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A CONCEPTUAL PERSPECTIVE IN MATHEMATICS THROUGH AUGMENTED REALITY AND 3D IMAGE MODELLING APPLICATION

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Abstract

Mathematics is a compulsory subject for every student in primary, secondary school and pre-university program. However, most of the teachers found that it is very difficult to teach the students because most of the mathematics concepts especially complex mathematics equations require students to have good imagination for better understanding. Therefore, the teachers always ask the students to memorize the equations or formula instead of asking them to try to understand the concepts. So, majority of students find the mathematics class very tedious and useless because they don't know when they are going to apply the concepts in real-life. As we know, majority of students suffer in understanding the complex mathematics operations for example, differentiation, integration and others during secondary school and pre-university program. Therefore, a mobile application that applying augmented reality to teach complex mathematics concepts is proposed to address this problem. Teachers can utilize this app to give students some real-life examples that they can relate to according to the list of equations available in the application. Therefore, students will find that mathematics class very interesting if teachers implement the right techniques and make it more engaging.

Keywords: Augmented Reality, complex mathematics operations, 3D modelling, mobile application.

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1. Introduction

Mathematics - a compulsory subject for every student in primary, secondary and pre-university program. Learning mathematics is very important in our lives because it able to nurture our power of reasoning, creativity, abstract or spatial thinking, critical thinking, problem solving ability and even effective communication skills (The Important of Maths in Everyday Life, 2015). However, most of the students found that mathematics class is very boring and stressful. Some of students even phobia to mathematics as they move on to the higher class when they need to memorise the formula or equation through abundant of exercises. Therefore, the students can't get the importance and practical application of the mathematics concept especially the complex mathematics operations and they are forced to learn and master it, so they could start to dislike mathematics.

Augmented Reality (AR) is a technology that takes the world around you and adds virtual content on top such that it looks like it's there in the real world (Zappar, 2018). The complex mathematics operations that are involved in this project are first order differentiation and second order differentiation. This application can help the teachers to give real-life examples to their students when they are explaining the mathematics concept. Teachers can select one equation from the list of the equations available and use the camera to scan a real 3D object from their surrounding environment. The AR activity of the scanned object will be triggered. An answer also will be generated based on selected equation, scanned object and the value of dimensions that entered by the teachers. A visualization of the result also will be displayed after applying the selected equation.

There are few existing applications in the market (i.e. applications on Google Play) which also focusing on teaching calculus for example Calculus Pro (2009) and *Calculus Course Assistant*. *Calculus Pro* is a mobile application that contains a set of calculus topics in the form of examples, tutorials and solvers. Calculus Course Assistant (2018) is a mobile application that helps the student to solve calculus problem by providing the step-by-step guidance. However, they only providing the explanation in text form. Therefore, the aim of this project is to provide an engaging, meaningful and technological way in real-time environment for the teachers to teach mathematics.

2. Problem Statement

The current existing applications that teaching mathematics using AR are relying on 2D flashcards to activate the augmented reality activity. Some applications for example *Aug That!* require specific target images to use the applications (Aug That, 2015). Therefore, the applications can't be used anymore if the flashcards/ target images are lost or damaged. Besides, the current applications also don't allow the teachers to utilize the surrounding 3D objects to make the class become more interactive as the information is not available in the database. They also mostly are focusing on teaching simple mathematics concepts to early learners instead of high school students. Besides, most of the calculus learning app also focusing on providing the explanation in text form without any animation and audio. So, it makes the students feel boring and not interested in using the app for their learning.

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3. Research Questions

Two research question were formed based on the research statement discussed above:

1) What are the suitable technologies involved in AR application for mathematics teaching?
2) How can this technology help to increase the enjoyment in teaching and learning mathematics?

4. Purpose of the Study

The objectives of the system are to apply object detection and do model target for AR application, to develop an interactive application for mathematics teaching and learning with AR technology, and to demonstrate the 3D visualization of real objects from selected mathematics equations.

