

**Deanship of Graduate Studies
AL-Quds University**



**Developing and Implementing of Augmented Reality
Internet Laboratory**

Shatha Sael Ahmad Abu Shanab

M.Sc. Master

Jerusalem – Palestine

1431-2010

**Developing and Implementing of Augmented Reality
Internet Laboratory**

**Prepared By:
Shatha Sael Ahmad Abu Shanab**

**B.Sc. AnNajah National University / Palestine
Supervisor: Dr. Salaheddin Odeh**

**A thesis submitted in partial fulfillment of requirement for
the degree of master of computer and electronic
engineering - Faculty of Engineering - Graduate Studies
Al-Quds University**

1431-2010

**Al-Quds University
Deanship of Graduate Studies
Electronic and Computer Engineering Master Program**



Thesis Approval

Developing and Implementing of Augmented Reality Internet Laboratory

**Prepared by: Shatha Sael Ahmad Abu Shanab
Registration No: 20320068**

Supervisor: Dr. Salaheddin Odeh

Master thesis submitted and accepted, date: 30-6-2010

The names and signatures of the examining committee members as follows:

1. Head of committee: Dr. Salaheddin Odeh

Signature

2. Internal examiner: Dr. Abdel-Karim Ayyad

Signature

3. External examiner: Dr. Radwan Tahboub

Signature

Jerusalem-Palestine

1431-2010

Dedication

*To my parents, to my family: Rami, Mira, Mohammad, and Yahya Hodrob, to my sisters, and my brothers.
They taught me to always keep looking.*

Shatha Sael Ahmad Abu Shanab

Declaration:

I certify that this thesis submitted for the degree of Master, is the result of my own research, except where otherwise acknowledged, and that this study (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed: 

Shatha Sael Ahmad Abu Shanab

Date: 30-6-2010

Acknowledgements

I have sincere gratitude to my thesis advisor, Dr. Salaheddin Odeh, for his support and fruitful discussions during studying at Al-Quds University. It was a great opportunity for me to conduct the experiments. His ability to solve basic engineering problems and practical knowledge and guided me throughout my research activities.

I am thankful to my parents, Eng. Sael Abu Shanb and Mrs. Salma Abu Shanab and my husband Rami Hodrob for their immeasurable support throughout my life. Without their love, patience and support, I would have never come this far.

Thanks also to all staff members of the Department of Computer and Electronic Engineering / Graduate Studies / Al-Quds University.

Developing and Implementing of Augmented Reality Internet Laboratory

Prepared by: Shatha Abu Shanab

Supervisor: Dr. Salaheddin Odeh

Abstract:

This research is mainly concerned with remote laboratories dedicated for disparate types of scientific and engineering experiments. Our research is aimed at checking and proofing the appropriateness of Augmented Reality to be used in representing client user-interfaces in remote laboratories. The experiment selected here is one of the electrical and electronic engineering. Laboratories present an essential part in engineering education because they provide practical knowledge for students. Unfortunately, laboratories are available for little and limited periods of time for a huge number of students. The number restriction of laboratory experiments refers to costly equipments and instruments required for this type of laboratories. An approach to bypass the mentioned problems is by employing virtual and remote laboratories that assist the students in developing their practical skills, but applying this type of laboratories leads to the fact that students suffer from the weakness of the reality representation of experiment equipments.

In this thesis, we will introduce a novel system that improves performing experimental laboratory through Internet using Augmented Reality technique. Building this system is of great significance, as a prototype is necessary to evaluate carrying out experiments through conventional and ARI laboratories.

To achieve the previously mentioned objective, the applications of AR technologies in other fields will be discussed. Understanding the ideas and the techniques behind such applications might be helpful for contributing of newer ideas to our remote ARI laboratory. Furthermore, in order to categorize our approach in the remote laboratories' landscape, it is significant to be familiar with other kind of remote laboratories as well as the e-learning theory located behind these techniques.

In this thesis, the architecture and the realization of the distributed ARI laboratory play a central for achieving the objectives discussed above; thus, it is significant to realize technical aspects of the implemented system, which combines the augmented reality and internet technologies in order to make the laboratory accessible for students at anytime and from

anywhere. The Augmented Reality Internet Lab (ARI-lab) to be implemented can be accessed from any conventional web browser containing a web-based user-interface, which allows students to set up their experiments. A user-interface based on Augmented Reality contains all required components, virtual and real, needed by the students to manipulate a specific experiment. A video stream of the experiment kit is obtained through a webcam, establishing a basis picture of the AR-based user-interface (AR-UI). The AR-UI, which will be fed with picture data of the physical experiment on the server side, represents one of the major concerns of this thesis. The student interacts with the remote system through the interaction devices mouse, keyboard and monitor. At the begin of an experiment session, she/he has to establish a connection to the remote located AR laboratory, offering a real view of experiment's circuit by adding an overlapping image or text on the delivered webcam picture of kit. Once the connection is established, the student can begin to manipulate the experiment.

After connecting the nodes of the experiment circuit visualized through AR in form of a combined virtual and actual reality, the client program determines what nodes are connected by means of HSL filter and other image processing techniques. Then, the client sends the acquired information to the laboratory server, which validates the correctness of these connections in order to avoid damaging the equipments of the laboratories; after that the laboratory server connects the corresponding switches of the experiment circuit.

Table of Contents

Declaration	i
Acknowledgements	ii
Abstract	iii
Table of contents	v
List of Tables.....	ix
List of Figures	x
List of Appendices	xiii
Publications	xiv
Chapter One: Introduction.....	1
1.1 Problem Statement	1
1.2 Contribution.....	3
1.3 Objectives	3
1.4 Overview of the thesis.....	4
Chapter Two: Augmented reality technology.....	5
2.1 Introduction	5
2.2 Definition of Augmented Reality.....	5
2.3 Milgram’s Reality-Virtual Continuum model	5
2.3.1 Imeersion	6
2.3.2 Augmented Reality against Virtual Reality	6
2.3.3 Computer Vision and Augmented Reality	8
2.4 Basic Components of Augmented Reality System.....	8
2.4.1 Scene Generator.....	9
2.4.2 Tracking System	9

2.4.3 Display Device	9
2.4.4 Power Computer and Software	10
2.5 Applications of Augmented Reality	11
2.5.1 Medical	11
2.5.2 Entertainment	12
2.5.3 Military	12
2.5.4 Design.....	13
2.5.5 Maintenance and Assembly	13
2.5.6 Consumer	14
2.5.7 Education.....	14
Chapter Three: E-learning Assistance in Changing Land of Laboratory	15
3.1 Introduction	15
3.2 New Trends of Education.....	16
3.3 E-learning.....	16
3.3.1 E-Learning versus Online Learning	16
3.3.2 Synchronous versus. Asynchronous Technologies	17
3.3.3 Models of e-Learning.....	18
3.3.4 Benefits of E-Learning	18
3.4 Developing Laboratory	19
3.5 Categories of Laboratory	20
3.5.1 Hands-on laboratory	21
3.5.1.1 Advantages of Hands-on laboratory	21
3.5.1.2 Disadvantages of Hands-On laboratory	22

3.5.2 Virtual Laboratory	22
3.5.2.1 Advantages of Virtual Laboratories	23
3.5.2.2 Disadvantages of Virtual Laboratories.....	24
3.5.3 Remote Laboratories	25
3.5.3.1 Remote laboratory versus Hand-on laboratory and virtual laboratory ...	27
3.5.3.2 Advantages of Remote Laboratories.....	27
3.5.3.3 Disadvantages of Remote Laboratories	28
Chapter Four: Architecture of the Augmented Reality Internet Laboratory System.....	31
4.1 Introduction	31
4.2 Lab Server	32
4.3 User Interface.....	34
4.4 Web Camera	35
4.5 Experimental Kit Development.....	35
4.6 E-Instructor.....	36
Chapter Five: Hardware of the implemented ARI Laboratory.....	37
5.1 Introduction	37
5.2 ARI lab's Kit	38
5.3 Series and Parallel Circuit Experimental Kit	38
5.3.1 Main Circuit.....	39
5.3.2 Auxiliary Circuit.....	44
5.3.3 Parallel Port	46
5.4 Summary	48

