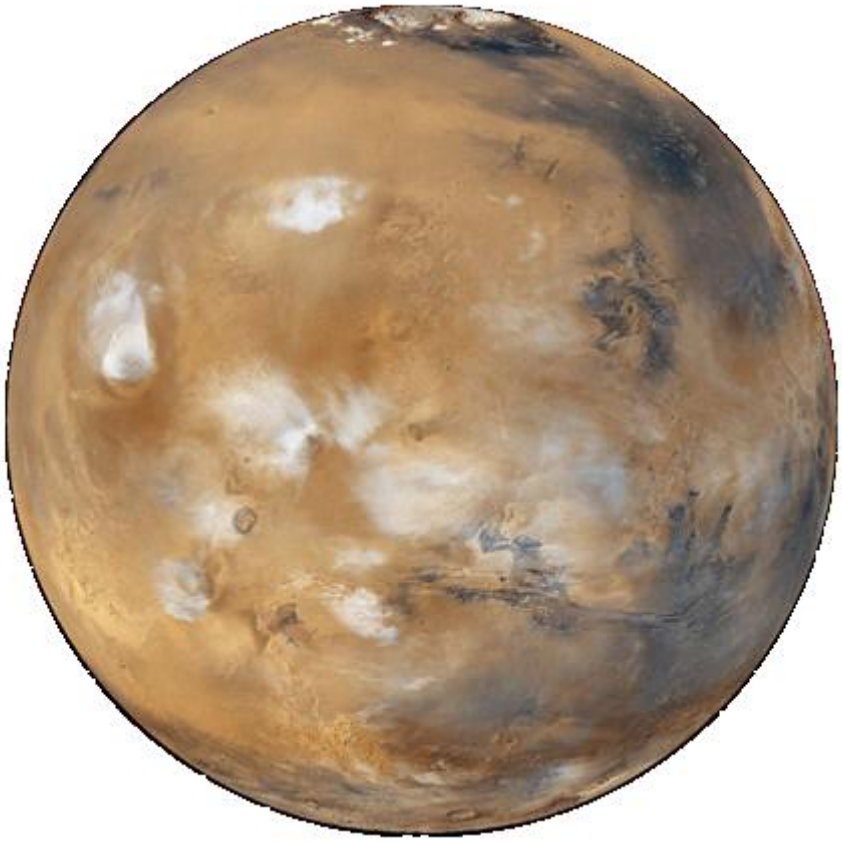

Figure 14: Mars Simulation Image

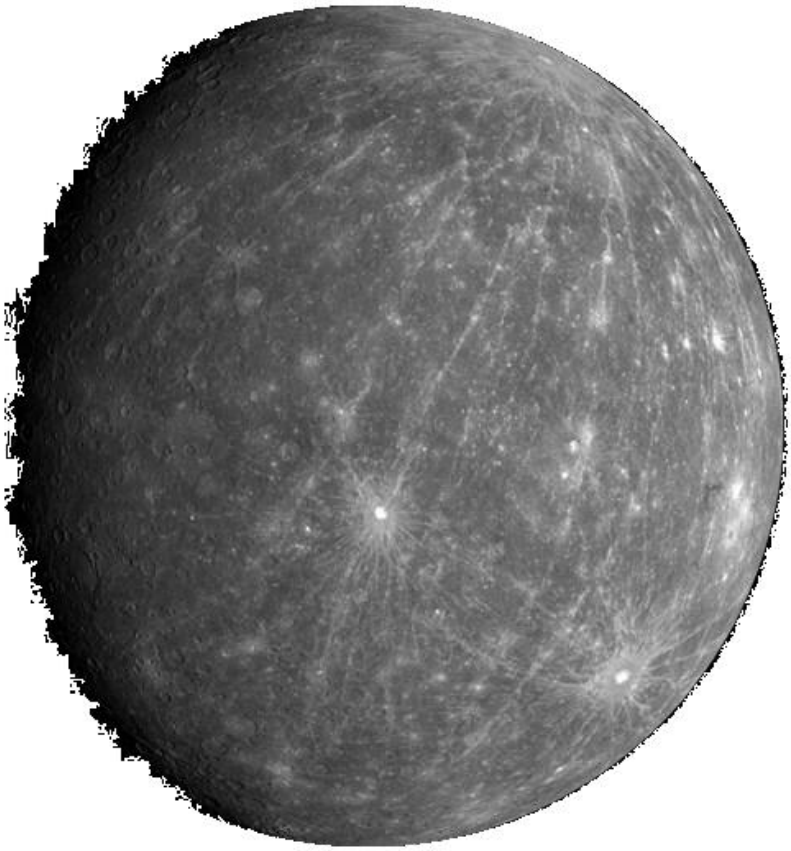

Figure 15: Mercury Simulation Image