5. Research Methods

An Augmented Reality (AR) app is proposed to solve the problem. The user can select one equation from the list of equations. Then, the user can use the camera to scan the real 3D object. A brief visualization of the equation on the scanned object with explanation will be displayed using AR. The app will calculate the answer according to the object, selected equation and the value of dimensions that entered by teachers. A detailed visualization of the objects with explanation will be displayed after calculation is performed. The application is divided into three modules and each module is defined by the use case accordingly (Figure 01).

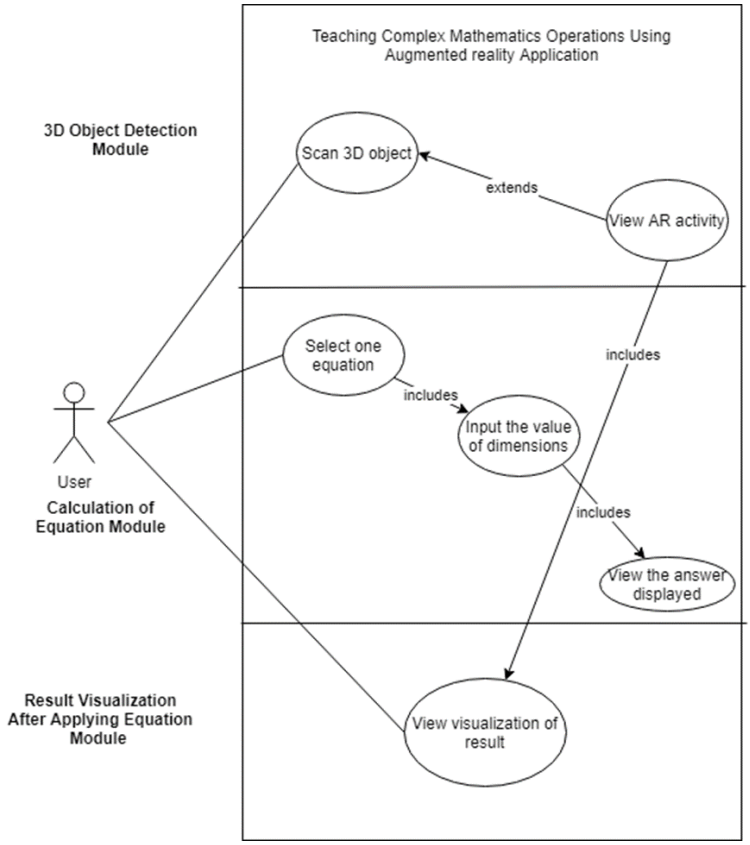

Figure 01. Use Case Diagram of MyToxApp

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5.1. Object Detection Module

This module basically responsible for detecting and tracking the 3D objects using the camera. *Vuforia* SDK will be implemented in this application for the object detection and tracking. The 3D object must be opaque, rigid and contain few moving parts for the object detection to work well. Pliable or deformable objects are not supported. Only 1 object target can be tracked simultaneously in *Vuforia*. Besides, the object should be viewed under moderately bright and diffuse lightning. To the extent possible, the surfaces of the object should be evenly lit and do not contain shadow caused by other objects and people. When the target is in the field of view of the camera, the AR activity will be triggered. For the object detection to perform well, the 3D object should be in static position.

5.2. Calculation of Equation Module

The user can select one equation from the list to perform calculation. An answer will be displayed after performing calculation based on the selected equation, scanned object and the value of dimensions entered by teachers. The list of equations that are involved in this project are shown as below:

- First Order Differentiation Equation:

  $y' + P(x)y = Q(x)$ (1)

- **Calculation of Equation Module**

  $y'' + p(t)\, y' + q(t)\, y = g(t)$ (2)

5.3. Result Visualisation after Applying Equation Module

This module is responsible for visualizing the result after applying the selected equation to the scanned object. The result will be visualized either in 2D or 3D. A brief visualization of result with explanation will be displayed using AR once the object is tracked and detected by the application. A detailed explanation of result will be displayed after the calculation.