Chapter Six: Software Implantation of Augmented Reality Internet laboratory	49
6.1 Introduction	49
6.2 Web-based User Interface.....	49
6.2.1 Home Page.....	50
6.2.2 Login Page.....	50
6.3 APIs of the Implemented ARI Laboratory	53
6.3.1 Setting-up an Experiment.....	54
6.3.2 Virtually Wiring the Real Circuit	60
6.3.3 Saving Results	68
6.4 Summary	69
Chapter Seven: Comparative Evaluation of the Augmented Reality Internet Laboratory .	70
7.1 Introduction	70
7.2 Methodology.....	70
7.3 Discussion of the Results	71
7.4 Summary.....	80
Chapter Eight: Conclusion and Recommendations for Future Works.....	81
8.1 Conclusion	81
8.2 Recommendations for Future Works	83
References	84
Appendix:	88
Arabic Abstract.....	100
Publications	102

List of Tables

Table 6.1: The configuration table is saved on server	47
Table 7.1: Survey results on hand-on, virtual, and ARI laboratories	71
Table 7.2: The experimental time needed in the three different laboratories	75
Table 7.3: Results of the survey of five general questions regarding the usage of the ARI laboratory	75

List of Figures

Figure 2.1: The Virtual-Reality Continuum	6
Figure 2.2: A different VRC representation	8
Figure 2.3: Image Guided Surgery	11
Figure 2.4: Ultrasound Imaging	12
Figure 2.5: Weather Maps	12
Figure 2.6: Cockpits of Military	13
Figure 2.7: Using of AR in aircraft manufacturing	14
Figure 3.1: The realism of Hand-on, Remote and virtual laboratory	20
Figure 3.2: Electronic laboratory in an engineering faculty	22
Figure 3.3: The upper picture is a virtual representation of the lower picture	25
Figure 3.4: Basic architecture of a remote laboratory	26
Figure 3.5: The experiments at client's side as a graphic representation	29
Figure 3.6: Actual experiments on the real laboratory side	30
Figure 4.1: Architecture of the distributed ARI lab system	32
Figure 5.1: General design of ARI lab's Kit in forms of a switching matrix	38
Figure 5.2: The implemented hardware of series and parallel circuit experiment	39
Figure 5.3: The top view and underside of main circuit	40
Figure 5.4: The implemented main circuit	41
Figure 5.5: A relay with double throw switches	42
Figure 5.6: The series circuit	42
Figure 5.7: The equivalent series circuit of the circuit shown in Fig. (6.6) by using a switch	43

Figure 5.8: The parallel circuit	43
Figure 5.9: The equivalent parallel circuit of the circuit shown in Fig. (6.8) by using a switch	43
Figure 5.10: Auxiliary circuit	44
Figure 5.11: The implemented auxiliary circuit	45
Figure 5.12: Pin configuration of the parallel port of the PC	46
Figure 6.1: Home page of the remote ARI laboratory system	50
Figure 6.2: ARI lab's access process in forms of block diagrams	51
Figure 6.3: The Login page of the ARI system	51
Figure 5.4: a web page listing various experiments	52
Figure 6.5: The start web page of a specific experiment	53
Figure 6.6: Video stream of the experiment displayed on the client GUI	54
Figure 6.7: Both terminals of resistor with red LEDS	56
Figure 6.8 : The flow chart of HSL color filter	57
Figure 6.9: Input (left) and output (right) image of the HSL filter	58
Figure 6.10: The result of transforming the output image of the HSL filter to a matrix of pure symbolic data of the values 1 and 0	59
Figure(6.11): A section of node matrix that contain the node's numbers of some components on a kit	60
Figure 6.12: A virtually wired real circuit in the remote ARI laboratory leading to augmented reality based visualization	62
Figure 6.13: The results of ARI laboratory's experiment that the student can show through the transmitted live video of the kit and its instruments for his computer's screen	64

Figure 6.14: Starting a new experiment session through a pull-down menu.....	65
Figure 6.15: The results of ARI laboratory's experiment of a second example.....	66
Figure 6.16: Remote laboratory gives actual results but the components and instruments of experiment are symbol or visual graphics	67
Figure 6.17: Color wire	68
Figure 6.18: Saving an experiment session.....	68
Figure 7.1: Survey results on hand-on, virtual, and ARI laboratories	72
Figure 7.2: Bar chart of the survey result of the question “I think that the augmented reality internet lab is more real than a virtual lab”	77
Figure 7.3: Bar chart of the survey result of the question “I think that I learn and understand more in an augmented reality internet lab than a virtual lab”	78
Figure 7.4: Bar chart of the survey result of the question “I can use augmented reality internet laboratory over the Internet instead of a physical hand-on lab”	78
Figure 7.5: Bar chart of the survey result of the question “I can use augmented reality internet laboratory over the Internet as supplementary to a physical hand-on lab”	79
Figure 7.6: Bar chart of the survey result of the question “I think that the augmented reality internet lab offers more relaxation than a hand-on because participants are away from electrical instruments and the instructor”.....	80

List of Appendices

Appendix A: The Implemented Code in programming language C#.....	89
Appendix B: RGB and HSL Color Model.....	96

Publications

Odeh, S., Abu Shanab, S. (2009) "Remote Experimentation Using Augmented Reality," *Ubiquitous Computing and Communication Journal*, vol. 4, no. 1, ISSN 1994-4608.

Chapter One

Introduction

The Internet allows conducting an experiment through web browsers from anywhere and at any time. This improvement has offered opportunities to explore new teaching methodologies that make use of these technologies to enhance science and engineering laboratories [1]. An example of this is the current thesis of building an Augmented Reality Internet ARI laboratory for electrical and electronic engineering laboratories.

1.1 Problem Statement

High pressure in universities and increased numbers of students reduce opportunities of learning, especially at engineering and science colleges where there are needs for practicing besides theoretical courses. In education of engineering, there are laboratories for most of the courses that give the students better understanding of theoretical concepts [1], [2].

Almost future works of engineering students will be in practical field, which demands from them more time and efforts in laboratories. After graduation, they will not only depend on their theories acquired during their study at the university, but on their practical knowledge they acquired by engineering laboratories. Unfortunately, laboratories are available only for a limited time for that huge number of students.

Virtual labs imitate the hand-on laboratory; that is, instead of performing the experiment on actual equipment, the tests, and possibly even the data, are simulated on a computer [2].

There are also remote labs, which enable students to carry out an experiment remotely through the Internet. Remote labs are simulated completely on computer; students are allowed to

connect remotely and to control laboratory's equipments, using cameras to visualize experimenting results. Furthermore, a remote laboratory provides access to expensive and scarce equipments. This consideration was one of the primary motivations in building the ARI lab [2], [3].

As it was explained, engineering students graduate with insufficient practical experience in many fields although their theoretical knowledge might be deep. One main reason is the lack of available laboratories. Unfortunately, other solutions such as virtual and remote laboratories that are innovated to assist the students to develop their practical skills, cannot completely replace hand-on laboratories, because they lack reality and try to visualize instruments and experiments as graphics. In virtual reality, experiments' data are obtained from mathematical model (theoretical calculation), missing of instrumental errors, what weakens students' reference to reality, and thus, they can't later deal with these components and instruments in real work [3], [4].

In this investigation, a new emerging technology called Augmented Reality (AR), which combines the interactive real world with a generated one by an interactive computer system in such a way that they appear as one environment, tries to bypass the previously mentioned problems through providing students with AR laboratories as a combination of "real" laboratories augmented by virtual objects [5]. ARI laboratories similar to other Internet-based laboratories are available for students independent of time and place, and can be seen as practical feature of e-learning.

The kit of ARI lab is transmitted through a camera from lab to computer screen of student, where the student does his experiment; the kit has particular designed, it hold all required real electrical and electronic components; student can set up their experiment through selecting and wiring the components from his computer, the system use augmented reality technology to wire the components by overlapping graphics of wires on a kit. Then, the client sends the acquired information to the laboratory server, which validates the correctness of these connections in order to avoid damaging the equipments of the laboratory; after that the laboratory server connects the corresponding switches of the experiment circuit. Real data can be obtained from the screen of instruments through a transferred live video.