Figure 16: Neptune Simulation Image

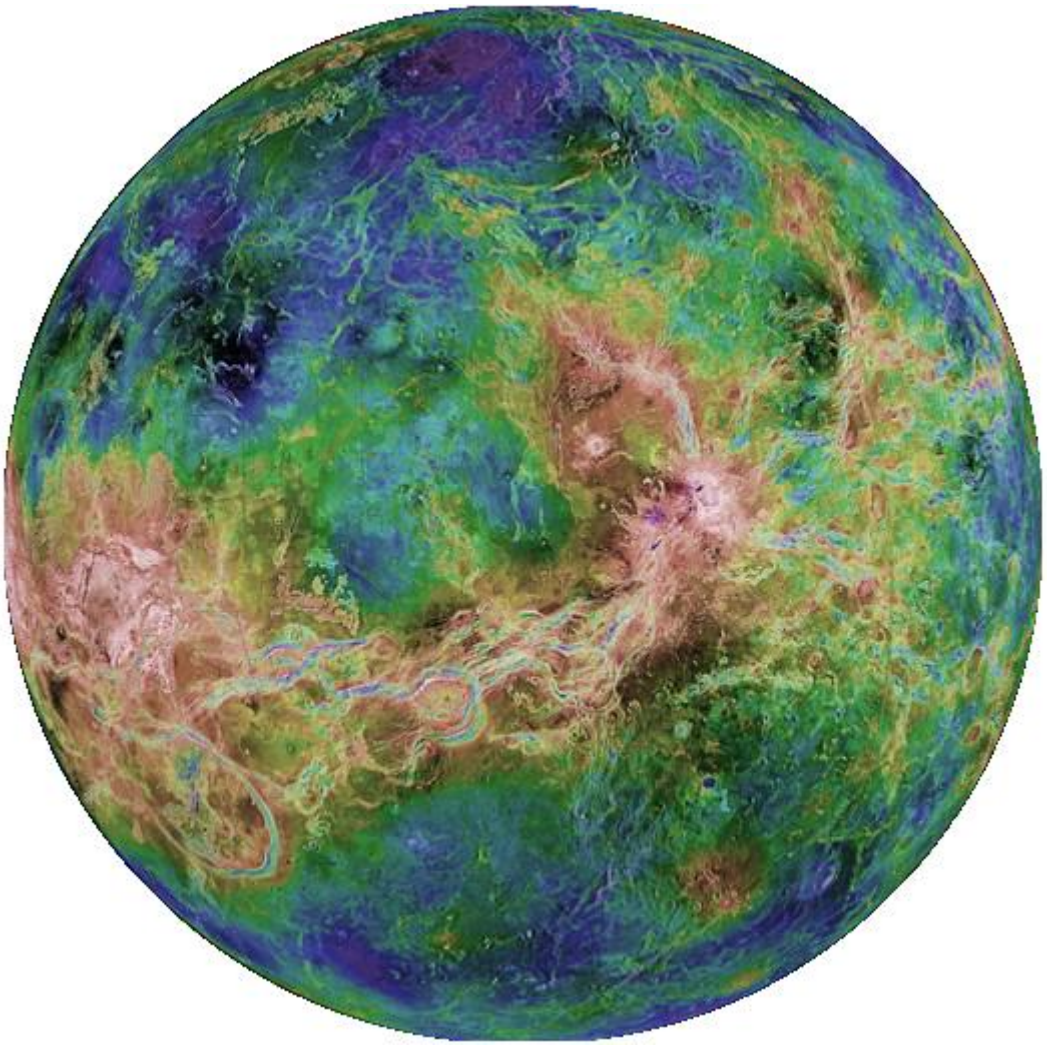

Figure 17: Venus Simulation Image

