

**A Portable Augmented Reality
Science Laboratory**

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

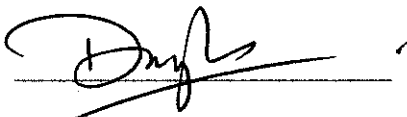
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in partial fulfilment of the requirements for the
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Approved by,



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January 2008

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.



FAIRUZ EFFENDY BIN ABD RANI

Information & Communication Technology

ABSTRACT

Augmented Reality (AR) is a technology which overlays virtual objects on the real world; generates three-dimensional (3D) virtual objects and provides an interactive interface which people can work in the real world and interact with 3D virtual objects at the same time. AR has the potential to engage and motivate learners to explore material from a variety of differing perspective, and has been shown to be particularly useful for teaching subject matter that students could not possibly experience first hand in the real world. This report provides a conceptual framework of a simulated augmented reality lab which could be used in teaching science in classrooms. The recent years, the importance of lab-based courses and its significant role in the science education is irrefutable. The use of AR in formal education could prove a key component in future learning environments that are richly populated with a blend of hardware and software applications. The aim of this project is to enhance the teaching and learning of science by complementing the existing traditional lab with the use of a simulated augmented reality lab. The system architecture and the technical aspects of the proposed project will be described. Implementation issues and benefits of the proposed AR Lab will be highlighted.

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ABBREVIATIONS AND NOMENCLATURES

Abbreviation	Description
2D	Two Dimensional
3D	Three Dimensional
AR	Augmented Reality
GIS	Geographic Information Systems
GPS	Global Positioning System
HMD	Head-mounted Display
HUD	Heads Up Displays
KBSM	Kemahiran Bersepadu Sekolah Menengah
KBSR	Kemahiran Bersepadu Sekolah Rendah
LBS	Location Based Services
PCDA	Personal Communicating Digital Assistant
RV	Reality-Virtuality
VR	Virtual Reality
VRML	Virtual Reality Modeling Language

CHAPTER 1

INTRODUCTION

1.0 CHAPTER OVERVIEW

This report describes a project called AR Lab which is implemented using the Augmented Reality (AR) technology. This project focuses on designing and developing an interactive portable virtual lab which will help the formal education students in understanding the science concept. Due to some constraints that will be discussed later, science education which is normally only could be done in laboratory, will be able to be done in normal classroom.

This chapter describes an overview concept of Augmented Reality (AR). Then, the problem statement which leads to this project to be proposed is described. This is followed by the project objectives and project scope of work.

1.1 OVERVIEW OF AUGMENTED REALITY

AR technology is an emerging technology, which renders three-dimensional (3D) virtual objects and allows people to interact with virtual and real objects at the same time. Unlike most 3D animations which are manipulated by using the mouse, AR allows people to handle the AR virtual objects by their hands providing an intuitive interface interaction. This kind of body learning allows people to have a first-hand experience. Therefore, AR provides an opportunity to interact with 3D objects more naturally and directly.

Nowadays, there are a lot of applications in various areas have been using the AR concept such as medical, military training, emergency services, manufacturing, building construction, virtual information, entertainment and as well as education. AR has its own way and style in designing the presentation which allows users to feel the presence of virtual objects and real objects comparatively to the existing traditional way of science laboratories in school nowadays that only use the concrete 3D objects to aid students.

1.2 PROBLEM STATEMENT

Current way of teaching science education is almost the same typical way for the whole country. The usual case is students first will be taught in the class theoretically. Then, they will do the experiment in the science laboratory. This way will fit most of the cases, but take these points into considerations:

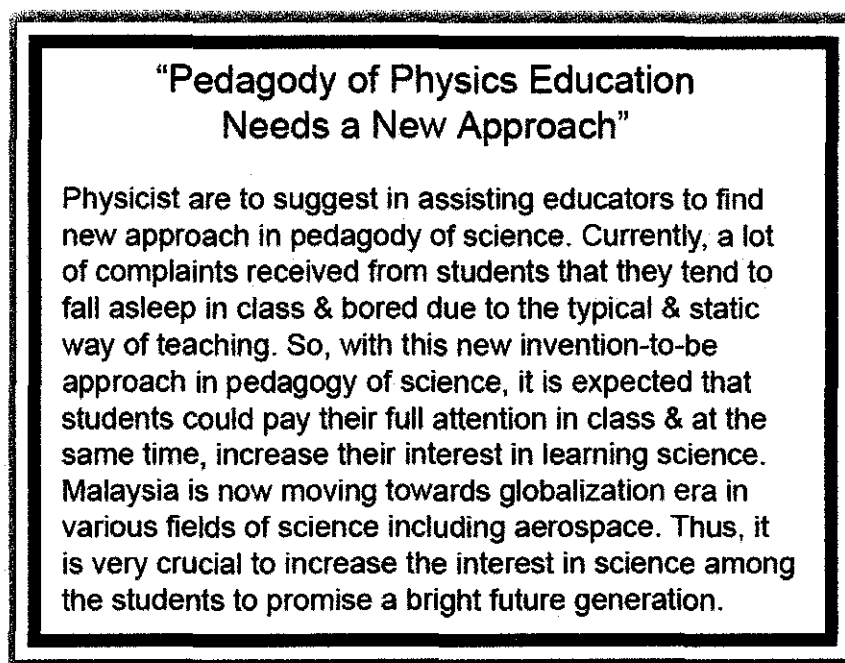
- The teachers very often have a limited space of time (about 30 – 40 minutes) in which to cover a large amount of the necessary material.
- This limits the freedom that both they and their students have to explore complex subject matter.
- Economic constraints that limit the number of laboratories allocated per school
- Incomplete apparatus provided for each laboratory allocated per school
- Some incidents frequently occur in the lab such as bunsen burner gas leakage

Traditionally, a teacher usually has a very limited time to teach the theory or science concept to the students in classroom, before it is practically done in the laboratory. But, such constraints mentioned above may lead to a problem such students might not fully benefiting from the effectiveness of laboratory education. On top of that, due to the increasing number of students per school and large class sizes may also result the same.

AR applications could help here, but it is needed to understand in more detail what design principles have to be applied. For example, if AR is going to be implemented

that give students a rich interactive experience whilst still fulfilling National Curriculum (KBSR/KBSM) requirements.

These problem statements are then supported by a newspaper clip from Utusan Malaysia (see **Appendix A**) which can be summarized as follow:



(Utusan Malaysia, Friday, 28th December 2007, pp.26)

Figure 1.2 : Newspaper Clip

Hence, by implementing this AR Lab in formal education of Malaysia, teachers can shorten the time of teaching complex subject as this application will increase interactivity. Students will increase their interest in learning and improve their understanding. Both teachers and students will gain the effectiveness of this proposed lab.

1.3 OBJECTIVES AND SCOPE OF STUDY

1.3.1 Project Objectives

The objectives of the project are:

- i. To enhance the teaching & learning of science by complementing the existing traditional lab with the use of a simulated AR Lab
- ii. To make the abstract science concept easier to understand & interesting to learn
- iii. To explore the use of AR concept as a supplement classroom exercise & hazardous experiment could be done safely

1.3.2 Scope of Study

It is very crucial to define the scope of study to assure that this proposed project will be able to be developed based on the requirement and functional requirements. At the same time, it is to assure that all the objectives mentioned in section 1.3.1 to be met. The scope of the study will be covered on :

- **Target User**

As AR technology as well as the term itself is still very new in Malaysia, the author is trying to introduce the proposed AR Lab to the minimal number of users consist of school students (13 to 17 years old) and the teachers. At the same time, students can test their understandability and the teachers can figure out the potential of using AR technology into the formal education in Malaysia.

- **Device**

For this proposed project, some special devices are needed to ensure it will be run smoothly and at the same time, functional requirements and the objectives can be met. This AR Lab requires a webcam as tracker to track the “physical marker” or “pattern”. This pattern will be discussed in detail in **section 2.4**.

For output display, will be the computer screen or for enhancement, the head-mounted display (HMD) or projector and a screen can be used.

- **Topics to be developed into AR Lab**

The proposed science topic that will be deployed into AR will be discussed in **section 3.5**. But, before final product with the proposed topics is going to be developed, the first prototype of the project will be discussed first.

CHAPTER 2

LITERATURE REVIEW

2.0 CHAPTER OVERVIEW

This chapter will review the concept of Augmented Reality (AR) in details. The proposed AR Lab will be described to illustrate how AR is used in this project which can mix the virtual and real world at the same time. On top of that, the author will briefly describe about the history of AR, as well as some examples of the applications that embed or enhance the features of AR. Finally, this chapter will narrow down its focus to the newly proposed application that is going to enhance the features and advantages of AR.

2.1 BRIEF HISTORY ON AUGMENTED REALITY

Augmented reality combines features of a virtual environment with the real world. This type of technology has been under development for more than 30 years, at such places as Harvard University, University of North Carolina at Chapel Hill, The University of Utah, the U.S. Air Force's Armstrong Laboratory, and the NASA Ames Research Center. In the 1990s, the term *augmented reality* was coined at Boeing, when scientists there developed a prototype solution to help workers put together wiring harnesses.

As computer technology improved, augmented reality developed more rapidly. In 2000, a project called Magic Book garnered excitement at the computer graphics SIGGRAPH

conference. Magic Book could be read like normal text, but when viewed through a HMD, animated 3D figures acted out the story.

In the last few years, the definition of AR has expanded as researchers have developed additional technologies. In addition to **visual augmentation**, AR can also encompass **auditory augmentation** (a computerized earpiece whispers information into a person's ear), touch augmentation (also called **haptic augmentation**) or augmentation via a personal digital assistant (PDA).

2.2 AUGMENTED REALITY CONCEPTS

Investigation of AR environments has become a popular research topic for engineers, computers and cognitive scientists. **Augmented reality (AR)** is a field of computer research which deals with the combination of real world and computer generated data.

The basic idea of AR is to immerse a user inside an imaginary, computer-generated "virtual world". In AR, the user can see the real world around them, with computer graphics superimposed or composite with the real world. Instead of replacing the real world, we supplement it. Ideally, it would seem to the user that the real and virtual objects coexisted.

The scene is viewed by an imaging device which is usually a webcam. The camera performs a perspective projection of the 3D world onto a 2D image plane. The generation of the virtual image is done with a standard computer graphics system. The virtual objects are modelled in an object reference frame. The graphics system requires information about the imaging of the real scene so that it can correctly render these objects. This data will control the synthetic camera that is used to generate the image of the virtual objects. This image is then merged with the image of the real scene to form the augmented reality image. This process can be summarized into the flow chart below:

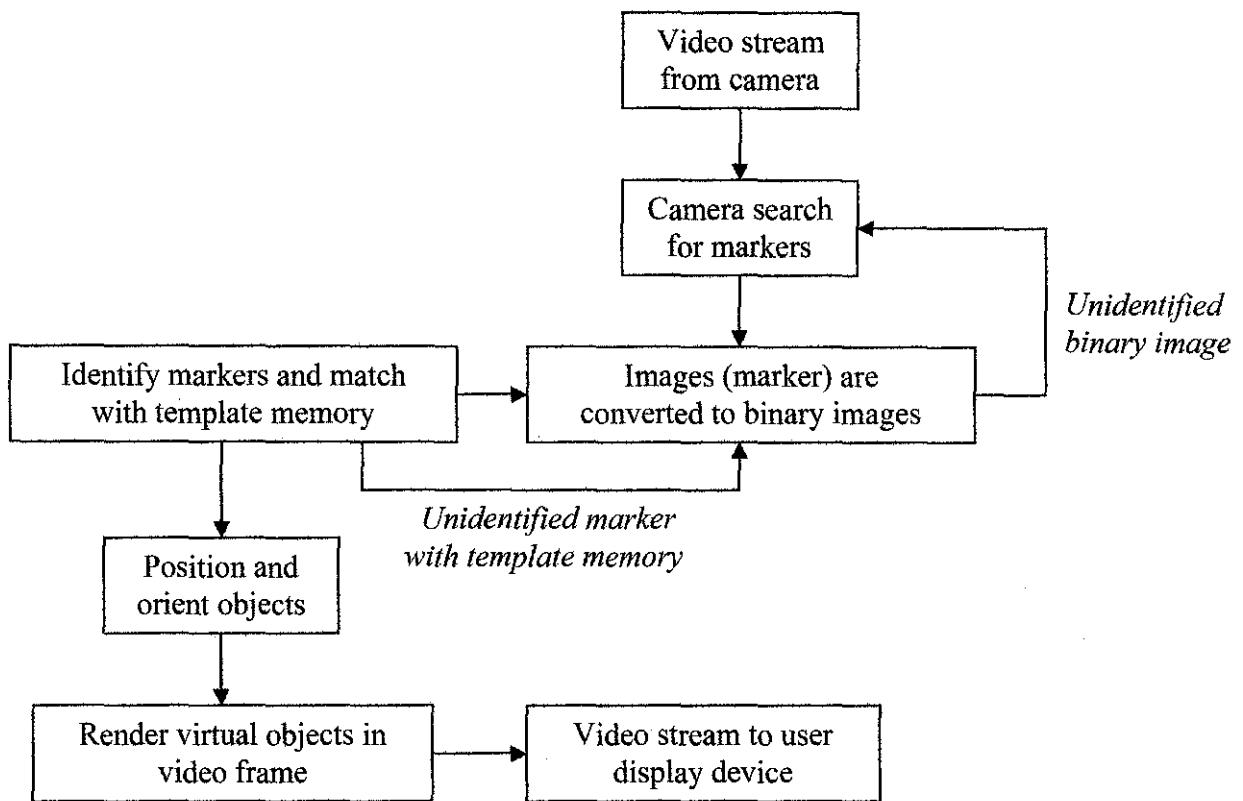


Figure 2.2 : Flow Chart on How AR works

(adapted from <http://www.hitl.washington.edu/artoolkit>)

ARTag works by using a camera as tracker to detect pattern on the card, a card as physical marker with a different pattern and a display output. The code that matches with the pattern will find the virtual object that store in the computer. Finally, after the hardware setup, the user can view the virtual objects which overlay on the real world with the base of physical marker.

In the past few years, Augmented Reality (AR) has received increasing attention from research and industry. By its very nature, AR is a highly interdisciplinary field engaging signal processing, computer vision, computer graphics, user interfaces, human factors, wearable computing, mobile computing, information visualization, and the design of displays and sensors [1].

2.3 DISPLAY TYPES IN AUGMENTED REALITY

AR concepts are applicable to a wide range of areas. AR technology allows for viewing things in a natural environment that otherwise would be impossible to show, such as labels on parts of an engine or forces on the poles of a magnet. The displays for viewing the merged virtual and real environments can be classified into two categories:

2.3.1 “Magic Lens” System

This class of displays is characterised by the ability to see through the display medium directly to the world surrounding the observer, thereby achieving both the maximal possible extent of presence and the ultimate degree of “realspace imaging”.