1.2 Contributions

As is obvious, this thesis is aimed at replicating hand-on laboratories as much as possible in order to overwhelm the lack being in virtual and remote laboratories in reproducing reality to be more effective in assisting students to develop their skills. In order to achieve this goal, we had to implement a novel system aimed at improving performing remote laboratory experiments through Internet using Augmented Reality technique. After having designed and implemented a prototype of the distributed ARI laboratory, an evaluation to compare carrying out engineering experiments through our novel ARI laboratory with a conventional one had been done. Through the comparative evaluation executed and our own experience with the ARI laboratory, we can summarize the major contributions as follows:

- Using stream videos of the real instruments located in remote laboratory are used to visualize measured values on the client user-interface allows the student to move seamlessly from AR representations of test equipment in a remote laboratory environment to actual test equipment in a real laboratory and to be capable of using this equipment competently as a direct result of their online experiences. Offering a real view of experiment's components and instruments relieves the students in distinguishing the instruments used in a hand-on laboratory through the transferred live video stream of that experiment carried out.
- Inventing an ARI laboratory that can be not only easy used by students, but enables them to understand the concept theory as well. Moreover, it must be flexible regarding usage in relation to time and place, offers a safety environment and satisfying than virtual laboratories.
- Using expensive and scarce instruments is no more a hindrance, as an e-instructor implemented as a subsystem informs of a software program prevents making any mistake connections, leading to prevent damage the instruments.

1.3 Objectives

By developing and implementing the augmented reality internet laboratory , the following goals and objectives were intended to be achieved:

- To reproduce hand-on laboratories (experiment and instruments) as much as possible to allow students to move seamlessly from AR representations of test equipment in a remote laboratory environment to actual test equipment in a real laboratory.
- To enable the students to access the laboratory from any PC's connected to the internet and at any time.
- To perform real experiments remotely. Then, results of an experiment will be online visualized imitating hand-on laboratories.
- To perform student's experiment with no fear of dealing with the instruments and components by hand.
- To protect the components or expensive instruments from damage through introducing an e-instructor, which is available to prevent connection mistakes.

1.4 Overview of the Thesis

This section provides a brief overview of this thesis which describes the design and the implementation of the ARI-lab. The thesis document is divided into seven chapters. The current chapter provides an introduction and a problem statement for this research. Chapter two introduces and defines AR technology and represents some applications of AR in other fields. Chapter three discusses the new technologies that assist in changing the learning in the laboratory. It also describes definitions, requirements, advantages and disadvantages of hands-on lab, and simulation and internet labs. Chapter four describes the system architecture of developed ARL lab. Chapter five illustrates the components of the hardware system such as interface and control, how each component interacts with others, and the roles of each component used in building the completed ARI lab system. Chapter six deals not only with the software part of ARI lab but also illustrates how a user interacts with laboratory equipment through the Internet. Chapter seven presents a comparative evaluation, which compares our system, the ARI laboratory, with hand-on and virtual laboratories. Chapter eight finalizes the work with a brief summary.

Chapter Two

Augmented reality technology

2.1 Introduction

Augmented Reality (AR) system is progressing more and more with developing technology. Augmentation can be made with various different techniques in order to enhance the users surrounding environment in real-time. Nowadays, applications of AR are not restricted in specific area but can be founded in many area and field in our life.

This chapter overviews the basic definitions of AR, the major concepts of this technology, in addition of describing some applications of AR.

2.2 Definition of Augmented Reality

Augmented reality is the combination of real environment with virtual computerized objects (such as text, 2D images, or 3D models) and/or enhancement to sound, graphics or other human senses. The appearance of user in this ultimate system samples as he is working in a single real environment [6], [7].

2.3 Milgram's Reality-Virtual Continuum model

Milgram (Milgram and Kishino 1994) explains a taxonomy that identifies the relation of real and virtual environments. He defines the Virtual-Reality Continuum (VRC) shown in Fig.(2.1). The real world and the virtual environment are at the two opposite ends of this continuum with the middle region called Mixed Reality (MR).



Figure 2.1: The Virtual-Reality Continuum.

On the right side of the Virtual-Reality Continuum axis, pure virtual objects which would be normally generated by computer graphics programs are located; oppositely, the left side includes completely real objects that include direct viewing of the same real scene, without any particular electronic display system.

A MR environment is a region in which real world and virtual world objects are presented together within a single display.

Virtual augmented systems are mostly virtually represented with some real objects added. AR lies close to the real-world at the end of the spectrum with the predominate perception being the real-world augmented by computer generated information.

There are several classes of displays used in AR systems that will be discussed in section 2.2.3. Every class offers a different sense of immersion in the virtual environment presented to the user [7], [8][9], [10].

2.3.1. Immersion:

Immersion is one way that is used to evaluate the virtual reality and augmented reality system; that is, the role of AR in combining and extending real and virtual worlds. The term of immersion examines the strengths of real world and virtual world in the manufactured environment. Achieving a perfect immersion would eliminate the line between reality and VR. There are two types of immersion [11][12], [13]:

- **Physical immersion** is achieved by presenting to users a world and synthetic stimuli to one or more of their senses based on participants' positions and in response to actions. Physical immersion is important element of an augmented reality and virtual reality system which distinguishes real from virtual objects. The components of physical

immersion: perspective-dependent images to each eye, synchronized audio to ears, and haptic information to body. These qualities must be adjusted in response to the users' positions. For example, approaching targeted objects means the object must provide a greater sound, be bigger in size and so forth when proximal.

- **Mental Immersion** can be achieved by fixed image visualization media. Mental immersion is described as "a sense of presence" within an environment. It is not as quantitatively controlled as physical immersion. Additionally, it is often difficult to measure the degree of necessary immersion or even how it is to be attained. Mental presence is dictated by various factors under different environments. How much sensory immersion is essential to create mental immersion is another topic that is still under investigation. Factors which present together for creating a mental immersion:
 - **Personally meaningful world** which covers the subject and presentation manner of content aimed to engage.
 - **Interactivity** which presents content through computer where the user can control action.
 - **Resolution** which includes a resolution of display modalities, spatial as amount of information in image, temporal (response to dynamic changes) as frame or sample rate.

The time and motion in virtual reality is not predetermined as in computer animation. It provides more chances to users to act as if they are in the physical world, making the user to obtain more accurate mental sense of visualized space.

2.3.2. Augmented Reality against Virtual Reality:

AR environment and virtual reality (VR) environment have been defined as the opposite ends of a continuum which are referred to as (VRC).



Figure 2.2: A different VRC representation.

In the VR, the user is completely immersed in, and able to interact with a totally virtual environment. Virtual environment is just a copy of the properties (abstraction) from some environments, whether this environment is really or fictional. This VR environment holds physical laws normally governing space, time, mechanics, material properties, etc.

In contrast, an AR system generates a combined view for the user. The user sees an image that is the combination of the real object and a computer-generated virtual object. The virtual object augments the real environment with additional information. An AR system augments the real world scene and attempts to preserve the user's sense of being in the real world. To preserve the user's immersion in the real world, an augmented reality system merges the virtual images with a view of the real scene to create the augmented display [9], [10], [14].

2.3.3. Computer Vision and Augmented Reality:

Computer vision is a diverse and nearly new field of study. There are an abundance of methods for solving various computer vision tasks. As there is not standard formulation of computer vision problems, these methods solve a specific task and rarely are used for a wide range of applications.

Augmented reality systems are using computer vision methods to assure an alignment between the real world and the virtual object since it depends on the accuracy of taken information from the pixels that improve its functionality in solving the problem of tracking the virtual objects over the real sense. [14][15].

2.4 Basic Components of Augmented Reality System

The main goal of AR system is to create a system such that the user can not notify the difference between the real world and the virtual augmentation of it.

Nearly all AR systems can be consisted of four components: first, they must have scene generator that generate some input object. Second, tracking system offers natural view by providing a virtual part in synchronous with real part. Third, display is a kind of the output device, such as monitor or head mounted display. Finally, a computer power and suitable software offer the desired control of these components [7][14][16], [17].

2.4.1. Scene Generator:

The scene generator is the device or software in order to rendering and processing the graphic. The graphic process starts as the system running. Only some virtual objects need to be added or drawn so it is not mainly component of AR system [7], [14].

2.4.2. Tracking System:

Tracking System is the software that aligns the real and virtual objects in order to appear in rich integrated ambient environment; the objects must be properly aligned with respect to each other. Many applications require accurate and rapid tracking, especially on medical field. It is to note that tracking system is the critical and important point in AR system [7], [14].

2.4.3. Display Device:

Displays are the output devices (terminals) of AR systems to users. The user can see through the displays the ultimate environment directly such as monitors, mirrors and head mounted displays (HMD). The technology for AR is still in improvement and solutions depend on design. There are some factors as resolution, flexibility, field-of-view, among others that depend on the used display device [7], [14],[17]].