5.4. Algorithm Involved

The main algorithm that will be studied and incorporated into this project is marker based augmented reality. In this section, we are going to study the marker-based augmented reality in detail on its characteristic and implementation. Marker-based AR is also known as image recognition or object recognition based AR. It is a most common technique in implementing AR because it is very easy to implement, and a lot of well-known marker-based toolkits are available in the market for example *ARToolkit*, *Vuforia* and others. By using the marker-based augmented reality, the augmented reality activity will be triggered after the marker from physical world is recognized by the system by using the camera. The system needs to detect the marker, identify it and then calculate the pose. A marker is any object that can be placed in a scene to provide a fixed point of reference of position and scale. It can be anything either in 2D or 3D, if it has enough unique visual points. The markers can provide an interface between the physical world and AR content. During the marker tracking, the markers allow the device that generating the AR content for example smartphone to calculate the position and orientation (also known as pose) of its camera. The marker tracking can be achieved without any need of additional sensor for example gyroscope.

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The characteristic of good marker is; high-detailed content and is distributed across the object, not made of repeating elements, do not contain only fine-scale detail which can be detected at certain distances, consists of detail over a range of scales, and has high grayscale contrast. In this application, an open source API, *Vuforia Model Target* is implemented to recognize and track the marker. A CAD model of the object for example cube is generated by using the 3D builder software in Windows 10 and saved as object file. Then the object file is imported into *Model Target Generator* which provided by *Vuforia* to generate the model target. A maximum of 20 model targets can be generated by the *Model Target Generator*.

6. Findings

Testing is an important phase in the application development before it is released in the market as the application will be tested for its functionality, usability and consistency. The model that is chosen for the application testing is V model. Unlike the Waterfall model, there is corresponding testing phase for each development phase. Therefore, it can detect the defects during the development phase instead of after the development to ensure all the requirements are fulfilled in the application. Diagram below shows the structure of V model (Figure 02).

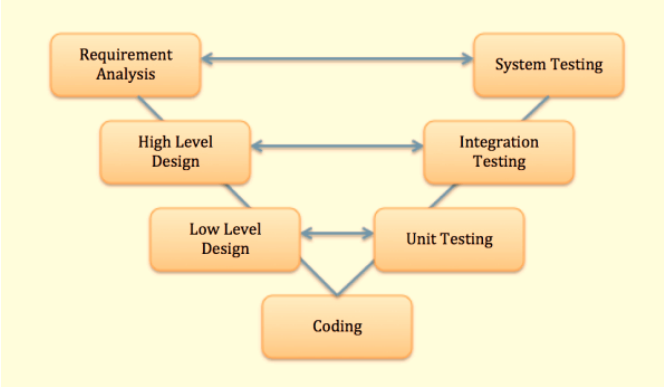

Figure 02. The V Model

The test cases are carried out according to the modules. For each module, the units of test case will be described in detailed. In this section, only selected test cases will be included. Each test case covers the details in Table 01 and Table 02 is the examples of test case of object detection module.

Table 01. The test case attributes

Number	Attributes	Description
1	Test Case ID	A unique ID to represent each test case. The ID will not be repeated.
2	Test Summary	A description to summarize the test content.
3	Prerequisite	Conditions that need to be fulfilled before the test is carried out
4	Expected Result	The expected output of the test.

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Table 02. The test cases of Object Detection Module (ODM)

Test Case ID	Text Summary	Prerequisite	Expected
ODM - 1	Detect **cube**	A **cube** model target is created and imported into the application	The AR activity is triggered.
ODM - 2	Detect **cylinder**	A **cylinder** model target is created and imported into the application	The AR activity is triggered.
ODM - 3	Detect **sphere**	A **sphere** model target is created and imported into the application	The AR activity is triggered.
ODM - 4	AR activity for **cube** is played until the end when the cube is detected.	A **cube** is detected by the system.	The AR activity is played until the end.
ODM - 5	AR activity for **cylinder** is played until the end when the cylinder is detected.	A **cylinder** is detected by the system.	The AR activity is played until the end.
ODM - 6	AR activity for **sphere** is played until the end when the sphere is detected.	A **sphere** is detected by the system.	The AR activity is played until the end.
ODM - 7	Any size and colour of **cube** is detected by the application	A **cube** model target is created and imported to the application. Prepare another **cube** with different size and colour	The AR activity for **cube** is triggered.
ODM - 8	Any size and colour of **cylinder** is detected by the application	A **cylinder** model target is created and imported to the application. Prepare another **cylinder** with different size and colour.	The AR activity for **cylinder** is triggered.
ODM - 9	Any size and colour of **sphere** is detected by the application	A **sphere** model target is created and imported to the application. Prepare another **sphere** with different size and colour.	The AR activity for **sphere** is triggered.