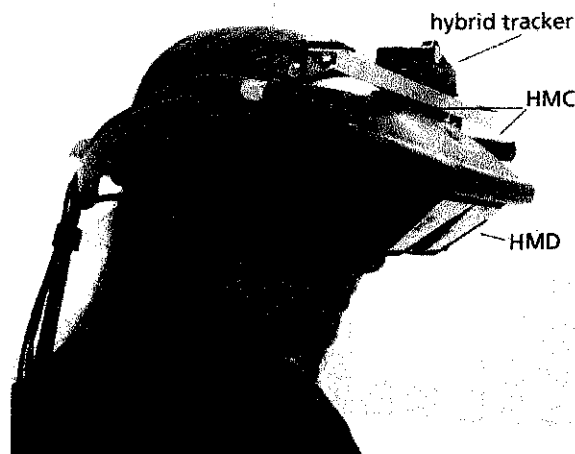


Figure 2.3.1 (a) : Head-mounted Display (HMD)

With a “Magic Lens” System, a user holds a tablet PC, PDA, or camera cell phone (or any computer device with a display and camera) and looks “through” it to see the mixture of real and virtual reality. A “Magic Lens” system is mostly a private experience, users need their own hardware. One of the famous hardware that is used in this system is called Head-mounted Displays (HMD) (see **Figure 2.3.1 (a)**).

Some AR systems use handheld, flat-panel LCD displays that use an unattached camera to provide video see-through based augmentations (Figure 2.3.1 (b)). The handheld display acts as a window or a magnifying glass that shows the real objects with an AR overlay.

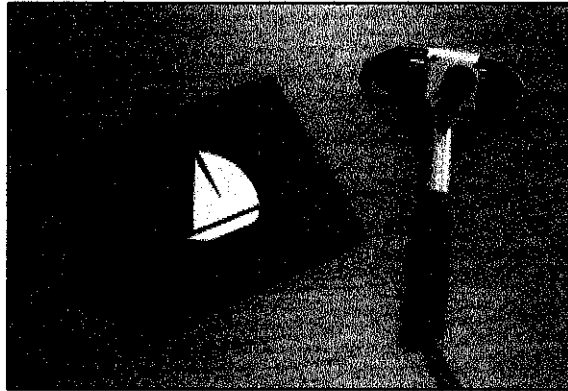


Figure 2.3.1 (b) : Handheld Displays

2.3.2 “Magic Mirror” System

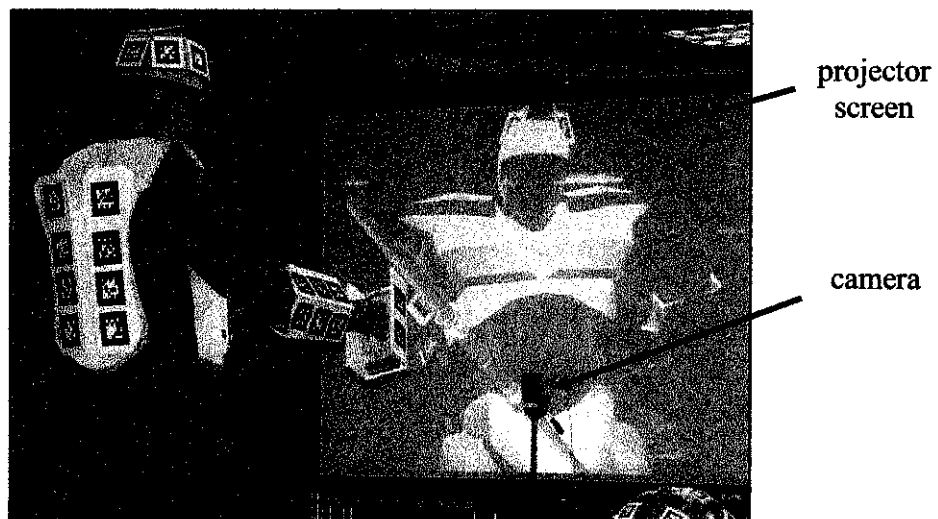


Figure 2.3.2 : Magic Mirror System

“Magic Mirror” system is a single video camera looks out from near a large screen and users see their "reflection" with 3D content added (Figure 2.3.2). As the projector and slide are to be used as the display, the desired virtual information is projected directly

on the physical objects to be augmented. In the simplest case, the intention is for the augmentation to be coplanar with the surface onto which they project and to project them from a single room-mounted projector, with no need for special eyewear.

AR excels at conveying spatial and temporal concepts especially through virtual objects that are too expensive, dangerous or fragile in reality. These can be placed in context to other virtual objects or the real world in order to maximise impact, contextual awareness, engagement and interaction.

2.4 AUGMENTED REALITY VS. VIRTUAL REALITY

In fact agree that AR and VR are related and that it is quite valid to consider the two concepts together. The commonly held view of a VR environment is one in which the participant-observer is totally immersed in a completely synthetic world, which may or may not mimic the properties of a real-world environment, either existing or fictional, but which may also exceed the bounds of physical reality by creating a world in which the physical laws governing gravity, time and material properties no longer hold. In contrast, a strictly real-world environment clearly must be constrained by the laws of physics. Rather than regarding the two concepts simply as antitheses, however, it is more convenient to view them as lying at opposite ends of a *continuum*, which we refer to as the *Reality-Virtuality (RV) continuum*. This concept is illustrated in **figure 2.4** below:

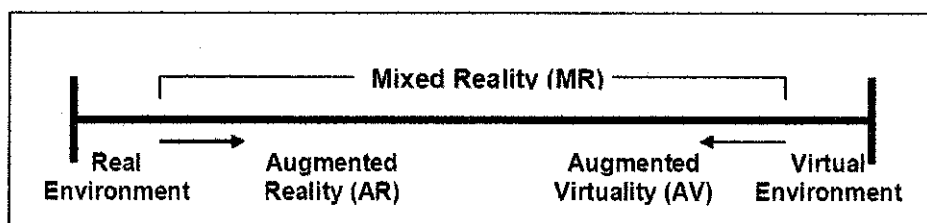


Figure 2.4 : Simplified Representation of An RV Continuum

On the continuum between Reality and Virtuality, there exists an area that many people are calling Mixed Reality. As a subset of Mixed Reality, Augmented Reality (AR) rests

somewhat closer to Reality. Because this field is so young, the boundaries are still vague, and there are a number of experiences that can be considered Augmented Reality.

The definition that fit the best is that, an AR experience is an experience of Reality enhanced with Virtual elements. Some examples of AR applications that have been widely used will be explained in **section 2.6**.

2.5 AR IMAGE MARKER

2.5.1 Introduction to AR Image Marker

In AR, the images are augmented from the physical *image marker* or *pattern*. AR application uses these markers to detect the image and the correspondences between the image and their known 3D location used to calculate this pose, and display the output such as a screen. These image markers are the AR system where virtual objects, games, and animations appear to enter the real world. The code that matches with the pattern will find the virtual objects that are stored in the computer.

It is all about aligning the virtual camera the computer uses to create virtual objects with where the real camera is so the virtual objects line up and appear to belong in the scene. 2D planar patterns can be added to the environment and recognized in the camera images. A 2D planar marker system consists of both a set of planar patterns and the associated computer vision algorithms to recognize them in an image. There are 6 parameters describing performance of fiducial marker system:

1. The False Positive Rate

The false positive rate is the rate of falsely reporting the presence of a marker when none is present.

2. The Inter-Marker Confusion Rate

The inter-marker confusion rate is the rate of when a marker is detected, but the wrong id was given, i.e. one marker was mistaken for another.

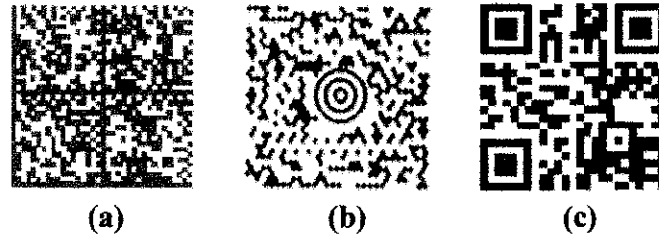


Figure 2.5.1 : Planar Pattern Marker Systems

3. The False Negative Rate

The false negative rate is where a marker is present in an image but not reported.

4. The Minimal Marker Size

The smaller the marker is allowed to be in the image, the larger the usable range from the camera the marker system can be used.

5. The Immunity to Lighting Conditions

The immunity to lighting condition will determine the robustness of the image to be augmented.

6. Detection Jitter

Detection jitter addresses how much “shaking” there is in the image position of the detected markers. This is a very important factor in AR systems.

Fiducial marker systems are selected points on an image that are used as a frame of reference in locating object. There are a lot of planar marker system widely used, depends on the purpose and usage. For example, US Postal Service used the Maxicode marker (**Figure 2.5.1 (b)**) to convey shipping information while Data Matrix (**Figure 2.5.1 (a)**) and QR (Quick Response Code) (**Figure 2.5.1 (c)**) are two other examples designed to contain information are used in industrial setting for part labelling. All these three marker systems have a common thread of encoding data using binary values for reflectance; the pattern is typically bitonal reducing the decision made per pixel to a threshold decision. This reduces the lighting and camera sensitivity requirements [3].

In general, these three markers systems are useful for encoding information, but are not as useful as for fiducial marker systems. The reasons are that:

- They are not intended for, and won't function well, in situations with large field of view and the perspective distortion that introduces. And when detected do not provide enough image points for 3D pose calculation
- They typically require a large area in the image limiting the range at which the markers can be used

To build the AR applications, there are a few popular approaches, such as ARStudio, ARToolKit and ARTag. For a camera-pattern pose to be determined from a single image, at least four point correspondences need to be found, and all these three approaches use four points on the periphery of the pattern [3]. Four points allow the full extraction of the 6 degree of freedom (DOF) of the relative marker to camera pose.

2.5.2 ARToolKit



Figure 2.5.2 : ARToolKit Image Markers

ARToolKit is an open source vision tracking library that enables the easy development of a wide range of AR applications. ARToolKit is popular because it is simple, relatively robust and freely available. **Figure 2.5.2** above shows some examples of ARToolKit image markers. ARToolKit is a popular system which applying a 2D planar marker system consists of both a set of planar patterns and the associated computer vision algorithm to recognize them in an image.

These are some of the features provided by ARToolKit:

- A simple framework for creating real-time augmented reality applications
- A multiplatform library (Windows, Linux, Mac OS X, SGI)
- Overlays 3D virtual objects on real markers (based in computer vision algorithm)
- A fast and cheap 6D marker tracking (real-time planar detection)
- An extensible markers patterns approach
- An easy calibration routine
- A simple graphic library (based in GLUT)
- A fast rendering based on OpenGL
- A 3D VRML support
- A simple and modular API (in C)
- Other language supported (JAVA, Matlab)
- A complete set of samples and utilities
- OpenSource with GPL license for non-commercial usage

ARToolKit marker consists of a square black border with a variety of different patterns in the interior. ARToolKit is useful for many applications, but has a few drawbacks:

- The use of correlation to verify and identify markers causes high false positive and inter-marker confusion rates
- The user typically has to capture prototypes of each marker as seen with the camera and lighting of their application
- The uniqueness of the markers deteriorates as the library size increases
- The processing time also rises as that the normalized center region of each quadrilateral must be correlated with all marker prototypes in the library e.g. to address the four possible rotations and possible differences in lighting, twelve prototypes are stored for each marker
- ARToolKit's inter-marker confusion rate still restricts the library size
- It can often falsely detect markers where there are none, and frequently confuse them.

2.5.3 ARTag



Figure 2.5.3 (a) : ARTag Image Marker

ARTag is a planar pattern marker system that has 2002 markers, with improved performance to ARToolKit in identification and verification, a larger library and no need of pattern files. The paradigm of using a square border with an interior pattern is maintained in ARTag, but the processing of the internal pattern is replaced with a *digital approach*.

The main characteristics are a square border of either polarity (white on black or black on white) and a 6 x 6 square grid dividing up the interior, representing ‘1’ and ‘0’. The whole marker is 10 x 10 units, which a border of thickness 2 units leaving 36 cells in the interior to carry information (see Figure 2.5.3 (a)). Each cell is only black or white and carries one bit of digital data. Thus, a 36-bit word can be extracted from a camera image of the marker once the boundary is determined.

For the proposed AR Lab, **ARTag** is going to be used to overcome the drawbacks of ARToolKit. ARTag was designed to contain the successful elements of ARToolKit and Datamatrix, and take the best of both and make a minimal but robust system for AR [3].

The name ARTag actually refers to the square markers and the image processing that is performed to find them. ARTag comes out many years after the original ARToolKit. To improve performance, ARTag is generated in “arrays” and these arrays are attached to objects or tables where the virtual action wants to be to be appeared on. Compared to ARToolKit, ARTag is a “fiducial marker system” that uses digital encoding method instead of correlation as in ARToolKit, to get a very low false positive and inter-marker confusion rate with a small required marker size, employing an edge linking method to

give robust lighting variation immunity. This results in an almost zero rate of falsely reporting a marker when it's not there, or confusing one marker for another.

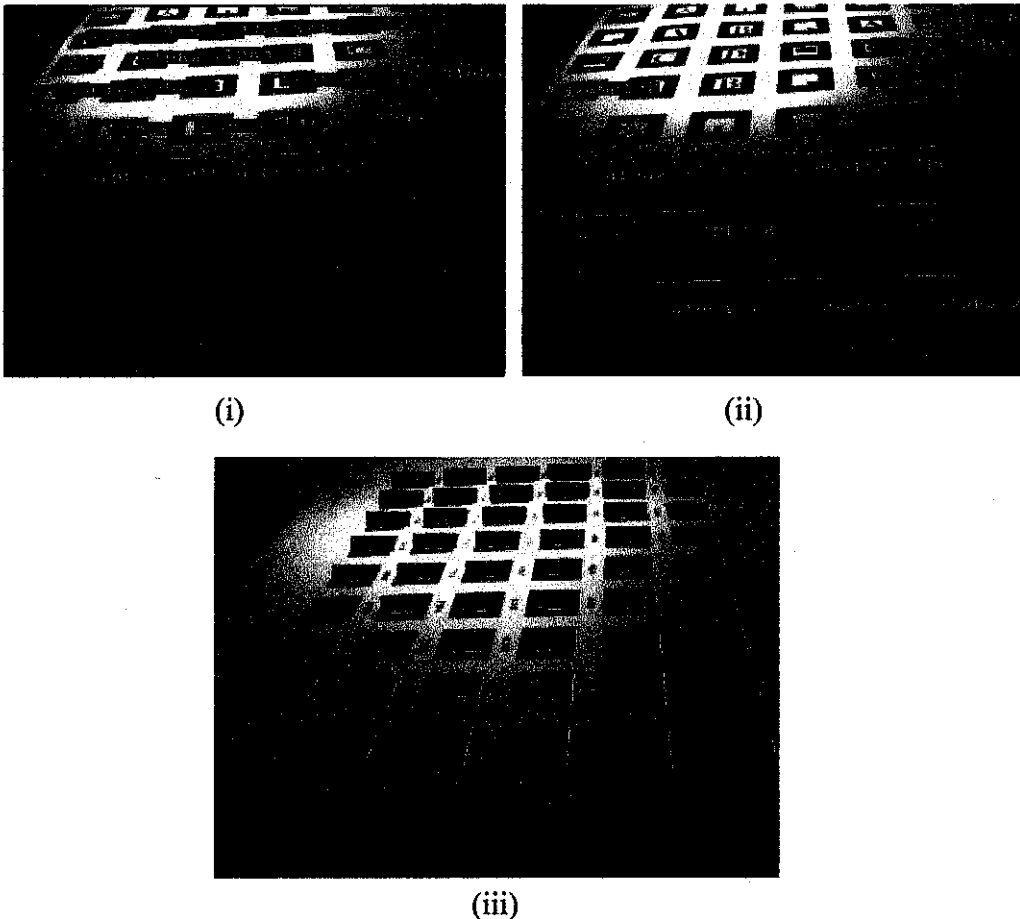


Figure 2.5.3 (b) : ARToolkit and ARTag Performance

Marker detection are very sensitive with lighting, thus it is one of the big challenges in implementing AR application. **Figure 2.5.3 (b) (i) and (ii)** shows ARToolkit performance, demonstrating how a threshold based method cannot recognize all markers simultaneously. **Figure 2.5.3 (b) (iii)** shows how ARTag recognizing all markers. The recognition of a marker is indicated by the overlaid box and number.