There are several classes of AR displays, which could reasonably be considered to constitute a different sense of immersion in the virtual environment presented to the user, Such as [6][7], [10][14]:

- **Window on the World:** Window on the World (WOW) system is the simplest augmented reality system. The client can show the augmented environment through a window as a computer monitor. The real part of an environment is recorded after that the augmented with computer generated objects is added to real objects and then

displayed on the window. In this system, the client is not in the center of the AR system, as he is outside of it.

- **Spatially Immersive Display:** Spatially Immersive Display (SID) surrounds the client with multi large screens. In SID system, the client is actually inside the environment. The client body is not hampered with weight of equipment.
- **Head Mounted Displays:** In this system, the client wears Head Mounted Displays (HMDs) that record the real environment, then add the augmented parts, and finally display them in a single environment with respect to the client. However, many augmented reality approaches are using (HMDs) because of their suitability in many application areas like maintenance, training etc.

There are two types of HMDs [10], [17]:

- **The optical see through:** This type combines the real environment with computer generated object using mirror optics. There are some drawbacks: the real environment does not need processing that makes the computer generated object delayed.
- **Video see through:** It is similar to WOW and SID systems; it records real environment with augmented then displays merged video from cameras on the HMD. Video see through is flexible when it comes to mobility as the user moves in real environment, and continually updated when user can view from different points. For that it seems as single and real environment in the sense.

2.4.4 Power Computer and Software

The previous components must be controlled in some way; the controls are performed by the computer and appropriate software. Ideally, this component would be small, portable, cheap, and powerful.

Many AR applications are all independent because any software creates for a specific task in certain applications. There is no general software that can be used for a wide range of tasks [14], [16].

2.5 Applications of Augmented Reality

Augmented Reality technology is in progress through developing the capability of real-time video image processing, computer graphic systems and new display and technologies that make possible creation of an augmented environment. Researchers working with AR systems have tried to find solutions in many domains. As AR technology develops more application extends in various domain of our life as entertainment, education, medical, engineering and manufacturing.

2.5.1. Medical:

Imaging technology is so important in medical field. Most of the medical applications deal with image guided surgery. Images, such as CT or MRI scans, of the patient afford the surgeon with the necessary view of the internal anatomy. From these images the surgery is planned. The surgeon visualizes the path through the anatomy to the affected area from the multiple views. Fig.(2.3) shows how augmented reality can be applied so that the surgery team sees the CT or MRI data correctly registered on the patient in the theater; the images will enhance the performance of the surgical team and may eliminate the need for the painful.



Figure 2.3: Image Guided Surgery

Ultrasound imaging is another application of AR, using an optical see through display the ultrasound technique can view a volumetric rendered image of fetus overlaid on the abdomen of the pregnant women [7], [8][17].



Figure 2.4: Ultrasound Imaging

2.5.2. Entertainment:

A simple application of AR appears in entertainment and news business. Whether you are watching the evening, or whether reports the speaker remains standing in front of changing weather maps, this real image is augmented with computer generated maps; this system uses calibrated cameras and careful measurements of the position of objects in the real studio.



Figure 2.5: Weather Maps

Augmented reality can be applied to improve games that people play. At this system, the players see the game area along with their real opponents and virtual players that are also playing along with them [7], [9], [17].

2.5.3. Military:

The cockpits used by military present information to the pilot on the windshield of the cockpit or on the visor of flight helmet.



Figure 2.6: Cockpits of Military

By autonomous ground units, aerial views are augmented with additional information into video surveillance equipment monitor. Also aerial reconnaissance units identify suspect objects and send the location of these objects to the ground units. The suspect objects may be hidden from the view of the ground forces but will appear in the augmented view on their displays [6], [7], [17].

2.5.4. Design:

The designers and clients can show design review even in physically separated . The designers have built the prototype that is imaged and displays in conference room. The clients can walk around the display at different view of it and he can point at these designs at earlier stage before it will be built [6], [7].

2.5.5. Maintenance and Assembly:

Recently, the complexity of equipments function has been improved and has brought more probability of error-arising. Occurring an error needs to display the status of equipments after maintaining and repairing of errors. To reduce the lost of equipment failure, we have both to increase the maintaining efficiency and to reduce the repairing time. In the procedure of repairing, maintenance must be discovering problems and then thinking equipment state. An AR display can view new and unfamiliar parts of equipment as a replacement of using several manuals. Moreover, it has the advantage to show additional information about the failed equipment.

AR systems incorporate into aircraft manufacturing and maintenance activities. As shown in Fig. (2.7), the augmented display shows the mapping of the cables on a frame used for all

harnesses. The augmented display allows a single fixture to be used for making the multiple harnesses. Augmented reality systems guide technicians through maintenance and repair sequences [7], [17].

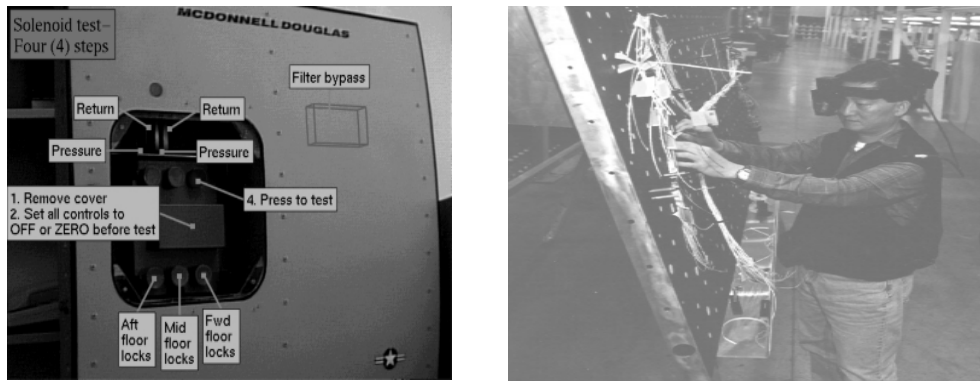


Figure 2.7: Using of AR in aircraft manufacturing

2.5.6 Consumer:

Augmented reality system would be benefit the fashion and beauty industry that can be imagined. Augmented system can display the image of particular style dress; so the consumer can see the three sided mirror of new dress on his body, also he can view changes in hem length, shoulder styles or other particulars of the design before he choices the order [14].

2.5.7. Education:

AR system contributes in changing the traditional education methods. It can visualize model which can contribute in improvement student's comprehension. AR adds interactivity to the learning process.

There are several applications of using AR in education. It has been concerned in teaching the geometry, spatial relationships between planets, molecule structures, surgical training and education of children [9], [17].

Chapter Three

E-learning Assistance in Changing Land of Laboratory

3.1 Introduction

The progression of E-learning is initially began in the form of correspondence such as printed materials, after that through multimedia, then depending on information technology such as audio-video conferences and, nowadays, through the internet [18], [19].

The development of e-learning and multimedia technologies is adding a new ways for teaching and training, enabling the e-learning approach to occupy a larger part of academic learning methodologies [20].

Nowadays, there are many engineering education researches, which focus on e-learning in order to create systems combined of experiment and theory for engineering science laboratories. The environments of laboratories have been changed by e-learning technologies. Different technologies allow changing in the laboratory education land. This begins with the hand-on laboratory, which enforces students to be locally present in laboratory. The next type, the virtual simulated laboratory, supports the distance learning approach, where students can do their experiment at any terminate computer from any place and at any time. Finally, a remote laboratory which samples a virtual laboratory in its representation on the user-interface, enables the students to carry out synchronous experiments at any time and from any computer that is connected to the internet [19], [20][21].

3.2 New Trends of Education

It is undeniable that contemporary technologies have made central changes in the ways of education. A lot of technologies such as bandwidth, video, internet and voice technology have been improved, leading to increase the demand on e-learning. Nowadays, an ordinary person can access huge quantities of information and knowledge from any terminate computer [20].

Although some people may consider the e-learning is a luxury, e-learning satisfies the needs of the community and adds new solutions for education problems such as the increasing demand on education, and the continually increasing numbers of students. Such problems occur not only in the developing countries but also in industrial countries. As mention, it is a way of learning that is not restricted of place or time [19].

3.3 E-learning

E-Learning is delivered or enabled learning via electronic technology. Electronic technologies cover the internet, television, videotape, intelligent tutoring systems, and computer-based training. E-learning via electronic technology assist the education and training environment. E-learning is increasingly complex since new technologies continue improvement [18], [22].

The requirements for successfully e-learning are: network security, suitable bandwidth, cheap and reliable access to the internet [19]. The requirements of educational processes on information and communications technology make a decision whether the teaching activities must be based on asynchronous or synchronous learning [23].