6.1. Discussion on user feedbacks

A survey is carried out to get some feedbacks from different people regarding the usability of the application and improvements that could be made in future. The respondents are required to understand how's the application works before filling in the feedback form. The feedback form is divided into 2 sections, general section and mobile application feedback section. There are total 6 questions in the form. The general section is focusing on how's the respondents learn the mathematics and another section is focusing on the effectiveness and usability of the application on learning mathematics.

- **Background of Respondents**

  There are total 15 respondents on this section. They are USM students which are from different schools for example School of Computer Science, School of Pharmaceutical sciences, School of Languages, Literacies and Translation and others. Most of them are third year and final year students.

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- **General Section**

  Most of the respondents learn mathematics from school either is kindergarten, primary school, secondary school or university courses since it is one of the compulsory subjects in our studies. Some respondents also learn mathematics from online video for example YouTube and reference books. However, most of them never try to use any mobile application in learning mathematics. Most of their teachers also didn't use mobile application in teaching mathematics.

- **Mobile App Feedback Section**

  Most of the respondents are agree on this mobile application makes the class become more creative and provides better mathematics learning method if compared with traditional way. They also agree that this application has attractive user interface and they have better understanding on calculus by using this application. Therefore, most of them will use similar kind of mobile application in learning mathematics. However, there are some improvement that could be made to provide a better learning method as shown in the following:

  - Provide wider scope
  - Provide subtitle on the introduction video
  - Auto-detect the shape of object
  - Include scanner of object dimensions so that they no need to input the number themselves
  - Scan question and give answer directly
  - Provide more simple explanation in video
  - Make the learning process as game level
  - Better user interfaces
  - More creative animation

6.2. Critical evaluation

This section will provide a critical evaluation of the system (Table 03) in terms of advantages, disadvantages, limitations and strengths as compared to existing system.

Table 03. Critical evaluation of system

Advantages and Strengths	Disadvantages and Limitations
• Provides an interactive way for students to learn calculus • Provides graphical explanation for users to understand the concept • Result is visualized in graphical way with animation and audio • 3D object can be detected instead of 2D flashcards • Result is also visualized and explained briefly with AR. • Any size and colour of cube, cylinder and sphere can be detected.	• Existing applications have detailed explanation on the concept • Existing applications have more complete set of the calculus topics • Only applicable for Android phone • Only cube, cylinder and sphere can be detected. • Only first order differentiation and second order differentiation are included.

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7. Conclusion

As a recap, this project is an application that teaching complex mathematics operations by using Augmented Reality technology. It covers three major modules, 3D Object Detection Module, Calculation of Equation Module and Result Visualization after Applying Equation Module. Each module plays a specific role in building this application.

This application provides a more interacting and interactive way for teachers to teach complex mathematics operations which are First-Order Differentiation and Second-Order Differentiation to students. As mentioned in the system objectives, one of the objectives is to do object detection and do model target for augmented reality application. This objective is fulfilled since it able to detect cube, cylinder and sphere. Besides, there is also calculation section available for the user to enter the value of dimensions for each object in order to perform calculation. The result after applying the equation is explained in detail with animations and audio. Therefore, all the objectives stated were fulfilled.

The development processes were going on smoothly even there is some unforeseen circumstances and minor changes on the application capability along the way. The system analysis and designs are considered successful as they provide a clear picture on how's this application should work and be developed.

However, there are some improvements should be made in this application. According to the user feedback, more topics on calculus should be included in this application for example integration, limits and others. More detailed explanation should be included with more creative animations. Besides, the current application only able to accept the value of dimensions from the user. Possibly, a new solution can be devised to capture the dimensions of the object automatically. By considering all these suggestions in the next version of this application, it can make the application goes live and big in the future.

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