Advantages of ARTag:

- ARTag has a very low and numerically quantifiable error rates, does not require a greyscale threshold as does other marker systems, and can encode up to 2002 different unique ID's with no need to store pattern.

- ARTag finds the real camera pose in order to set the OpenGL virtual camera pose to align the real and virtual worlds. It does this by first finding individual ARTag markers in the image and matching them to arrays. The design of the markers and the computer vision software algorithms to find them was carefully done so as to give a highly reliable performance with maximal speed, minimum pixel size in the image, and robustness to uncontrolled lighting and occlusion (partial blocking of a marker).
- Employing an edge linking method to give robust lighting variation immunity
- Low false positive and inter-marker confusion rate with a small required marker size

2.6 EXAMPLES OF AUGMENTED REALITY APPLICATIONS

2.6.1 Magic Book

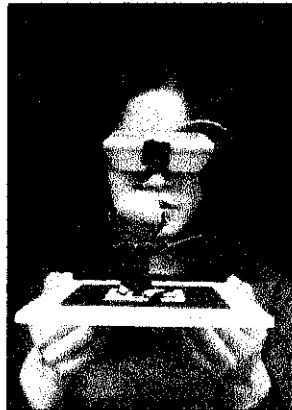


Figure 2.6.1 : Magic Book

A Magic Book looks like a regular storybook with colourful pages and simple text. When readers look at the same pages wearing lightweight head mounted displays (HMD), the pictures pop off the page and come to life as three-dimensional animated virtual scenes. By touching a switch on the HMD, readers can fly into the virtual scene and freely explore the immersive environment. Several readers can gather around a single

Magic Book and experience it together. Wearing HMDs, each reader can view AR scenes from their own perspective or fly into the immersive world and see each other represented as avatars in the same virtual scene. Readers that remain in the AR setting have a God's eye view of their fellow readers as miniature avatars in the virtual scene before them.

2.6.2 VRGIS Solution

VRGIS stands for 'virtual reality geographic information systems'. This system will help quickly finding your way in a new place as if one had lived there for years. It is the ability to automatically receive information about nearby points of interest, immediately locate friends, get accurate directions, and create dynamic geo-referenced information around the world to share with others.

The VRGIS solution is a unique integration of AR, Location Based Services (LBS), and Geographic Information Systems (GIS), combined with the power of the Internet to provide people with a portal to dynamically share information in a revolutionary new way.

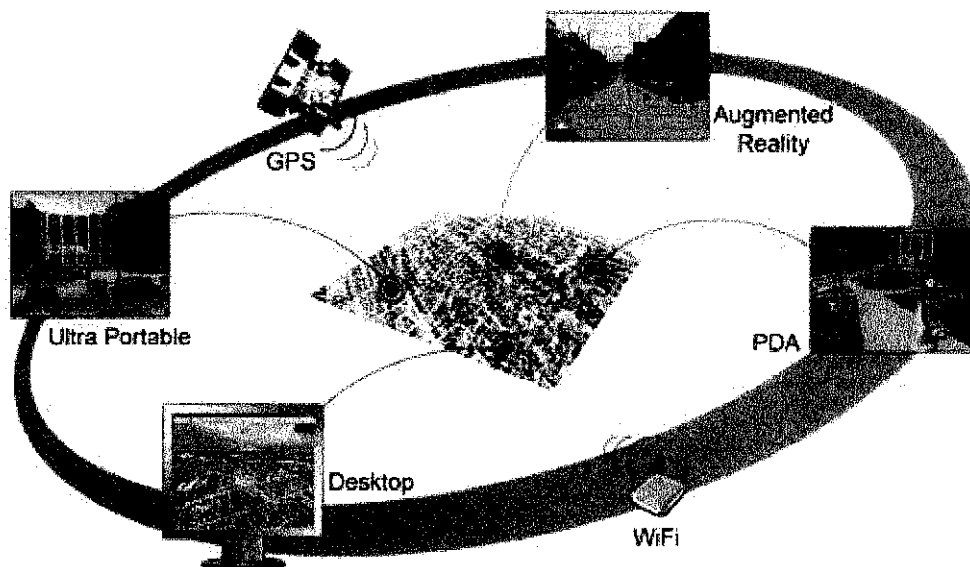


Figure 2.6.2 : Overview Concept of VRGIS Solution

The VRGIS technology receives information from databases via the Internet. It then puts the information together in ways that are easy for people to use. The technology is extremely versatile and connected to far more than desktop computers. It allows users to share location-based information and to communicate freely between smart phones, laptops, desktop PCs, PDAs, tablets and browsers.

2.6.3 Medical

AR is being applied to a wide range of medical areas, including remote and local surgery, surgery planning, medical education and training, treatment of phobias and other causes of psychological distress, skill training, and pain reduction. It is also used for the visualisation of large-scale medical records, and in the architectural planning of medical facilities.



Figure 2.6.3 (a) : Augmented Image of a Brain
(University of Rochester, Computer Science Department)

AR could give the surgeons 3D interactive views of areas within the patient. Planning is carried out preoperatively, to find the best approach to surgery, involving minimum damage. So, the 3D images must be of high resolution, precise, faithful to the actual patient data and provide a realistic sense of the inter-relation of anatomical structures in 3D space since life-critical decisions are based on the presentation of patient data.

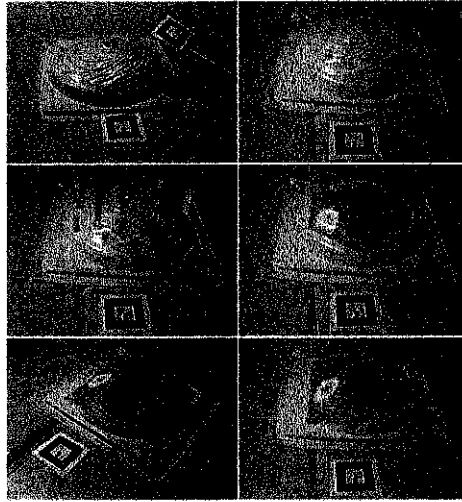


Figure 2.6.3 (b) : Breast Cancer

Figure 2.6.3 (b) above shows the snapshots of sensing breast cancer model. As mentioned above, the augmented image could be viewed from any perspective by rotating the “pattern” or the “marker” that will augment the image, to see different orientations of the virtual objects. This is usually very impossible to do by using the real organ. So, different data can be obtained from different angle. Thus, these allow the surgeon to practice difficult procedures under computer control before the real surgery.

2.6.4 Military Training



Figure 2.6.4 : Parachute Flight Training

A unique, low-cost parachute simulator provides a highly effective tool for teaching, planning and practicing parachute flight and missions. This simulator supplements current field training techniques such as drop towers, towed launches and actual jumps. International installations are providing training for smokejumper fire fighters, and military operational personnel and aircrew emergencies.

Wearing a VR head-mounted tracker and display, the trainee scans a richly detailed 3D jump scene. This scene, which can be based on real mission terrain digital data maps, moves smoothly and accurately in response to parachute toggle inputs and head motions. This interactive scene motion provides the trainee with realistic perceptions of turning, drifting and maneuvering. The trainee can look overhead and react to simulated parachute malfunctions, and scan in any direction to avoid collisions and conduct operations with other recorded or networked jumpers.

With this simulator a trainee completes many jumps in a short time. The instructor uses these repeated simulator jumps to focus on specific points. One of the most important skills a student must learn is judging the effect of wind on touch down location.

The instructor may select from a variety of wind profiles. These provide each student with numerous and varied experiences in manoeuvring to a desired touchdown spot in the presence of wind. Through these many experiences a student develops proficiency in handling winds.

2.6.5 Manufacturing

Augmented reality (AR) is a new form of the man-machine interaction. Computer-generated information is shown in the user's real field of view. The shown information is context-dependent concerning the viewed object. Therefore, AR can replace the common installation manual, e.g. by showing installation details in the technician's field of view (see **Figure 2.6.5**)

HMD

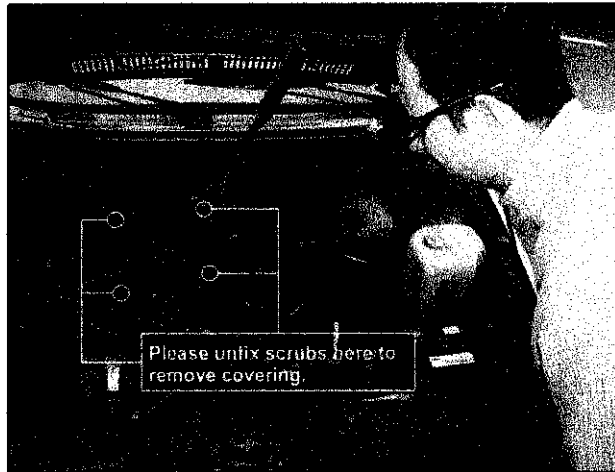


Figure 2.6.5 : Installation details are shown via HMD

The position is determined by the tracking system which brings the real and the virtual world together. This has to be highly precise in order to project the virtual objects exactly onto the real objects. This system provides real-time guidance for training and problem-solving on production-line machinery. Some of the benefits are:

- Relatively inexperienced personnel can provide machine servicing and the dependency on the vendor to repair or maintain equipment is significantly reduced
- Additionally, servicing, training or part change-over schedules can be exercised more predictably and with less training.
- It performs augmentation of information on the display in order to provide guidance in real-time.

This approach utilizes HMD technology that can be readily adapted for various machines on the factory floor with training steps for a new location. Such a system can support various applications in manufacturing such as direct video guiding or applying scheduled maintenance and training to effectively resolve servicing emergencies and reduce machine downtime. It can also provide training of inexperienced operators and maintenance personnel.

2.6.6 Building Construction

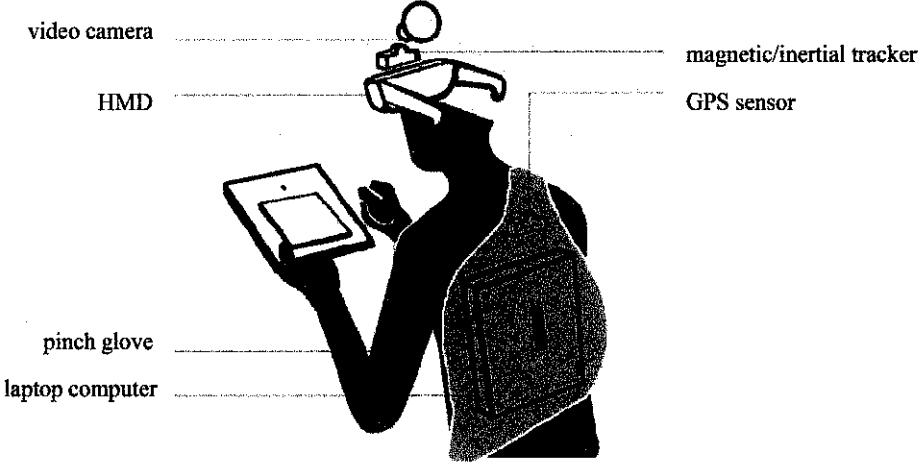


Figure 2.6.6 (a) : Hardware Setup for a Mobile Outdoor AR System

Recent advances in computer interface design, combined with the ever increasing power and miniaturization of computer hardware, have enabled the creation of augmented reality test beds for building construction, maintenance and renovation.

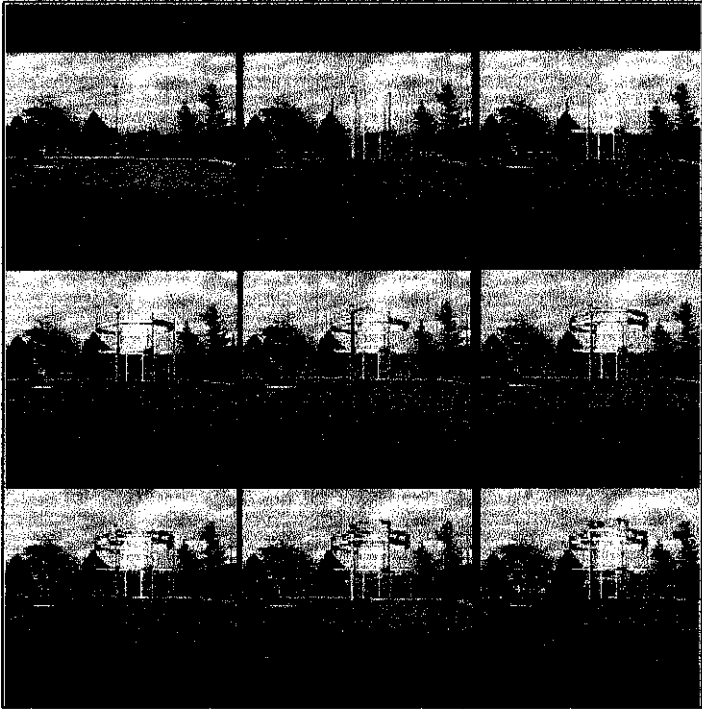


Figure 2.6.6 (b) : AR Visualization of a Steel Structure Erection Operation

An augmented reality system is implemented to improve methods for the construction, inspection, and renovation of architectural structures. As the person moves about, the position and orientation of his or her head is tracked, allowing the overlaid material to remain tied to the physical world (see **Figure 2.6.6 (a)**). This figure shows the hardware and components needed for this purpose.