3.3.1. E-Learning versus Online Learning:

A lot of people believe that the e-learning and the online learning are the same and there is no difference in meaning. But every term has a particular identifier.

E-Learning is derived from the words 'Electronic Learning' that contains all electronic media such as internet, satellite broadcast, audio/video tape, interactive TV, and CD-ROM. Nowadays, e-learning has a number of application that can be easily seen in our life as computer-based learning, Web-based learning, virtual classrooms, and digital collaboration

what makes e-learning to be considered as the whole category of technology-based learning [18].

Online learning, whose definition is synonymous with web-based learning or Internet-based learning, includes animations, simulations, audio and video sequences, peer and expert discussion groups, online mentoring, links to material on a corporate intranet or the Web, and communications with corporate education records. It is obvious from the previous definition that online learning presents a subset of e-learning [18].

3.3.2. Synchronous versus Asynchronous Technologies:

As previously explained, the applications of e-learning determine whether the content of e-learning is synchronous or asynchronous; the differences between the two technologies or their mixtures is shown in the following [24]:

- Synchronous models are a real-time communication that carries out actions at the same time such as instant messaging or chat rooms and audio/video conferencing. The advantage of synchronous models supports the social side of learning, but synchronous models are more costly and require more developed technology such as higher network speed, and more complex equipment as web cameras [24]. The synchronous models can be used when the students work remotely with the laboratory equipment. The Internet enables the students with remote access to control physical laboratory apparatus, using video stream in quasi real time that give students a sense of actual environment of the experiment [25].
- Asynchronous models enable the user accessing the information whenever needed at anytime and from anywhere, such as multimedia presentations, message boards, web pages or online quizzes [24].
- Hybrid models are mixed from previous two models for exciting possibilities for e-learning which encourage social learning [24].

3.3.3. Models of E-Learning:

There are three models of e-learning [24]:

- **Presentation Model:** The information of this asynchronous model is presented via text, graphics and sound as a demonstration, a simulation, a story or a movie. Presentation models attract learner's attention. One advantage of presentation models is that there is no need for more devices to present the information for a large numbers of learners, but argument doesn't exist in this model.
- **Interactive Model:** Using the interactive model, the information can be presented to the learner by interacting directly with the learning material such as answering test questions, running experiments, or connecting objects and concepts. As an example, a chemistry student can do their experiment in a simulated environment, where he can mix the chemistry material and takes the results from simulated model.
- **Collaboration Model:** The collaboration model describes interaction between users in an online society. Contemporary Internet technologies such as web-based video conference, email, and broad message make the discussion and collaboration between the participants more effective.

3.3.4. Benefits of E-Learning:

The benefits of e-learning quickly widen in our life; many people can continuo their education dependent on this technology. A number of benefits of e-learning [17], [21], [24] are listed in the following:

- Information are reachable form anywhere, at anytime and from anyone; the expansion of the World Wide Web, high-capacity networks, and high speed of computers assistance increasing the demand for e-learning so that an ordinary person can access information resources at home or in the office.
- Elimination the expense of travel for the students and instructor; e-learning doesn't enforce the existence of the student and instructor at the same place.

- Web-based allow instructors to retrieve information across the entire network immediately so that they offer fresh data to the students.
- Online environments in e-learning improve the collaboration and interactivity among students. It may include text, audio and video-conferencing. Distance education can be more encouraged than a traditional class because it allows the kind of interaction that takes place nearly full in small group.
- Students are less frightening in online courses than in traditional classrooms. If the student does not success, he can go back and tries again. This method of learning reduces the embarrassment of mistakes in front of a group.
- New models (sound, virtual depictions, alternative explanations) are created to teach the student which can not clearly be understood at the first time. Huge of information can be presented in dynamic ways, making learning more quickly.
- E-learning changes the traditional model for education, which relies on physical plants, libraries and laboratories as simulations and animations support experiential learning and teaches complex processes.

3.4 Developing Laboratory

The main purpose of engineering education is to prepare engineers who can deal with equipments and instruments. Since engineering is an applied science, its courses are containing the biggest part of laboratory studies. Therefore, laboratories are essential in scientific education [21], [25], [27].

Recently, the environments of laboratories have been changed by e-learning technologies, which have opened many doors in education. Students learn more efficiently if they have the chance to carry out experiments because they allow students to compare theories with experiments, collaborate with each other, and give them chance to follow their interests [28]. Unfortunately, many engineering courses do not contain laboratory component because of great expense and space considerations [21], [25] [27].

Different technologies offer new ways of many educational objectives that changed the laboratory education land [20]. By using text, pictures and illustrations, and multimedia, we can build simulations of complex processes of biological and medical sciences, agriculture, engineering and educational practice, which are not easily accessible in real time and settings. Simulations allow a student not only to see what is complex, but he can learn from hands on experience as well [23].

Universities are trying to reduce or eliminate financial of maintaining expensive equipments in traditional laboratories. Remote and virtual laboratories may be created as way to share hand-on laboratory for improving requisite skills of future engineers and satisfy economic constraints [21], [27].

Remote Laboratories can consider a section of e-learning in actual scientific researches, such as on-line courses, virtual classrooms, educational intranets, self-training, e-projects and role playing [29].

Remote laboratory differ from virtual laboratories in degree of accurate and reliable description of a real- world system. Every category of laboratories attempts to reach the reality as appear in Fig.(3.1).

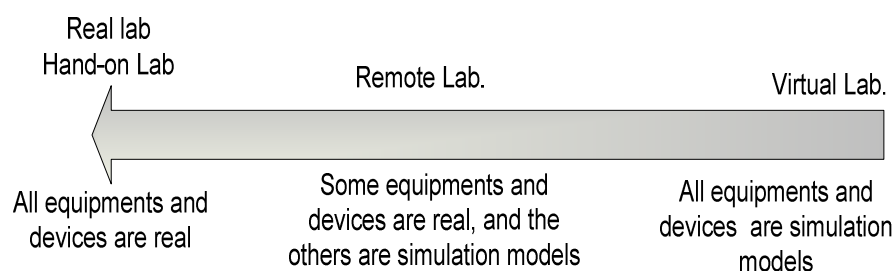


Figure 3.1: The realism of Hand-on, Remote and virtual laboratory.

3.5 Categories of Laboratory

Continues development of new diverse technologies supports the changing of laboratory education land. New categories of laboratories are invented to assist the hand-on laboratories

for improving the students' skill in application parts of their studies, and for protecting the rare and expensive instruments from damage.

Nowadays, many types of laboratory appear beside hand-on laboratories in the form of software or both software and hardware. These types of laboratories are classified in three categories:

1. Hand-on laboratories.
2. Virtual laboratories.
3. Remote laboratories.

The following sections discuss in-depth these types regarding different characteristics, and advantages and disadvantages.

3.5.1. Hands-on laboratory:

In a hands-on laboratory, a real experiment is locally realized. Two characteristics differentiate hands-on from the other two laboratories [21]:

- The real equipment that is used in the laboratory is physically locally connected.
- The students and the equipments must locally present in the same land of laboratory.

3.5.1.1. Advantages of hands-on laboratory:

A Hand-on laboratory achieves numbers of benefits that all researchers are trying to reach them in other categories of laboratories such as:

- Hands-on laboratories give real results, from which part of these results such as unexpected data spans the gap between theory and practical experiments that are necessary to enable the students to understand the objectives of experiments [20].
- As design is an essential element of laboratories, hand-on laboratories can increase the design hand's skill of the students that are not present in virtual laboratories [20], [25].

3.5.1.2. Disadvantages of Hands-On laboratory:

Unfortunately, several drawbacks that contemporary researches are trying to avoid, accompany; some of these drawbacks are:

- Numbers of students and allocated times is restricted that refer to limitation on numbers of equipments and devices [21].
- Hands-on experiments are very expensive as there is a necessity for rare or expensive equipments that require a costly frequent maintenance. Moreover, instructors must be present with students in laboratories [21], [25].
- Hands-on laboratories need a space that accommodates the students and equipments for experiments as it is illustrated in Fig. (3.2) [21].



Figure 3.2: Electronic laboratory in an engineering faculty

- The duty of hand-on laboratories increases by increasing student numbers, while staff and funding resources have scarcely changed [29].

3.5.2. Virtual Laboratory:

In the last decades, the usage of virtual laboratories (simulation laboratory) has increased rapidly in engineering education. Virtual laboratories enable the student to access the engineering applications easily at anytime and from any computer. Examples of these

engineering applications are simulations, demonstrations, and exercises. Virtual laboratories are very essential for proving the theory by practicing mathematical models [30].