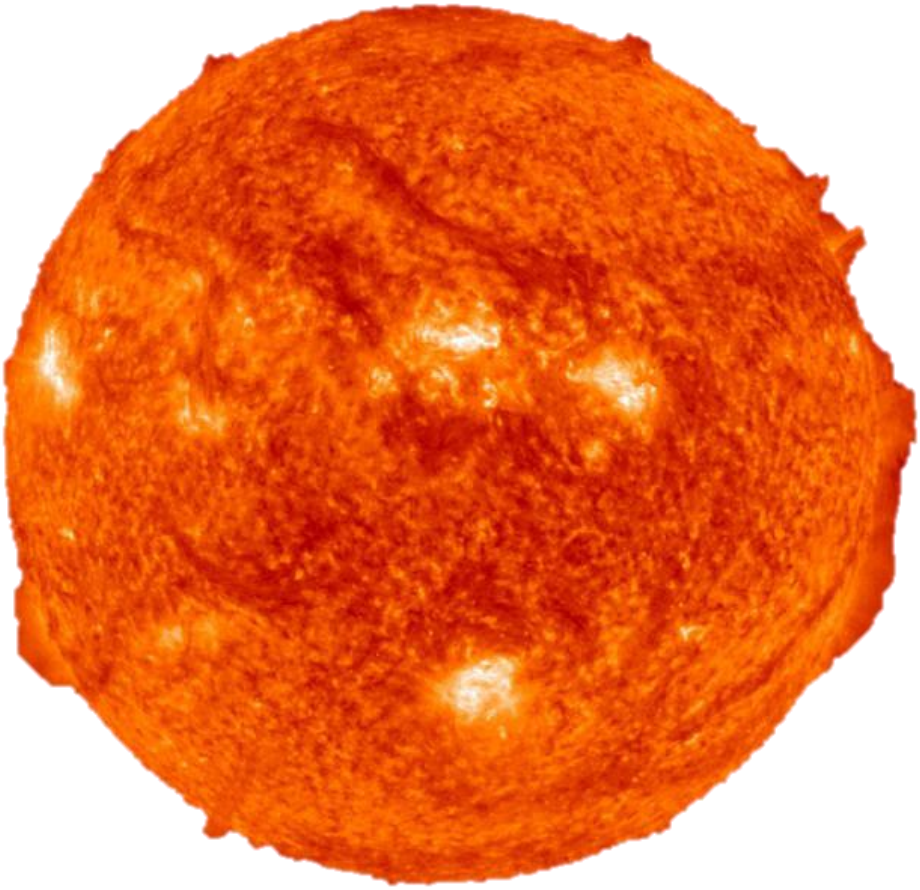

Figure 18: Sun Simulation Image

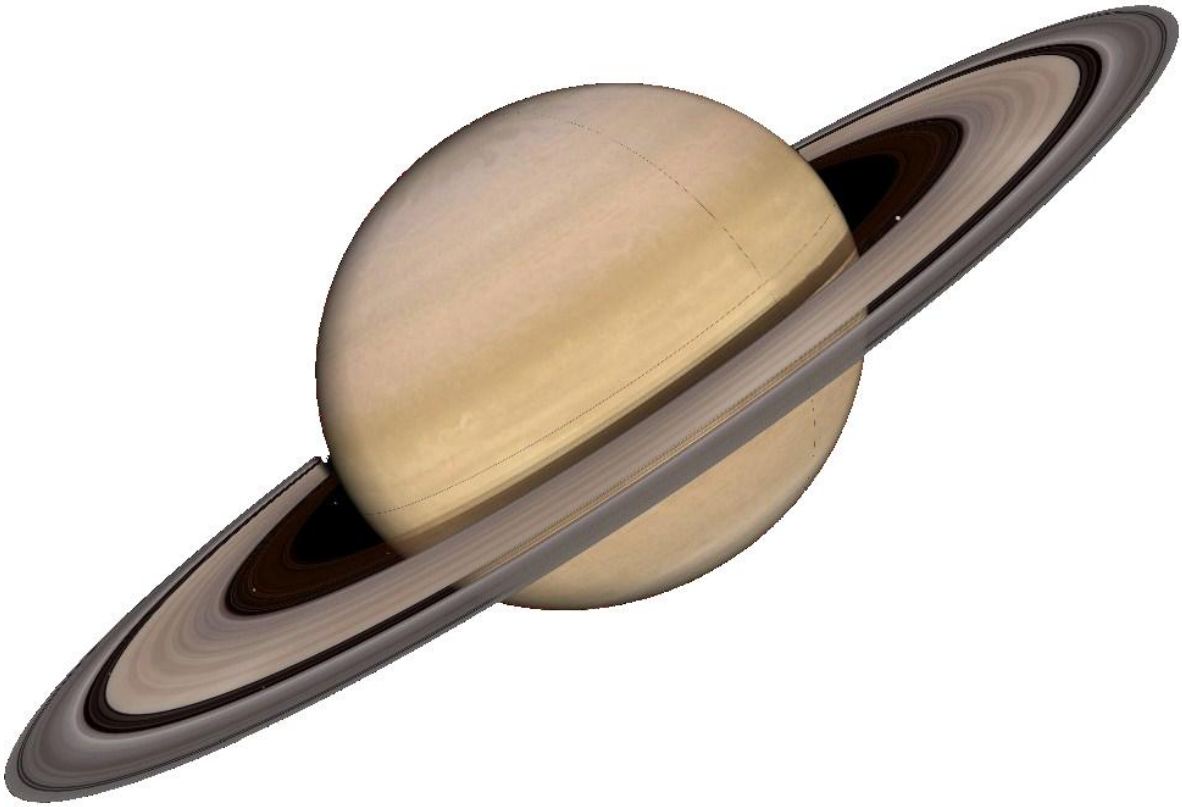

Figure 19: Saturn Simulation Image