Markers can be attached to a particular object that a person is working on, and the augmented-reality system can draw graphics on top of it. This is a more simple form of augmented reality, since the system only has to know where the user is in reference to the object that he or she is looking at.

2.6.7 Entertainment

The entertainment industry sees an AR will help them for some aspects especially games. AR has come out with new concepts through games. Instead of using input devices such as keyboard, mouse and joystick, AR creates a condition where it allows the users to feel and “touch” the virtual object.

2.6.7.1 The Arquake



Figure 2.6.7.1 : The ARQuake Game

ARQuake is an Augmented Reality (AR) version of the popular Quake game. Augmented reality is the overlaying of computer generated information onto the real world. We use a head mounted display, mobile computer, head tracker, and GPS system to provide inputs to control the game. Using ARQuake, users can walk around in the real world and play Quake against virtual monsters.

Unlike a Virtual Reality (VR) world, where the viewer sees a completely synthetic (virtual) environment, users immersed in an AR environment can still see the real world. A classic example of an AR device is the HMD. One of the tasks is to take all the monsters and the guns etc. out of the quake game and to make them roam around a real environment. The players of the game are also required to move around the real world and have all the monsters appear as though they were standing next to and behind real buildings.

This game is using combinations of digital compasses, inclinometers, GPS tracking and pattern recognition technologies just to work out exactly where the players are in the real world, then tell quake about it. There are issues with the alignment of the two worlds, accurate tracking in the outside world and lighting problems to solve.

2.6.7.2 The Invisible Train

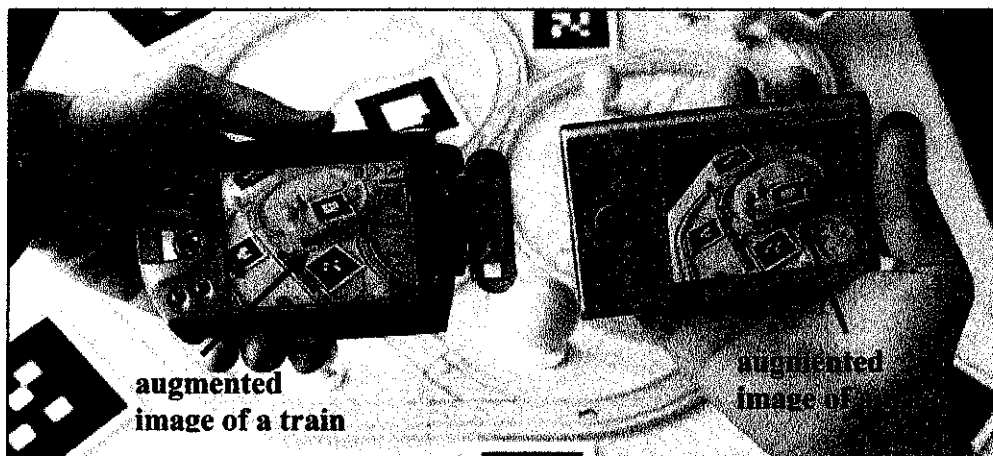


Figure 2.6.7.2 : The Invisible Train Game

The Invisible Train is the first real multi-user Augmented Reality application for handheld devices (PDAs). The Invisible Train is a mobile, collaborative multi-user Augmented Reality (AR) game, in which players control virtual trains on a real wooden miniature railroad track. These virtual trains are only visible to players through their PDA's video see-through display as they don't exist in the physical world. This type of user interface is commonly called the "magic lens metaphor". Players can interact with the game environment by operating track switches and adjusting the speed of their virtual trains. The current state of the game is synchronized between all participants via wireless networking. The common goal of the game is to prevent the virtual trains from colliding.

2.6.7.3 The MonkeyBridge

Lifelike animated characters have received significant attention in recent years. Augmented Reality as a new a media demands broader acceptance, which can be achieved by widening its application base to include entertainment and education. In this project we show how animated agents make autonomous decisions based on their observation of an AR environment in which they are embedded.

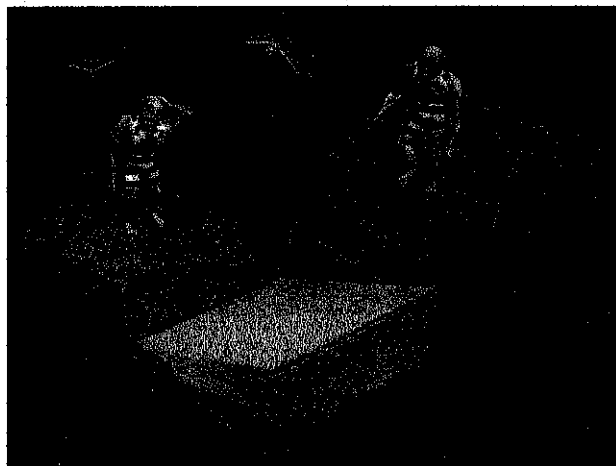


Figure 2.6.7.3 : The MonkeyBridge Game

The game includes many spectacular virtual and physical visual elements such as animated 3D ocean waves, a flock of virtual seagull boids, a physical volcano with real smoke and a lighthouse with rotating lights. Sound effects enhance the game experience.

2.6.7.4 Virtual Information

One of the examples is the tour guide system which embed a virtual human that acting as a tour guide into a mobile indoor navigation application. The user wears a mobile AR setup and perceives the augmented world through HMD. While one is walking around with the setup, the system guides the user in the selected destination.

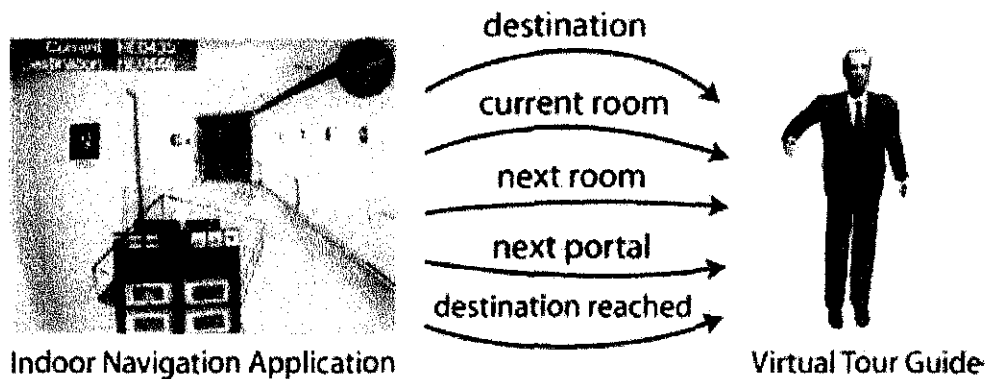


Figure 2.6.7.4 : Virtual Tour Guide

The virtual tour guide agent is placed in the reference frame of the real building and explains about the place visit. The indoor AR navigation system exposes its attributes to the virtual tour guide agent so that it can deliver location-based information. Using hand and head gestures (2D and 3D visual elements and sound) it is able to show the right direction, point out locations of interest in the building, is able to warn users when a door is approaching and send a notification when the destination has been reached.

2.6.8 Education

Although AR is still considered as new field, there are quite a number of AR applications widely used in education, but not in Malaysia. This section will give some examples of AR application that have already been using in education field.

2.6.8.1 AR Piano Tutor

AR is also widely used in education. Through AR piano tutor, virtual objects are superimposed on top of a real MIDI keyboard. **Figure 2.5.9.1** shows how the AR PianoTutor is works. The webcam (A) will track the optical marker (B) and through the HMD, the user can see the augmented piano key (C).

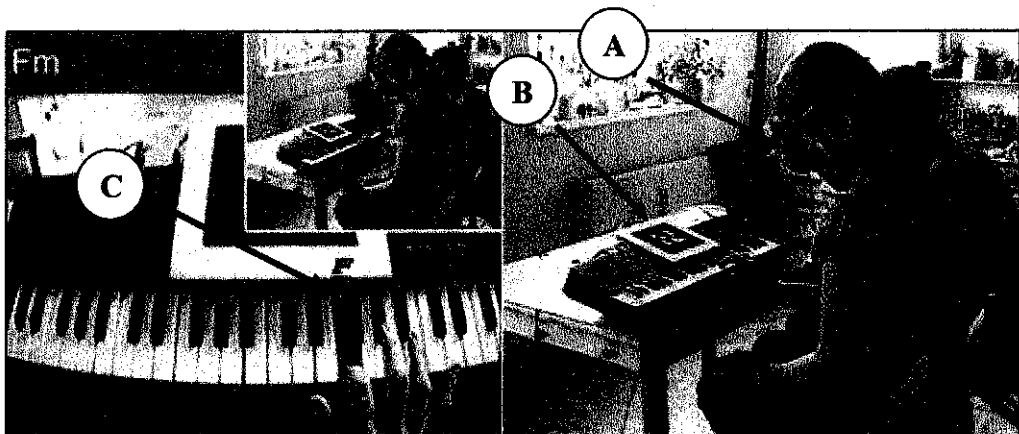


Figure 2.6.8.1 : AR Piano Tutor

The input and output channels of the keyboard are connected to a computer via a MIDI interface. The application serves as a piano teacher that teaches about basic chords, scales, etc. The keys pressed by the “student” user, the order and the timing of the piano key presses are all captured by the computer with the help of the MIDI interface, therefore the teacher can immediately “check” whether the student has correctly followed the instructions and may give instant visual feedback over the real keyboard (e.g. marking wrongly pressed or missed keys with different colours).

2.6.8.2 Mathematics and Geometry Education

A project of AR based geometry education tool was carried out by Vienna University of Technology. This project is called **Construct3D**, which is a three dimensional geometric construction tool that can be used in high school and university education. This project also consists of hardware and software, user interface design and initial experiences. The main goal of this project is to fill the gap of next-generation virtual reality (VR) interfaces for mathematics and geometry education.

Geometry education is to improve spatial skills; spatial perception, special visualization, mental rotations, spatial relations and spatial orientations. So, in order to achieve this, this project uses Augmented Reality (AR) to provide a natural setting for face-to-face collaboration of teachers and students and to support various teacher-student interactions. The main advantage of using AR in implementing this project is that, students actually see 3D objects, which they, until now, had to calculate and construct with traditional methods (mostly pen and paper).

Through this project, students are able to work directly in 3D space, complex spatial problems and spatial relationship can be comprehended better and faster than with traditional methods.

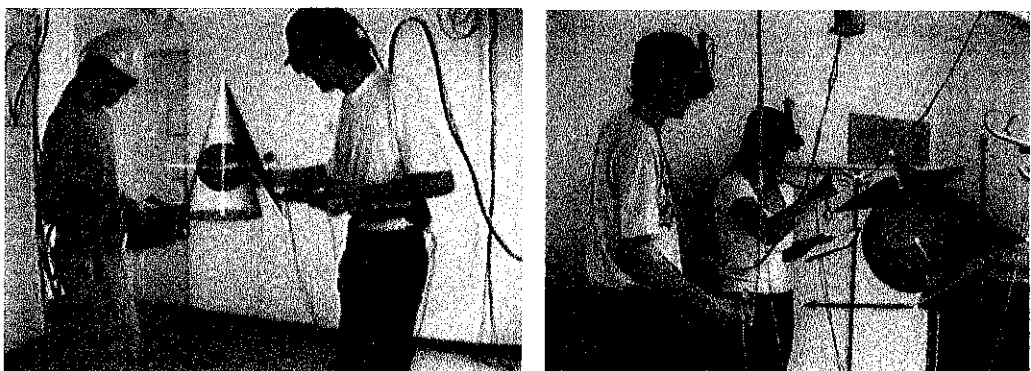


Figure 2.6.8.2 : Students are working with Construct3D

Through this concept, AR is used to allow multiple users to share a virtual space. HMDs are used to see the overlaying computer-generated images onto the real world, thereby achieving a combination of virtual and real world and allowing natural communication among users. **Figure 2.6.8.2** above shows some students are working with Construct3D in the lab.

2.6.8.3 Geography Education

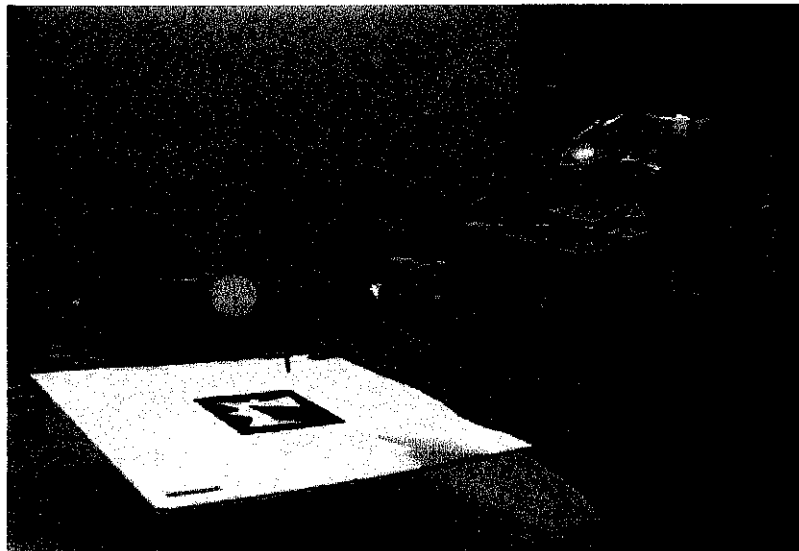


Figure 2.6.8.3 : One of the participant perspective of earth-sun AR exercise

According to further analysis of Shelton and Hedley (2003),

“Learning complex spatial phenomena is closely linked to the way students’ control “when” and “how” they are able to manipulate virtual 3D objects” [5].

There are a lot of students who have difficulties in accommodating spatially related knowledge involving complex concepts and phenomena. This results as challenges to instructors, to find new ways of representing spatial systems that are more cognitively beneficial for students learning, since the pedagogical challenge exists in many forms. The problem is that it is difficult for instructors

to accurately represent explicit spatial phenomena using conventional 2D means [5].

This significant issue became a motivation to Shelton and Hedley (2003) to carry out a project called “Using Augmented Reality for Teaching Earth-Sun Relationship to Undergraduate Geography Students”. This project is utilizing AR to teach the concepts of rotation/revolution, solstice/equinox and seasonal variation of light and temperature. **Figure 2.6.8.3** shows one of the participants are trying to manipulate the AR model of sun-earth relationship.

Through this project, Shelton and Hedley [5] were to examine the understanding of the students, by providing an AR virtual model of Earth-Sun relationships, to investigate the potential of AR to improve education and lastly to come out with the advantages of using AR interface over the traditional way of teaching. At University of Washington, Geography courses aims to provide students with a working knowledge of the physical landscape and natural environmental processes. For this study, AR virtual models were designed to build an understanding of rotation and revolution, solstice and equinox, and seasonal variation of light and temperature of the northern and southern hemispheres.