A virtual laboratory is a software simulation, which is an imitation of a real experiment represented by a mathematical model. The entire infrastructure required for laboratories is not real but achieved through computer generated graphics [21][27].

Simulations have an extensive usage in education and entertainment; examples of simulations are flying a plane, sailing a boat, practicing investment strategies, practicing negotiations skills, and simulating a surgical operation. Traditional simulations have been generally designed for running on a single machine. The explosion of internet and new technology has allowed creating web-based simulation. Web-based simulations have three categories [31]:

- Virtual laboratory's programs can be accessed remotely through a Web browser on the server.
- Virtual laboratory's programs are downloaded from servers and execute on the client computer.
- Virtual laboratory's programs display web-based execution on the client computer like java applets.

3.5.2.1. Advantages of Virtual Laboratories:

A virtual laboratory offers the following benefits [21], [30], [31]:

- Virtual laboratories are seen effective as traditional hands-on laboratories that improve students' performance.
- Increasing the number of experiments in order to improve understanding the concepts of experiments.
- In dangerous modeling experiments (such as nuclear plants), students can carry out their experiment and take their results at safe places.

- Modeling of expensive equipments decreases the cost; these kinds of model enable the students to perform several experiments without worrying about the costs.
- The number of users of the virtual laboratory increases when accessed through Internet.
- The design of virtual experiments can be ergonomic and thus more user-concerted that is accomplished by using color such as showing the degree of temperature what can be restrictively done in a hands-on laboratory. This way makes the most useful teaching approach.

3.5.2.2. Disadvantages of Virtual Laboratories:

Despite of achieving all these benefits from a virtual laboratory, some problems notice in this category of laboratory such as [21], [31]:

- The results of virtual laboratories are not real because they are obtained from a mathematical model what eliminates the error that may be occurred from components and instruments in a hand-on laboratory. Therefore, the students can't learn by trial-and-error.
- A virtual laboratory is somewhat costly; the cost of simulation is not necessarily lower than hand-on laboratories.
- A virtual laboratory does not give the same feeling as working in a real laboratory as it is indicated from in Fig. (3.3).
- Student must learn how to use a virtual laboratory which requires more time and efforts.
- The development of a virtual laboratory is started from scratch and reuse is restricted because several graphic components needed for the presentation must be tailor-made.
- The built virtual models are not correctly mapped with the conceptual model.

- A virtual model is not flexible and has a restricted option for experimentation.

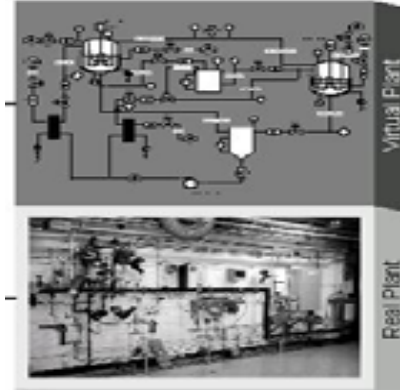


Figure 3.3: The upper picture is a virtual representation of the lower picture.

3.5.3. Remote Laboratories:

Remote Laboratories benefit from contemporary e-learning and Internet technologies. Now, many academic institutions provide a variety of remote laboratories experimentations designated as web-based laboratories or online laboratories; these laboratories support remotely controlled physical experiments [21], [27], [32].

Remote laboratory may be defined as a laboratory accessed via a communication network in order to execute a laboratory experiment, whose usage involves real devices and equipments. The laboratory server communicates between the user and the physical experiment in the laboratory[33].

This type of laboratory is suitable to distance learning courses where students do not need to be locally present on campus. The students can use it at any terminal computer in the world. Traditional electronics laboratories for undergraduate education at universities contain nearly the same equipments although these instruments are manufactured by different companies. Most instruments already support remote control. Teachers and many students are already familiar with these laboratories. It is easy to make such a laboratory accessible for remote operation and control [27], [30],[31]. The instruments that is controlled through personal computer, is the core of the remote laboratory. These instruments can be remotely configured by software that makes it easily to share of expensive instruments and equipments [25].

A remote laboratory must be provided with an interface to send commands and receive feedback from the laboratory equipments. There are a number of methods that provide remote access to the laboratory equipments. The general method is the use of a web browser (such as Netscape and Internet Explorer) and a client server system. User access is regulated by schedule and limited time. Security can be achieved by using user name and password authentication [25].

The common principle of remote laboratory experimentations is that students can access the system through Internet; Fig. (3.4) demonstrates that remote laboratories allow students to directly deal with real equipments, to change control parameters, to run the experiment, and to see the results and data through a web interface [25], [27].

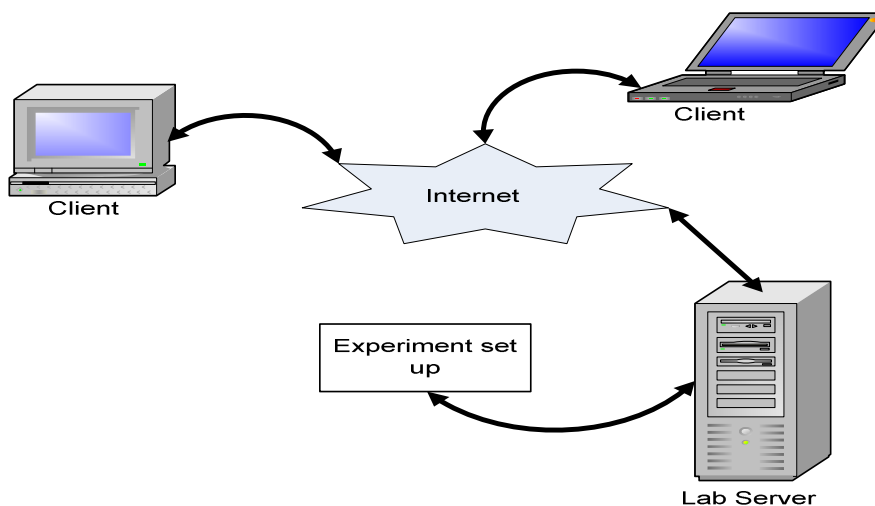


Figure 3.4: Basic architecture of a remote laboratory

Remote laboratories are increasingly being in universities for various reasons [25], [27], [30], [34]:

- Distance learning laboratories are the most common uses of this technology.
- A low cost implementation is essential that enables access to the expensive equipments.

- Low hardware, software and maintenances costs.
- Reducing the number of laboratories because hand-on laboratory work requires more space.
- Standards are defined to a common for the functionality of instruments in an electronics laboratory.

3.5.3.1. Remote laboratory versus Hand-on laboratory and virtual laboratory:

Remote laboratories samples hands-on laboratories in that they require space but only for equipments and devices. But they differ from hand-on laboratories in that there is a distance between the experiment and the students who can get data by controlling equipments from physical distances.

The output of some experiments may be measured by a PC connected to the experimental equipment. From pervious, a pure hands-on laboratory is rare, So the interactive feature of laboratory may not differ much, whether the student is presented with the apparatus or not. On the other hand, most laboratory environments may be a mixture of hands-on and virtual (simulated) tools. For that reason, hands-on and remote laboratory of some experiences may be similar for the student [21].

3.5.3.2. Advantages of Remote Laboratories:

Remote laboratories have the following benefits [25], [27], [30], [33]:

- The idea of the remote laboratory is to use the World Wide Web (WWW) and a Web Browser as its interface. The user just needs Web Browser to perform his laboratory experiment from anywhere.
- Remote laboratories make available access to expensive and rare devices.
- A remote laboratory decreases maintenance costs needed for a laboratory.

- A remote laboratory reduces space because students do not need to be locally present in the laboratory, and space is needed only for experiment instruments.
- Remote laboratories give students the opportunity to work in a remote manner, which gives the students new skills in remote engineering jobs that are present in many applications in industrial, medical, commercial and entertaining fields.

Some benefits of industrial use of remote laboratories are [25], [27], [30]:

- Instruments can be controlled from any places.
- Systems in dangerous environment can be directly controlled from the scientist's office.
- Group members working at different places can take advantage of the same test-run results without additional traveling.