With AR, there is no need for students to pretend an apple is the earth, nor an orange the sun, like some instructors have attempted to use. Manipulating only the 3D objects, provide the necessary information needed to make the connection of how earth-sun relationships operate.

2.6.8.4 Chemistry Education

A study was carried out by Chen (2006) to investigate how students interact with AR in learning about amino acid, comparing the students’ understanding by providing both AR 3D virtual models and 3D physical models. It was conducted in the Human Interface Technology Laboratory (HIT Lab) at the University of

Washington. Participants in this study possessed basic chemistry knowledge such as basic chemical representations.

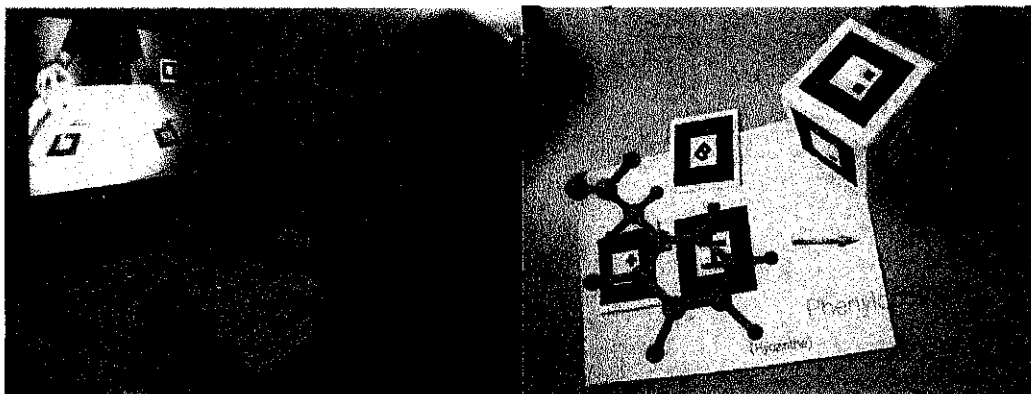


Figure 2.6.8.4 (a) : A user is to compose and interact with virtual 3-D molecular models

Before computer-based technologies were created, 3D physical models were used in the education field. Physical models allow students to touch, observe and to interact with in order to obtain concrete experience. But, AR also provides an opportunity to interact with 3D objects naturally and directly because AR allows people to handle the AR virtual objects by their hands providing an intuitive interface interaction. This kind of body learning allows people to have a first hands experience. On top of that, it is to help students understand concepts which are abstract and not visible in our daily life. AR offers an alternative way to see the chemistry world and allows students to interact with the system and discover knowledge by themselves [6].

Through this study, Chen was to investigate on how students interact with AR and physical models and evaluate their perceptions regarding these two representations in learning about five amino acids; Alanine, Valine, Leucine, Isoleucine and Methionine. Unlike any other AR applications, the participants did not require to put any devices on their body such as goggles or other HMD devices. This system only requires a laptop and a webcam to render all virtual objects [6].

For the result of this study, Chen further stated that,

“The results show that some students like to manipulate AR by rotating the markers to see different orientations of the virtual objects. When interacting with AR markers, the participants handled AR markers as though they were manipulating physical model”.

The findings of this study imply that the participants interacted with AR in a natural way such trying to tilt or rotate the marker in 180 degree dimension, the AR marker to observe structure. They also tried to flip the marker in order to see the other orientation of the AR-generated virtual objects, as they usually do when they are interacting with the physical models. Also, when they attempted to count the number of atoms on AR, they did not count the atoms on the screen directly by pointing. Instead, they counted the atoms “in the air” by pointing their finger above the marker and watching the image on the screen. These two phenomena imply that AR created an intuitive interface for these users to interact with the amino acid.

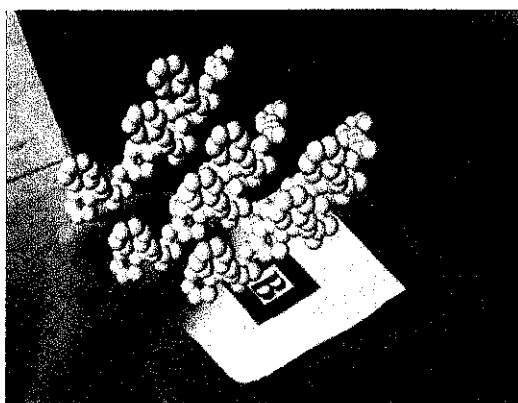


Figure 2.6.8.4 (b): Augmented 3-D virtual molecules from the image marker

Showing dynamic change of one chemical phenomenon in the classroom would help students understand complex chemical concepts. **Figure 2.6.8.4 (b)** shows an example of complex molecule structures augmented from an AR marker. AR

is not is not only able to present dynamic animations, but also provides an interface to have a direction interaction with animations.

Another important finding from the study is that things are easier when AR-generated images are projected on the screen, which is sometimes called as “mirror image”, so that everyone could see the AR virtual objects at the same time instead of passing the physical models around. In addition, the professor could manipulate the AR marker in front of the class and students are able to see the immediate change, while physical models only offer static structures [6].

2.7 THE IMPORTANT OF LABORATORY-BASED COURSE

Laboratory-based courses play a critical role in scientific education. Even our most modern, advanced educational institutions (universities) are frustratingly outmoded in terms of teaching students. The entire process of giving lectures, taking notes, reading facts from books, and taking final exams is a throwback to institutions of learning dating back to the Renaissance. Remarkably, very little has changed today: with notable exceptions, the vast majority of university professors continue to bore students with ineffective, non-interactive approaches to education that result in little more than the professor's notes becoming the students' notes without passing through the minds of either.

True learning is experiential. Humans learn best by doing, not by reading or listening to lectures. The more senses are involved (sound, sight, touch, emotions, etc.), the more powerful the learning experience. That's why today's best teachers are those pioneering individuals who take the effort to engage their students in meaningful activities that reach students at multiple levels.

Science professors may see laboratories as a way of confirming beliefs and teaching scientific methods [7].

- Simulations purportedly reduce the amount of time it takes to learn

- Simulated lab are seen as a way to the deal with the increasing expenses of traditional labs
- Simulated lab are seen as being at least as effective as traditional labs
- They are also embraced for creating an active mode of learning that thereby improves students' performance

2.8 TRADITIONAL WAY OF SCIENCE EDUCATION

As mentioned in problem statement (**section 1.2**), the teachers usually very often have a limited time to cover everything in the class. Some cases, the students have to do the practical in the laboratories without having a clear understanding of the concept and theory in the classroom. And what if the school is not able to provide enough laboratories for the students or laboratories without enough apparatus?

Now, imagine a small kid of 7 to 12 years old for instance, in a boring classroom with the same old static way of teaching, looking at their book which only consists of 2D or static images which sometimes are hard to be well understood by the kids at that ages.

There are a few important key points that the author would like to highlight here which are:

- Small numbers of laboratories provided
- Young ages students
- Same old type of teaching
- 2D or static images

These points are the inspiration for the author to come out with this project. Taking advantages of all the points above will result these:

- The proposed virtual science laboratory can be done in normal classroom.
- Kids will naturally attract and enthusiastic response to animated images which they can control by themselves.

- The use of AR in formal education will create big changes in traditional way of teaching. With the blend of hardware and software application, it will be a promising technology which allows students to gain the fully effectiveness.
- No more boring, colorless, static 2D images. 3D virtual animated images will be used as an augmented result of the physical image

The potential for using this kind of technology for learning is what strikes the author the most.

2.9 AR FROM THE SCIENCE EDUCATION PERSPECTIVE

Some researches are already being done to explore the potential of augmented reality for teaching primary school science. AR has the potential to engage and motivate learners to explore material from a variety of differing perspectives and has been shown to be particularly useful for teaching subject matter that students could not possibly experience first hand in the real world [2].

One of the problems of such simulations is that the students have sometimes difficulties with understanding abstract visualization even if they presented in 3D space. The problem is how to decrease the gap between the real world which surrounds us and the abstract model which are used in simulations. The most frequent solution to this problem is to mix the real life phenomena presented with some abstract or virtual information to such sequences.

Based on the above cases, it is very clear that something has to be done to overcome the problem in science education. As to solve the problem as mentioned in **section 1.2 and 2.7**, the author is proposing a Portable Augmented Reality Science Laboratory which is built using ARTag image processing. AR Lab gives the possibilities of the user to interact virtual and real world concurrently.

After doing some research on how AR applications are used in education field, based on the examples above, from the author's personal view, these are the main reasons why AR Lab should be implemented for the formal education school in Malaysia, at least to assist or to act as a supplemental tool for the existing traditional laboratory in teaching science:

- AR naturally draws people's attention
- It is a trend to use technology to create a constructivist environment to enhance learning
- AR not only creates visual images, but also conveys the spatial cues directly to users because by using AR, users can obtain a sense of spatial feeling
- AR can be a tool which requires users to interact and think carefully. Since users have to concentrate on the AR system and focus on the virtual objects, they may pay more attention to think about what happen next, and thus make them think more deliberately.

AR provides an efficient, powerful tool that allows students to view and interact with sophisticated phenomena while providing flexibility to allow query and exploration of component parts of this system such as time, position, angles, rotation and revolution. AR allows the designers or developers to present any 3-D phenomena they wish, scaled to dimension that are convenient for classroom observation and manipulations. And by using this technology, the power of virtual objects can be leveraged, that is representing anything all at once.

By bringing AR interface into classrooms, the author believes that there may be significant benefits to the quality in which curriculum involving complex 3D spatial phenomena and concepts are taught in various disciplines. AR has great potential to be applied to the knowledge domain of spatial concepts resulting in a more intuitive way of teaching and learning.

The applications of AR in education can be numerous. By implementing this AR Lab, it is believed that virtual objects could replace a variety of expensive experimental models in normal laboratory. Such substitutes are very appropriate for the traditional laboratory where the real apparatus could not be available. The teacher and the students are able to accomplish an experiment in a classroom, which is usually done in a traditional laboratory by using different virtual models which could be associated to the fiducial markers. This could be even feasible if the experiment and such 3D representation are mixed and projected on the screen.

The usage of AR can permit individual experiments based on abstract models. This could be useful in the case of personalized learning without having multiple instances of real experimental apparatus. In the case of classroom it is easy to change immediately the experimental apparatus and there is no time consuming setup of such experimental classroom [4].

So, AR interface is a visualization technology that can take advantage of the limitations of the traditional way of teaching science education. Through this proposed project, there are some concerns that taking into considerations since until today, there is very little of AR technology has been used outside of a laboratory setting [2]. In order for the students to have a good understanding, these are the general characteristics of the proposed project:

- The 3D virtual objects will be manipulated on a small hand-held platform that changes its orientation in coordination with the viewing perspective of the student.
- The students will be able to control the angle of viewing in order to understand how unseen elements work in conjunction with those that were previously seen.
- Thus, the students will be able to observe and to interact with in order to obtain concrete and hands-on experiences.
- The teachers will be able to make some subject matters accessible to the students in a manner that 'brings them to life'.

The AR features offer a clear advantage over traditional methods of teaching science. Nevertheless, AR does not intend to replace physical models. Instead, AR could be used as a supplemental tool for students since it provides an alternative way to show visual images in order to make the abstract concepts more concrete and more accessible to learners.

The author believes that with better quality of learning infrastructure, technology can increase the reach of pedagogy by allowing teachers, professors or instructors to teach more effectively, which results the increasing of students understanding in learning.

2.10 THE PROPOSED “PORTABLE” VIRTUAL SCIENCE LABORATORY

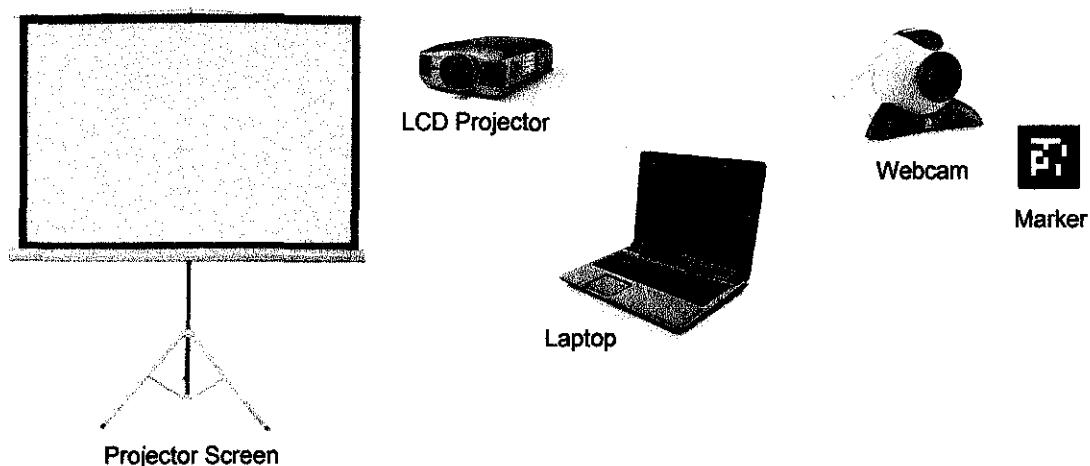


Figure 2.10 : Components of Proposed Laboratory

For the proposed laboratory system, “Magic Mirror” system will be used instead of “Magic Lens” system. This is because, if this proposed laboratory was to implement in a classroom, each and every student in the class has to be provided with their own device (HMDs or tablet PC), which is very costly. So, due to cost factor, “Magic

Mirror” system is going to be used. The author believes, either system will give the full benefits to the students.

The proposed “Portable” Virtual Science Laboratory consists of:

1. Marker

A few markers are printed on cards.

2. Webcam

The webcam represents the users’ eyes and its operation is to capture the real world to capture the image of the physical image marker to be associated with the correct virtual model in the database.

3. Laptop

The database of the pattern and virtual models are stored in the laptop.

4. LCD Projector & Projector Screen

Virtual models are superimposed on video images of real objects and are displayed on projector screen.

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.0 CHAPTER OVERVIEW

This chapter describes the methods used to implement this project. The development methods used in this project are mainly divided into three:

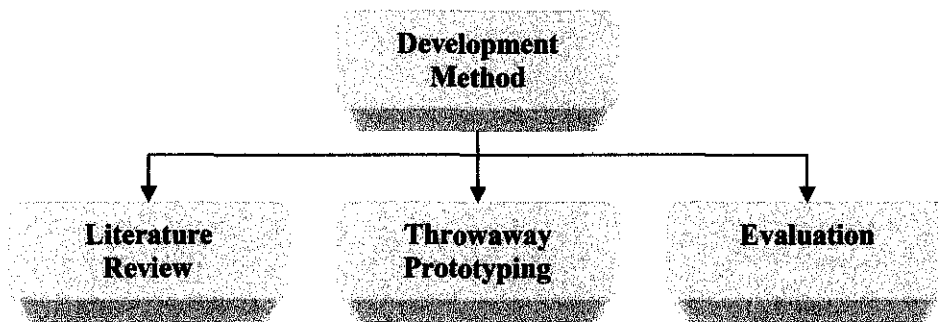


Figure 3.0 : Development Method

The throw-away prototyping method is used to develop the proposed AR Lab. Then, a description of the software tools and devices needed to implement will be described. Finally, a detail description of the project will be described.

3.1 LITERATURE REVIEW

A thorough literature review has been done on Augmented Reality (AR). As explained in Chapter 2 of this report, through the literature review, these are the points that the author can summarize from the studies:

- **Brief history on Augmented Reality**

The first project on AR was introduced which is called Magic Book. The author then introduced some terms related to AR such as *visual augmentation*, *auditory augmentation* and *haptic augmentation*.

- **The Concepts of Augmented Reality**

Through this subtopic, the author explains about the major components involve in AR systems and also, how the AR actually works. This included the display devices for AR such as "*See-Through*" AR Display, which consists of Head-Mounted Display (HMD) and Handheld Display, and *Monitor Based AR Display*.

- **Image Marker (Pattern)**

A thorough study has been done on this topic. The author explains about the six important parameters describing performance of image markers, types of marker systems, two approaches of image marker systems; ARToolKit and ARTag as well as the advantages and disadvantages for both. For the proposed project, ARTag is used because it could overcome the drawbacks of the other image marker approaches such as ARToolKit.

- **Examples of Augmented Reality Applications**

In this subtopic, the author describes some existing projects that use AR applications in various fields. There are, Magic Book, VRGIS Solution, AR Piano Tutor, Military Training Simulator, Robotics, Manufacturing, Building Construction, Virtual Information and Entertainment, mainly on games application.

- **Augmented Reality in Education**

To support the idea of the proposed "*Portable*" Virtual Science Laboratory in Formal Education, the author has done thorough studies on the implementation of Augmented Realities in education. Mostly from journals, the author has found

some examples of AR applications widely used in education especially in mathematics and geometry education, geography and chemistry education.

- **Problem Statement**

The author has come out with a problem statement to identify some problems faced by the students in Malaysia in learning science through the traditional way.

- **The Important of Laboratory-based Course**

Another important point to support the proposed *“Portable” Virtual Science Laboratory in Formal Education* is that, the author has identified the important of laboratory-based course.

- **A “Portable” Virtual Science Laboratory**

Based on the examples of AR applications in education, the problem faced by the students in learning science through the traditional way and also the important of laboratory-based course that has been identified, the author proposed a *“Portable” Virtual Science Laboratory in Formal Education* using Augmented Reality. Although it is not going to completely replace the existing traditional way of science laboratory, but at least it is to assist the students and teachers, or could be used as a supplemental tool since it has the ability to make the abstract concepts more concrete and more accessible to learners. The characteristics of the proposed AR Lab are listed out.

- **Issues related**

Lastly, the author also listed out some issues related that need to be taken into considerations when the proposed *“Portable” Virtual Science Laboratory in Formal Education* is to be implemented in Malaysia.

3.2 THROWAWAY PROTOTYPING DEVELOPMENT

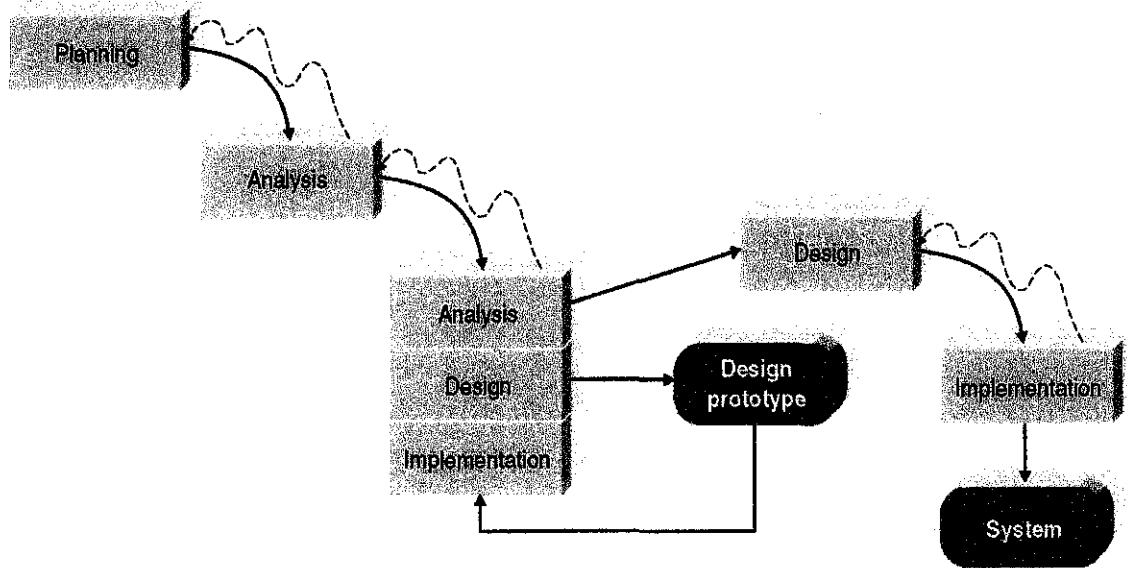


Figure 3.2 : Throw-away Prototyping Method

For the proposed AR Lab, the development method is deployed *Throwaway Prototyping* method. This method is chosen because:

- Enable to develop “*quick and dirty*” system quickly
- Enable refining until adequate system is developed

The *Throwaway Prototyping* has a thorough analysis phase that is used to gather information and to develop ideas for the system concept. There might be some issues which are not cleared and these issues are revised and examined by analyzing, designing and building a *design prototype* (see **Figure 3.2**). A design prototype is not a working system; it is a product that represents a part of the system that needs additional refinement.

For example, to give a clear picture on how AR works the author built a mock-up application, to represent the whole system, but indeed, they really do nothing. Each of

the prototypes is used to minimize the risk associated with the system by confirming that important issues are understood before the real system is built. Once the issues are resolved, the project moves into design and implementation. At this point, the design prototypes are thrown away.

The advantages of using this type of prototyping method are:

- It balances the benefits of well-thought-out analysis and design phases with the advantages of using prototypes to refine key issues before a real system is built
- Usually, it produces more stable and reliable final products

3.3 EVALUATION

As mentioned in **Chapter 1, section 1.3.2**, target users for this application are mainly school students (7 to 17 years old) and the teachers. Thus, evaluation needs to be done to:

- assess the extent and accessibility of the system's functionality
- assess users' experience of the interaction
- identify any specific problems with the system

It is important that evaluation should occur throughout the design process. It is ideally being performed before any implementation work has started. There are two types of evaluation:

1. Evaluation through expert analysis
2. Evaluation through user participation

But due to time constraints, only evaluation through user participation could be done.

3.3.1 Evaluation through User Participation

Evaluation through user participation involves with the actual users. User participation in evaluation tends to occur in the later stages of development when there is at least a working prototype of the system in place. In this section, the author will discuss some methods such as observational techniques and query techniques.

Usability testing involves recording typical users' performance on typical tasks in controlled settings. As the users perform these tasks they are watched and recorded on video and all their activities are logged. This data is used to calculate performance times, identify errors and help explain why the users did what they did. Type of technique that is going to be deployed is *Observation Techniques*.

Through this technique, user is asked to talk through what he or she is doing or observed; for example, describing what he or she believes is happening., why a particular action is taken and what he or she is trying to do.

The advantages of using this technique are:

- It requires little expertise to perform
- Enable to observe how the system is actually used
- The user is encouraged to criticize the system
- The user can clarify points of confusion at the time they occur and so maximize the effectiveness of the approach for identifying problem areas

3.4 SOFTWARE, TOOLS AND EQUIPMENT REQUIRED

3.4.1 ARTag

In this project, ARTag is chosen on the main development. As mentioned in **Chapter 2**, ARTag is a software library to build the AR applications. ARTag works by using a camera as tracker to detect image marker on the card (physical marker), with

different pattern, and display the augmented image as the output through a screen. The code that matches with the pattern will find the virtual objects that store in the computer. Finally, after the hardware setup, the user can view the virtual objects which overlay on the real world with the base of physical marker.

3.4.2 Software & Hardware Specifications

Table 3.4.2 : Software & Hardware Specifications

Software	Hardware
[1] Modelling & Rendering Software <ul style="list-style-type: none"> • OpenGL API • ARTag or ARToolKit • VRML • 3D Studio Max 9 [2] (Windows) Direct X 9.0b Runtime [3] Microsoft Visual Studio.NET 2003 [4] Adobe Photoshop CS (or any image editing software)	[1] Computer: <ul style="list-style-type: none"> • OS : Windows 2000 or XP or newer • Processor : 1.0 GHz or better • Memory : At least 512 MB of RAM • High-end Graphics Card [2] Webcam (high resolution) [3] LCD Projector & Projector Screen

3.5 PROJECT DETAIL

3.5.1 Project Planning

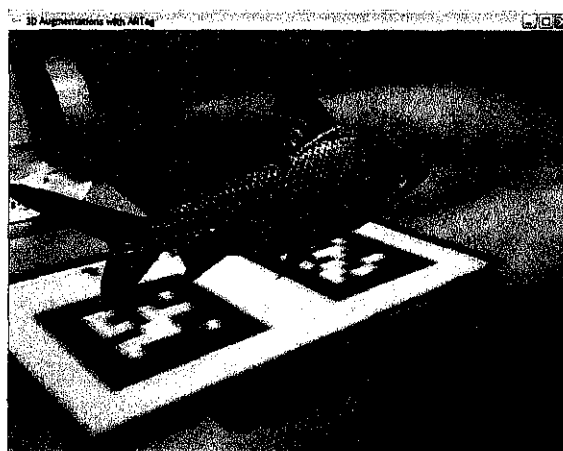


Figure 3.5.1 (a) : Augmented Fish of an ARTag Image Marker

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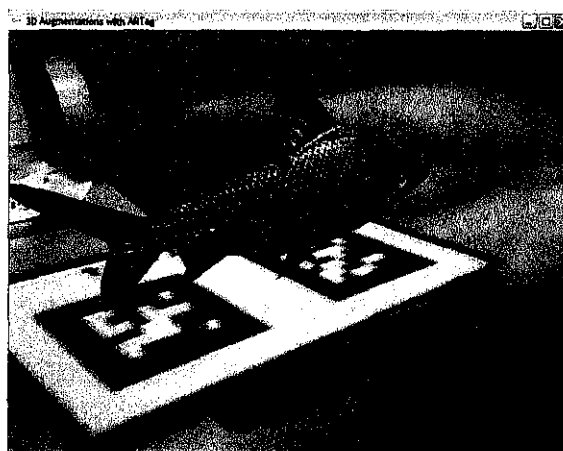


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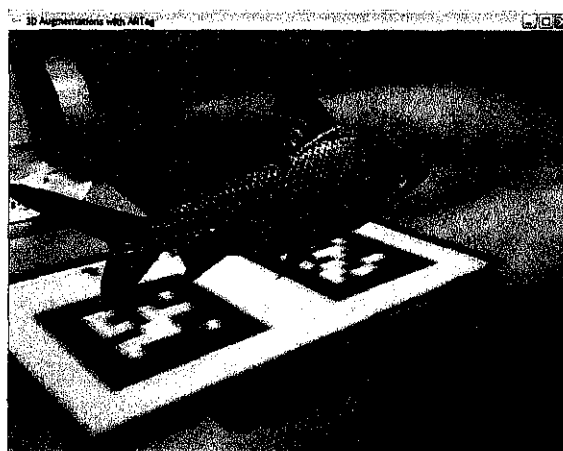


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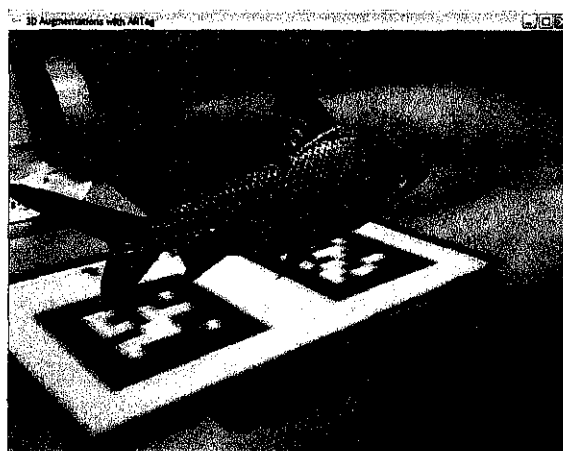


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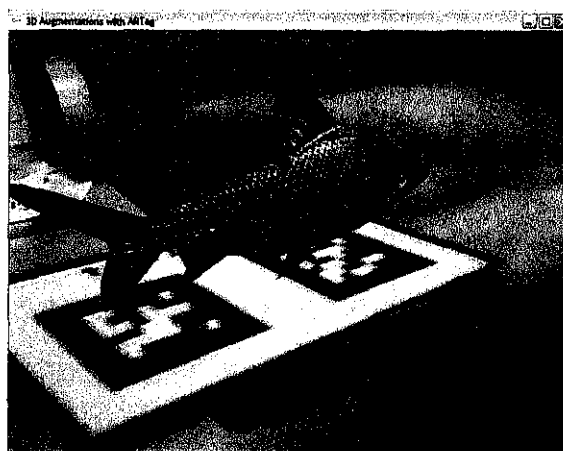


Figure 3.5.1 (a) : Augmented Fish of an ARTag Image Marker

The story line descriptions of each section are described below:

Phase	Description	Action Taken
1	The users are expected to understand the heat absorber and radiator concept, theoretically before starting the experiment. They also need to aware the materials and equipment needed for the experiment.	All the patterns required for the experiment will be but in the place provided to augment the 3D image model of the apparatus needed for this experiment.