3.5.3.3. Disadvantages of Remote Laboratories:

Although remote laboratory nearly reaches the real laboratory (hand-on laboratory), it suffers from some problems as:

There are certain restrictions such as bandwidth requirement, Internet time delay, and Internet traffic management [27]:

- In a remote laboratory, implementation of an experiment is restricted and limited avoiding the complexity existing in its corresponding hand-off one. Remote laboratories focus on conceptual understanding and professional skills, thus they are more useful in teaching concepts than design skills [25].
- Although the remote laboratory obtains and presents actual data or results from the real experiment, it ignores the reality view of components and instruments of the physical laboratory. Most of instruments and equipment are virtually presented, which reduces the real world feeling. While Fig. (3.5) shows the graphical representation of a remote

laboratory at the client side, Fig. (3.6) illustrates the corresponding physical experiment at the laboratory side.

It is to note that our investigations in this thesis is mainly concerned with the latter drawback, aimed at bypassing it the introduction of an Augmented Reality Internet laboratory, trying to reach realistic representation of a hands-on laboratory through eliminating or reducing computer-graphic components and instruments of laboratory. Moreover, ARI laboratory offer an interactive experimental laboratory that enables the student to connect the required components of the experimental circuit through the Internet. After the student sends the required connections on the experiment board, the system establishes the required connections between the nodes of components and instruments. Finally, after displaying the actual results on the screen of instruments, a video stream of the instruments and their screens are transferred through a web cam to computer's screen of the student.

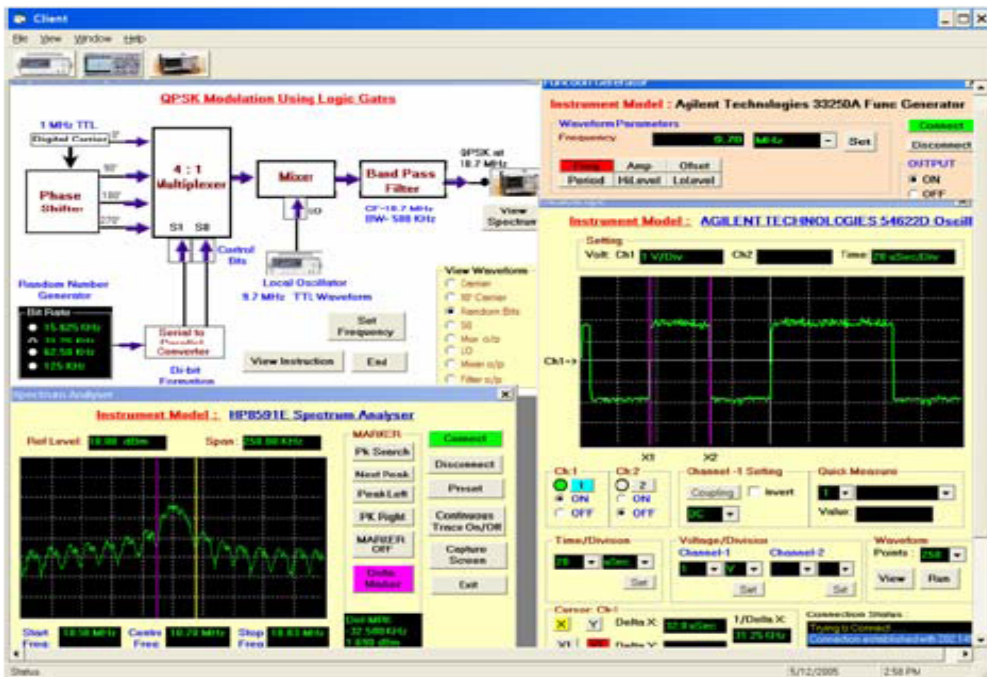


Figure 3.5: The experiments at client's side as a graphic representation

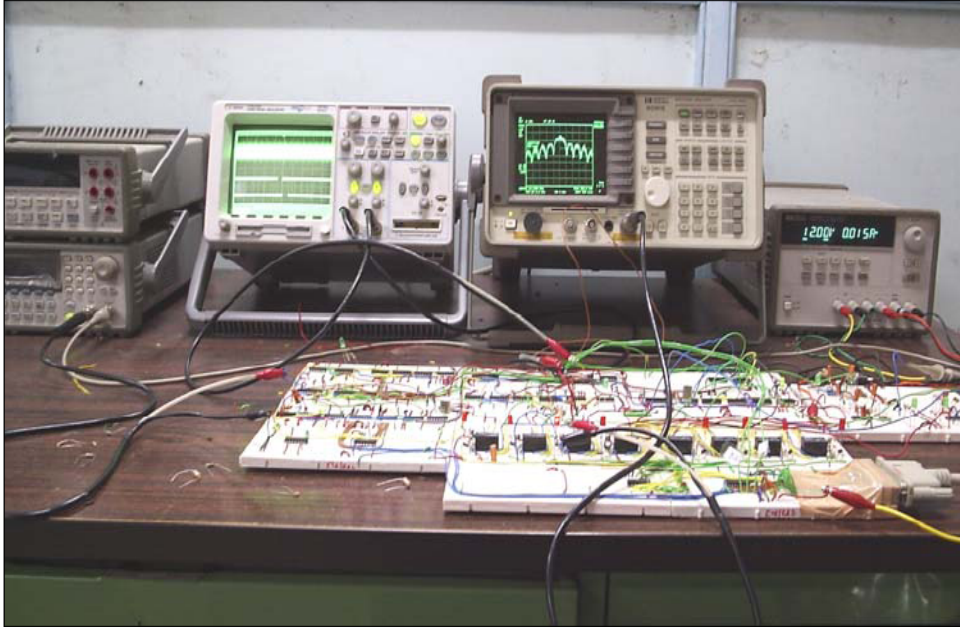


Figure 3.6: Actual experiments on the real laboratory side.

Chapter Four

Architecture of the Augmented Reality Internet Laboratory System

4.1 Introduction

An Augmented Reality Internet Lab (ARI Lab) is a system composed of hardware and software components that involve the ability to access physical laboratories through internet. Such distributed systems are generally classified as remote laboratories and may be considered as online labs. Thereby, individual students utilize a communication network to perform a laboratory experiment, and interact with a webpage to access the lab from their homes independent from time and place.

The architecture of the distributed ARI lab system with its subsystems and components are illustrated in Fig.(4.1).

The system software and hardware have been incrementally crystallized within an iterative system and software engineering process, in which each increment includes new system functionality. In the iterative process, the stages: specification, design, development, and testing are not chained, but rather interleaved and concurrent. From Fig. (4.1), the augmented reality environment for ARI lab is not only composed of pure technical software and hardware components, but encompasses ergonomic aspects [35] for allowing effective human-computer interaction [36]. The user-interface plays a central role for obtaining a harmonic interaction with the whole lab, necessitating to create it with an interactive development system like Microsoft Visual Web Developer 2005 Express Edition along with these tools: Microsoft Visual C# 2005 Express Edition [37], Microsoft SQL Server 2005, Web Server: IIS (Internet Information Service), as well as a Web Development tool. All these tools are integrated in a

convenient developmental .Net environment with powerful user-interface tools and rich libraries for creating user-interface components to enable data to be displayed in many forms.