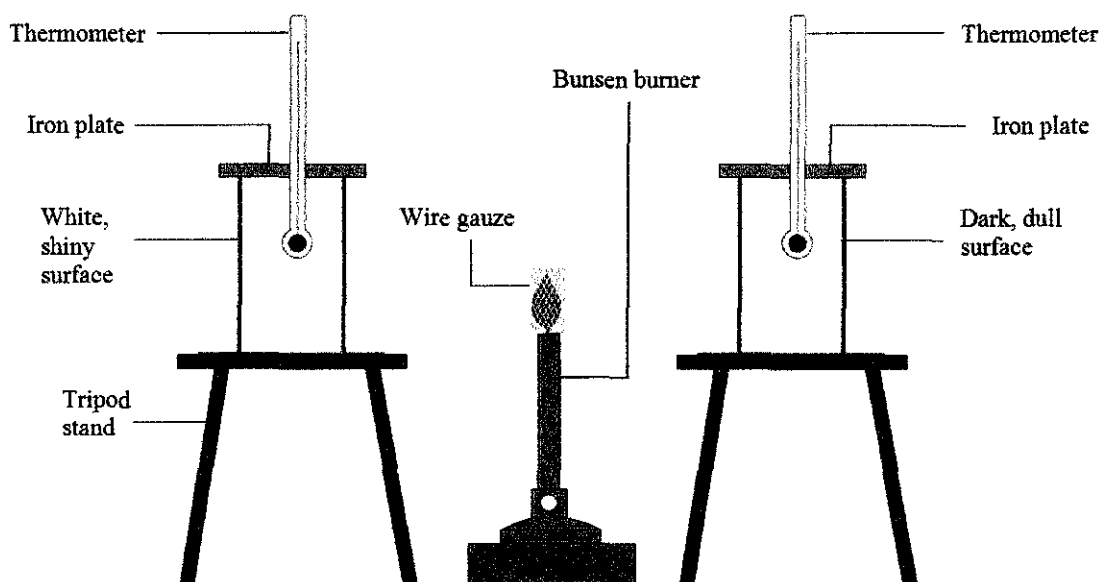


Figure 3.5.3 (b) : Sample Apparatus Needed for the Experiment

Phase	Description	Action Taken
2	<p><u>HEAT ABSORPTION</u></p> <p>The experiment begins by conducting these steps:</p> <ol style="list-style-type: none"> 1. The physical objects of <i>Tripod Stands</i> will be put in place provided. 2. Users will choose 2 out of the 3 "<i>Tin Can Patterns</i>" which covered with <i>cork</i>, (3 tin cans covered with black rough paper, white and glossy paper each) to be put on the tripod stands. 3. "<i>Bunsen Burner Pattern</i>" is put in place. 	<p>Users (theoretically) should aware the different of the thermometer reading between the 2 tin cans selected will be different in terms of speed and the level of heat. The reading of the thermometer is recorded before and after the Bunsen burner is lighted.</p> <p>(<i>caution</i> : Make sure that the cans are equally far from the Bunsen flame)</p>

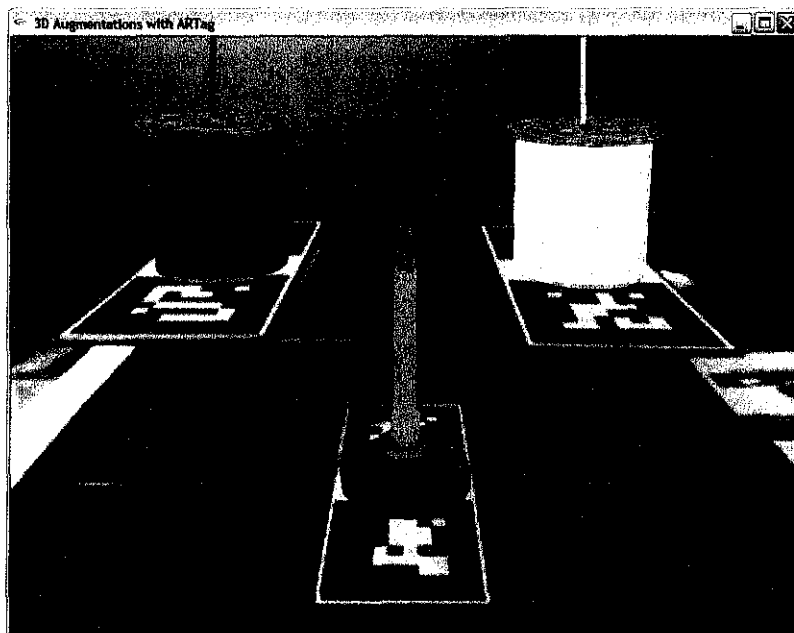


Figure 3.5.3 (c) : Sample Apparatus that will be Augmented

Phase	Description	Step Taken
3	<p><u>HEAT RELEASE</u></p> <p>Next, the users need to conduct these steps:</p> <ol style="list-style-type: none"> 1. “<i>Bunsen Burner Pattern</i>” is removed from the place. Theoretically, is to see how the surface color affects the release of the heat. 2. The users may repeat the steps above with other tin cans that covered with different kind of color surface. 	<p>The readings of the thermometers is observed and compared between the 2 tin cans selected. The reading of the thermometer is recorded.</p>

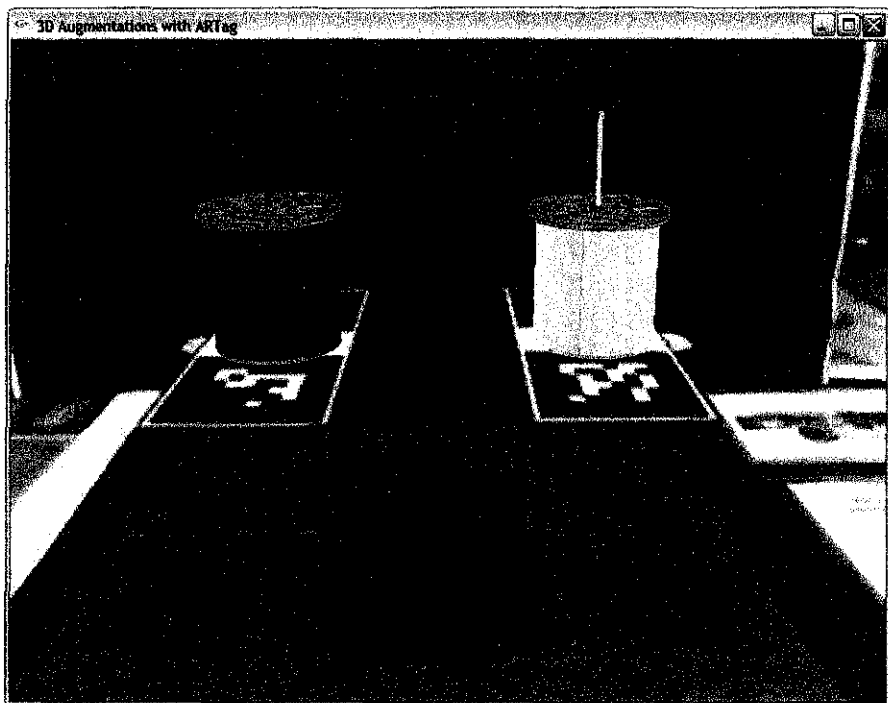


Figure 3.5.3 (d) : Sample Apparatus that will be Augmented

CHAPTER 4

RESULT/DISCUSSION

4.0 CHAPTER OVERVIEW

This chapter will first show the results after the first prototype of the project is built using ARTag. The prototype then is improved, by substituting them with proper 3D image models created using VRML and 3ds max. This is based on the storyboard of one science experiment topic picked up from Integrated Curriculum for Secondary Schools, Science Form 1 text book. The rest of this chapter will discuss more about the storyboard and will follow by some discussions.

4.1 PROJECT SETUP

4.1.1 Project Value

Generally, in the traditional way of science laboratory, students have their hands-on experience by physically present in the laboratory. Through this proposed virtual lab, it has its own approach of presenting the users in the real world, and at the same manipulating the pattern markers, as if they are manipulating the real lab apparatus in the real lab.

4.1.2 Rules and Instructions

Basically, the rules for the users to use this virtual lab is to determine which pattern to use in order and what are the 3D image models are expected to be augmented from the patterns selected. More importantly, users have to really aware of the surrounding

source of lights, because the patterns are highly light sensitive. On top of that, users need to put the patterns and materials involved in this system in place according to the range provided in **Table 3.5.2**. The accuracy of the measurements is very crucial to augment correct 3D image models with minimum distortion.

Besides, the users also need to understand the basic theory of the science concept for each experiment that is going to deploy in AR. In this case is the theory in heat absorber and radiator concept.

Objectives:

To examine the effect of different type of surface on heat absorption and heat release

Before using the system:

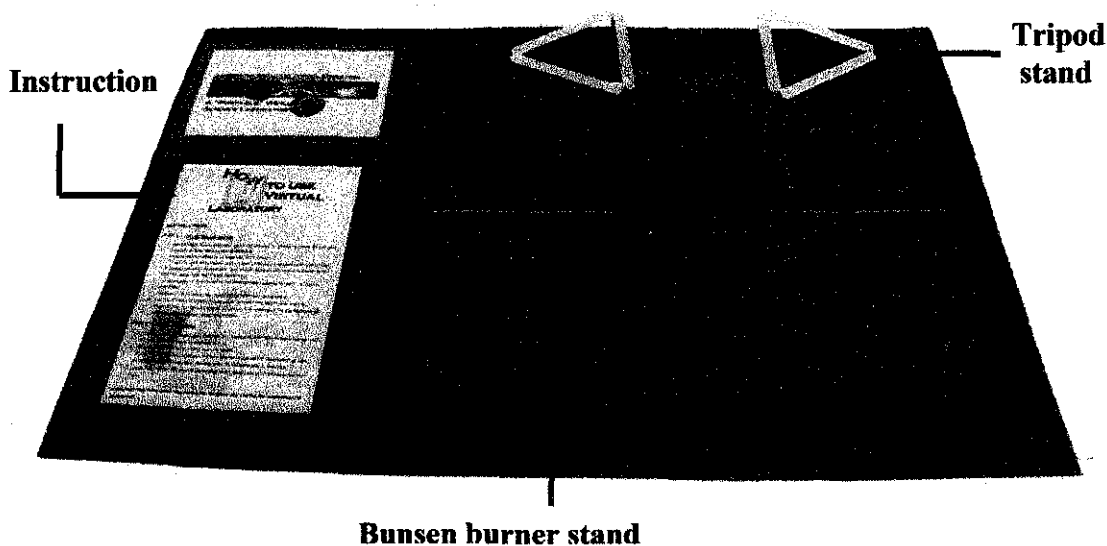


Figure 4.1.2 (a) : Basic Requirements for Virtual Lab

The above figure shows the basic equipments required for this virtual lab. It contains a tracker, a board, two tripod stands, a Bunsen burner stand and also a piece of instruction on how to use the system on the right hand side of the board. The users need to place the tracker, tripod stands and the Bunsen burner stand as shown. The usable range of the

parameters of these equipments is summarized in Table 3.5.2. Figure 4.1.2 (b) below shows how to put the patterns and the tracker in place.

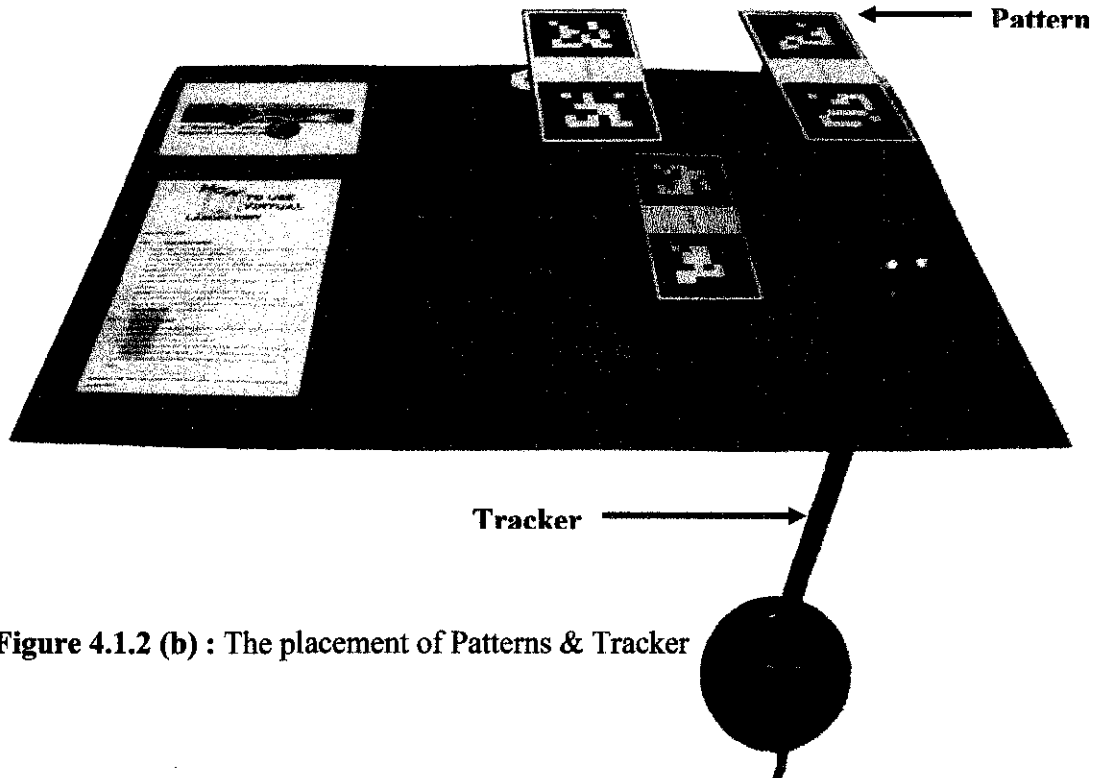


Figure 4.1.2 (b) : The placement of Patterns & Tracker

4.2 INFORMAL SURVEY

To check the usability of the implementation of the proposed AR Lab, an informal survey was carried out. As stated earlier in section 3.3, due to time constraint, only evaluation through user participation could be done. Through this method, an observational technique has been carried out, where users are needed to talk through what he or she is doing or observed; for example, describing what he or she believes is happening., why a particular action is taken and what he or she is trying to do.

The aim of this informal survey was to find answers for the following questions:

1. How the easiness of using the AR Lab?
2. How the users define the enjoyment of using AR technology?
3. How the usefulness of the AR Lab to the users?

4. Do they think by implementing AR Lab in formal education could overcome or at least minimize the problem as mentioned in **section 1.2** and **1.3**?

For finding the answers for the questions above, the action of the users were being observed and recorded while they were playing around with AR Lab.

The result of this finding can be summarized as follow:

1. From the observation, it was found that more than 80% of the users easily can use the system with minimum supervision. By only received a brief explanation on how AR works and the example of experiment, they just manipulated the pattern cards, in front of the tracker, by using the sample board provided. Some of the comments are:

"AR Lab is easy to use. All you need to do is just manipulate the card as if you are manipulating the real apparatus".

"The concept is very easy. We just follow the instruction and play around with the pattern cards".

Yet, the rest of the percentage was commenting on the stability of the augmented image that is displayed on the screen. Due to the light condition that is not very good, the augmented image were distorted, keep blinking, and hard to detect by the tracker. Thus, it is not easy to use since it is very sensitive, in terms of light condition and the distance between the tracker and the pattern cards.

2. However, almost 100% of the users were enjoying using the AR Lab since they have never heard and seen such technology before. Most of them were trying to grab the 3D image that augmented from the physical marker, while keep moving the card upside down, to see what kind of changes will happen. Some of them were trying to check the structure of the pattern card itself, because they thought there is a built-in chip inside.

3. Despite of the sensitivity of ARTag image marker system and its stability, more than 90% of the users agree that AR Lab has the potential to improve the understanding of students towards lab-based course learning. This is because, the ability of AR Lab to naturally draw people attention to try and use it. In a way, when it has the ability to draw people's attention, at the same time will improve the understanding and increase the interest towards the subject because of the curiosity.
4. Almost 100% of the users agree that the proposed AR Lab has the potential to meet the objectives and overcome the problem statements, especially in terms of to conduct a safety experiment and improve the understanding of a particular science concept before it is conducted in the real lab.

4.3 DISCUSSION

First prototype is built to examine some issues arise in AR application such as:

- **Lighting Condition**

Lighting condition is a very crucial issue in AR. Yet, it is very sensitive for the tracker (in this case is a webcam) to track the physical marker and display the image onto the display (in this case is a PC screen). The lighting condition cannot be too bright and also not too dim.

- **Display Technology**

Display technology is another basic building block for augmented reality. HMDs are the dominant display technology for AR applications today. However, due to some constraints such as cost, the proposed project is going to use a PC screen or projector to display the augmented images.

- **Tracking and Registration**

Accurately tracking the user's viewing orientation and position is also crucial for AR registration. A correct and consistent registration between the physical marker and the tracker is one of the most important tasks for augmented reality. Thus, it becomes one of the most fundamental challenges in AR research today to have a precise, fast and robust tracking system.

- **Real-time Rendering**

Since AR mainly concentrates on superimposing the real environment with graphical elements, fast, and realistic rendering methods play an important role. An ultimate goal could be to integrate graphical objects into the real environment in such a way that the observer can no longer distinguish between real and virtual. On top of that, a good real-time rendering ensures that there is no lagging between the tracking of the graphical image until it is displayed on the screen.

Based on the four issues discussed above, the first prototype has been examined and as a result, there are some findings obtained:

- By using ARTag image marker, the physical marker is much easier to be tracked by the tracker (in assumption that the webcam is a high resolution camera), compared to the ARToolKit image marker. Under a light condition that is a little bit dim, the tracker still can display the augmented image on the screen without any distortion.
- The real-time rendering also is fast, robust and realistic. The augmented image displays on the screen in real time without lagging.
- Tracking and registration in ARTag is better than ARToolKit because the physical marker is easily detected and displayed on the screen, without distortion (in assumption that the lighting is in good condition).

CHAPTER 5

CONCLUSION/RECOMMENDATION

5.0 CONCLUSION

Augmented Reality (AR) has been widely used in various fields such as medical, military training, robotics, building construction, entertainment and also in education. By narrowing down the scope of education, AR in education promises a new way of science teaching and learning in formal education in Malaysia.

“Portable” Virtual Science Laboratory is an Augmented Reality (AR) based lab that serves the purpose to introduce the AR technology and concept in education. This lab is presented in a tangible user interface which user can interact between virtual objects in virtual environment overlay the real world environment. The development of the “Portable” Virtual Science Laboratory is to achieve the objective, which is mainly to help primary school students, to have a better understanding in science education.

Thus, through this AR Lab, it is hoped that although not to replace the existing traditional way of science laboratory, it may be as a supplemental tool and assist and give benefit to both students and teachers in science education, especially in learning and teaching. The abstract science concepts might become more concrete and more accessible to learners, in a way of intuitive learning and teaching.

5.1 RECOMMENDATION

For future works, virtual lab should support background music and animation. It will be more interactive and attractive. The system also should include a variety of functionalities such as events trigger (if possible) to create challenge for the users. Thus, the author also should think of a very applicable and practical experiment topic to be deployed in AR technology.

Evaluation should be done to a group of primary school students and teachers. One or two chosen topics will be taught to the students, using the normal traditional way of science teaching. And then, the same topic will be taught to the same students, using AR Lab. Comparison between these two approaches will be experimented.

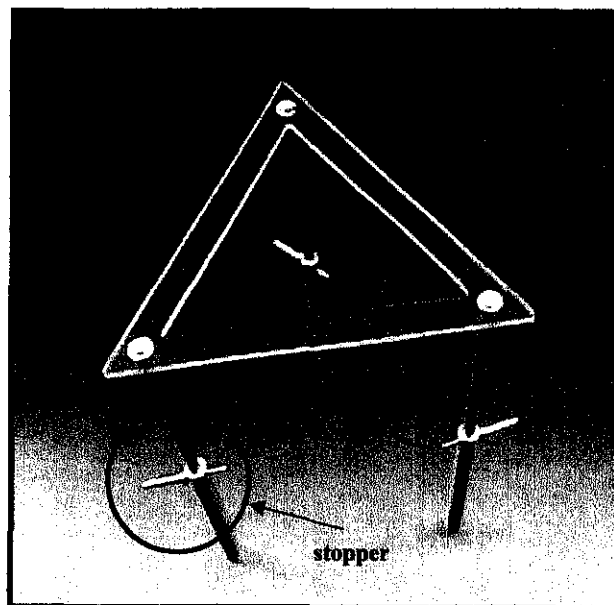


Figure 5.1 : New Design for a Tripod Stand

But, there are some constraints that need to be taken into consideration before this AR Lab is taken for evaluation for the primary school students and teachers:

- Before introducing AR to students, they should be allowed to have enough time to get familiar with the AR system since AR is relatively a new technology, especially in Malaysia scope.

- The teacher should prepare the environment in advance (such as the source of light), which will affect the quality of marker registration.

In terms of 'portability' concept, all the apparatus (real apparatus) such as tripod stands and the board should be designed within the concept. In such, the real apparatus have to be designed so that it will fit the concept.

The board could be foldable as well as the stands of the tripod. For instance, **figure 5.1** above shows a sample on how the design of a tripod stand could be improved to fit the concept of 'portable'. The stands are made of 2 types of aluminum rod; solid and hollow type, where the stands can be re-assembled easily. On top of that, the height can be changed easily by using the 'stopper' to set to the desired height.

This new design will fit the concept of 'virtual' and 'portable', thus it can be easily conducted in the classroom.

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APPENDIX

Pengajaran fizik perlu kaedah menarik

KUALA TERENGGANU 27 Dis. – Warga penyelidik fizik disaran membantu warga pendidik dalam mencari kaedah pengajaran baru bagi semua mata pelajaran sains di sekolah supaya lebih menarik dan tidak membosankan para pelajarnya.

Pengerusi Jawatankuasa Pelajaran, Pengajian Tinggi, Sains dan Teknologi dan Pembangunan Sumber Manusia negeri, Datuk Dr. Abdul Latiff Awang berkata, kaedah pengajaran baru perlu dicari supaya para pelajar dapat menumpukan sepenuh perhatian dalam kelas dan tidak mudah bosan.

Katanya, ketika ini, beliau menerima

rungutan daripada para pelajar yang mengikuti pelajaran Sains Tulen bahawa mereka mudah mengantuk dan bosan ekoran penyampaian guru yang statik.

"Mungkin dengan penemuan kaedah pengajian yang baru ini bukan sahaja membantu dalam meningkatkan penumpuan dalam kelas, malah menarik minat pelajar untuk mengikuti bidang pelajaran sains.

"Malaysia kini mula melangkah ke era baru dalam pelbagai bidang sains termasuk penerokaan angkasa, justeru kita perlu menarik minat anak-anak kita terhadap bidang ini bagi memasti-

kan negara dapat melahirkan lebih ramai pelapis dalam bidang sains," katanya.

Abdul Latiff berkata demikian selepas merasmikan Persidangan Fizik Kebangsaan 2007 anjuran Universiti Malaysia Timur (UMT) di Pulau Duyong di sini malam tadi.

Beliau berkata, sekolah-sekolah di Terengganu mengambil pendekatan menubuhkan kelab-kelab berasaskan sains bagi menarik minat murid-murid dan para pelajar kepada bidang sains.

"Penubuhan kelab-kelab seperti Kelab Sains, Kelab Robotik dan Kelab

Suria di sekolah-sekolah rendah dan menengah dilihat berjaya menarik pelajar-pelajar untuk mendalami pelajaran Sains dan penyertaan mereka dalam kelab berkenaan amat memuaskan," ujarnya.

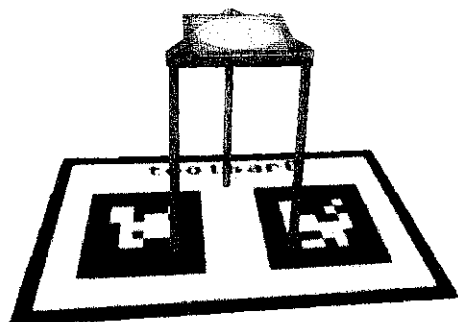
Dalam pada itu, beliau berkata, para ibu bapa terutama di kawasan pendalaman juga perlu diberikan pendedahan mengenai pentingnya anak-anak mereka mengikuti bidang sains.

"Ini berikutan ramai ibu bapa bertaunya kepada saya jika anak mereka mengikuti bidang sains kerja apa yang mereka boleh buat, apa masa depan dan jaminan hidup mereka," katanya.

(Utusan Malaysia, Friday, 28th December 2007, pp.26)

Appendix B – Snapshots

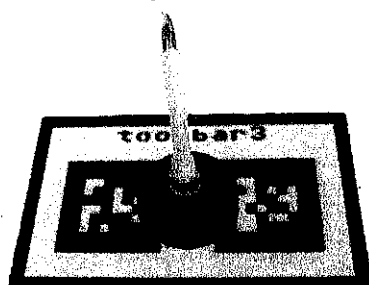
(i) Apparatus Needed for the Experiment



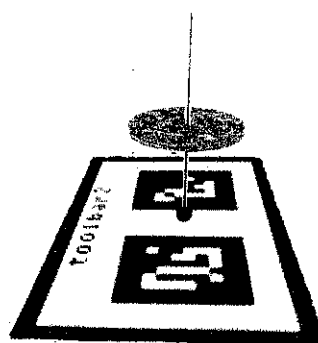
Tripod Stand



Tin Can

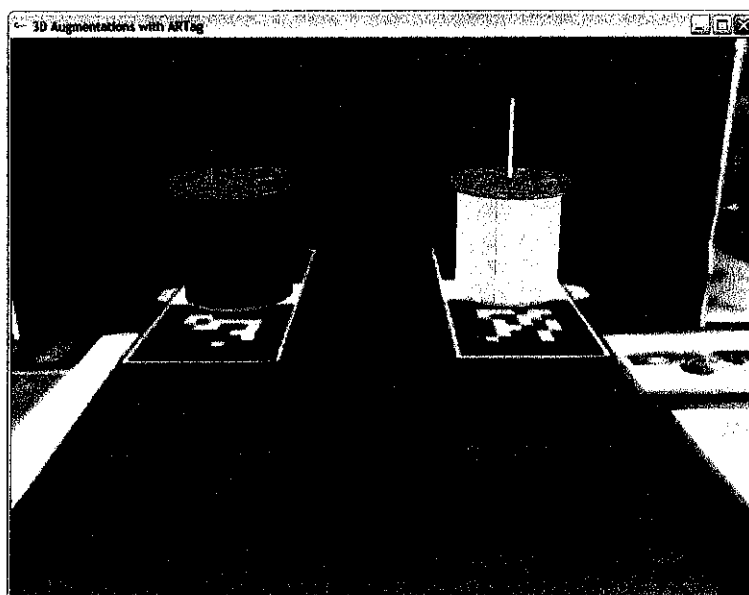


Bunsen Burner



Thermometer & Tin Can Lid

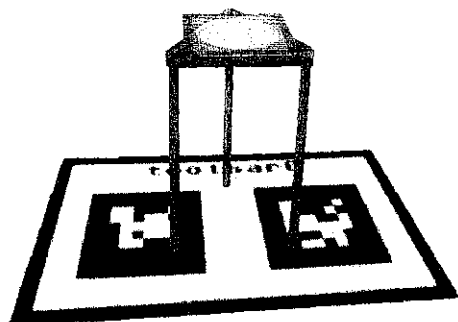
(ii) Example of Experiment – Heat Absorption & Radiation



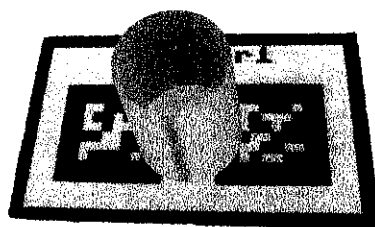
2 Tin Cans with Dark & White Surface

Appendix B – Snapshots

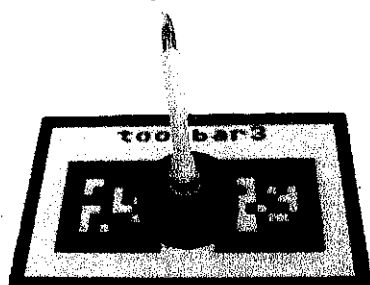
(i) Apparatus Needed for the Experiment



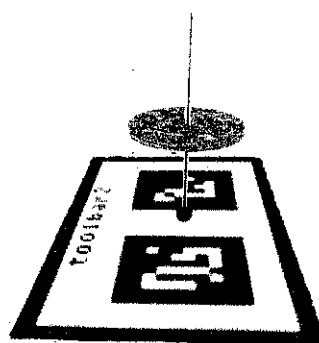
Tripod Stand



Tin Can

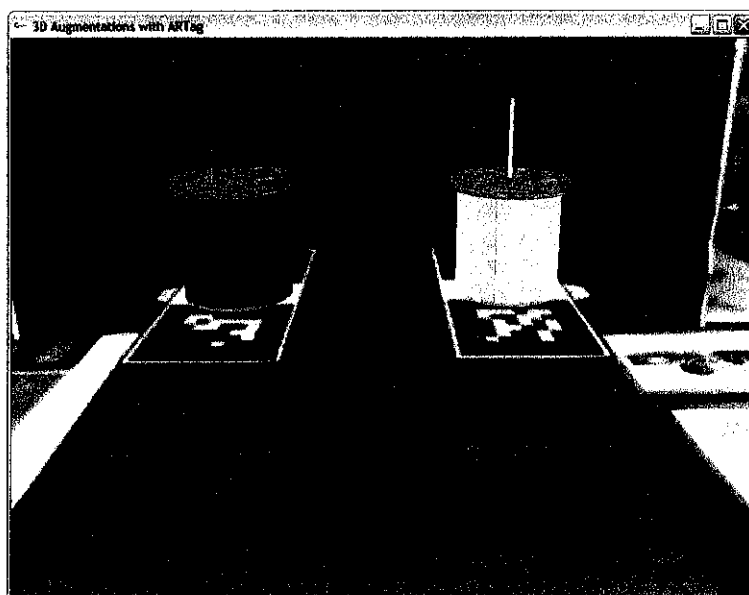


Bunsen Burner



Thermometer & Tin Can Lid

(ii) Example of Experiment – Heat Absorption & Radiation



2 Tin Cans with Dark & White Surface

(iii) Sample Board for the Experiment