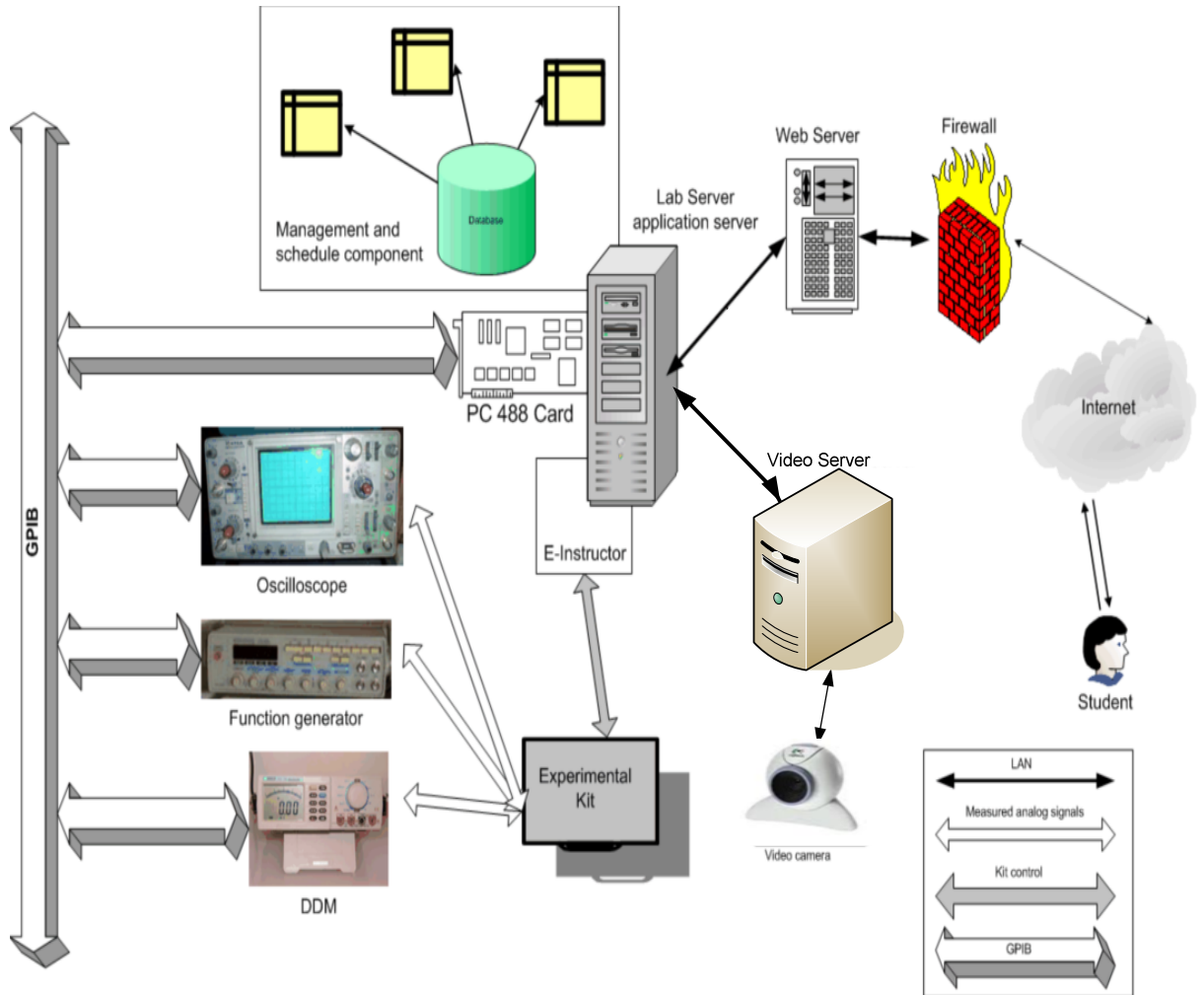


Figure 4.1: Architecture of the distributed ARI lab system.

4.2 Lab Server

The lab server is the communication middleware over the internet between the clients (the students) and the remote experiment, whose visualization on the client side bases on the augmented reality. A web browser serves as mediator between the implementing student and the lab server, representing the central unit of the e-learning environment, and functioning along with the lab server as a coordinator between the various components. At the server end, laboratory instrumentations and the experimenting kit are connected to the lab server. As previously discussed, ARI lab are aimed at using of real instruments and equipments in

laboratories instead of virtual graphics. Fortunately, most of the current instruments such as oscilloscopes and digital multimeters (DMM) are provided with control through PCI GPIB (General Purpose Interface Bus) card and GPIB cable [38], allowing PCs to communicate with over 2000 instruments made by over 200 manufacturers. This technological progress is what makes internet remote laboratories possible because of the facts that these instruments make measured values available for other systems sharing the same GPIB. The main purpose of the general purpose-interface bus (GPIB) is to send information between two or more devices. An ARL lab's experiment can be any one of engineering or science labs covering topic related to electric circuits or electronics that consist of resistors, capacitors, inductors, electromechanical modules and so on.

Before sending any data, GPIB devices must be configured to send the data in the proper order and according to the proper protocol. The electrical specifications as well as the cables, connectors, control protocol, and messages that are required to allow information transfer between devices are defined by the IEEE-488 standard [38]. For instance, by chaining IEEE-488 cables from one device to the next, it is possible to connect up to 14 devices together. IEEE-488 supports data transfer at up to 1 Mbytes/sec. In addition to simple data transfers, the IEEE-488 standard defines a number of specialized commands for interface programming in the form of subroutines available as programming libraries for different programming languages such as C, Pascal, C# etc.

Another functionality of the lab server is to manage and to schedule students' accesses into the system. On the lab server, every registered student has an account, in which his/her login name and password, results and marks of the experiment quizzes and tests, schedule data of accessible time are stored. When a student tries to access to the experiment, the management and the schedule component examines whether he/she is allowed to do this according to a schedule time-table. Moreover, this component manages the registration procedures of the students for enabling them to execute the experiment. The entered data will be temporarily stored and after its verification by the experiment administrator, it will be stored in the database permanently. Once the login name and password entered by a student are correct, the lab server establishes a connection between the user-client and the remote experiment. Students and instructors have different webpage user interfaces tailored to their special needs.

Augmented reality interfaces for ARI lab demand real-time videos combined with virtual user-interface objects. This section describes how the ARI lab user-interface allows students to control the experiment kit and instruments remotely through operating the virtual elements presented on the live-video frame, causing real responses of the remote physical experiment to be transferred back to client; thus, students feel as being in the real hand-on lab.

4.3 User Interface

One important goal of this thesis is to access the ARI lab through a webpage over the internet using a conventional web browser such as Microsoft Internet Explorer and Mozilla Firefox, Chrome etc., providing a suitable mean for data exchange between the user-interface and the lab server. Once a student activates the URL address of the webpage ARI lab, the web browser loads the start webpage of the experiment lab, which encompasses an authentication page for entering the system through a correct user name and password.

While designing the web ARI lab interface, various human-computer interaction rules for user-interface design [39] have to be taken into account such as:

- Consistency of data display (labeling and graphic conventions).
- Efficient information assimilation by the user.
- Minimal memory load on user.
- Compatibility of data display with data entry.
- Flexibility for user control of data display.
- Presentation of information graphically where appropriate.
- Standardized abbreviations.
- Presentation of digital values only where knowledge of numerical value is necessary and useful.

The interaction between the students and the user-interface takes place visually and through an interaction device such as keyboard and mouse.

The system architecture of the ARI lab follows the thin-client model because all of the application processing and data management is carried out on our application server and the

representation software interacts with the users, enabling them to perform on real (physical) experiments remotely whenever they want and anywhere they are. The user-interface represents the remote experimental kit using a mixture of virtual and real (video-captured) objects and the students can connect these objects by means of various virtual wire and cables interactively.

4.4 Web Camera

The web camera is very important in this kind of applications because AR establishes on real-time video streams in order to achieve quasi real presentations. Therefore, a high quality web-cam is necessary to send real-time video of the experiment to give realistic feedback for the students.

4.5 Experimental Kit Development

As previously discussed, on the ARI lab user-interface, video-captured images are used along with graphical objects, so that users cannot differ between the real world and the virtual augmentation [9], [10]. Since we deal with remote e-laboratories for teaching the practical side of engineering or science studies to strengthen the students' skills required after graduation, the techniques and the methods for developing and for designing ARI user-interfaces discussed here can be used to present any one of engineering or science labs covering topic related to electric circuits, electronics, mechanics etc. This is accomplished in the form of mixed virtual and real (video-captured) laboratory elements that can not only be simple elements such as resistors, capacitors, inductors, electromechanical modules, but also more complicated units such as oscilloscopes, DDMs, function generators as presented in (Fig. 1.4).

The represented AR circuit-board (kit) is built in such a way that the underlying image of the remote real kit is captured by a video camera and processed by a video server in real time that is finally augmented by virtual (graphic) experiment elements. Circuit elements that are not exist on the video presentation of the kit can be graphically selected by means of a graphical component bar and can be then placed on the kit. In the bar, more than one resistor, capacitor, inductor, etc., are possible to be selected by the experimenting student, depending on his decisions or calculations required in the experiment. The laboratory server computes the final

AR display consisting of computer graphics (virtual objects) and the video-presented kit in order to display it to the user.

If the mouse cursor moves on such nodes, the software recognizes the corresponding connections through their x y positions. If the wiring and connecting mode is selected and the student moves the cursor while pressing the left button of the mouse, a connection between the desired locations is graphically created. After proving the correctness of the created connection by the e-instructor, the server connects the equivalent switches in the remote experimental kit.

Real instruments deliver measured values from the instructed circuit. Afterwards, the acquired measurements will be sent to the client for mediating these values to the student.

However, in this investigation, setting up computer graphics of electronic elements and equipment overlaid on real-time video of the experiment kit is what makes our distance learning environment augmented-realistic, aiming at providing engineering students a quasi real environment laboratory.

4.6 E-Instructor

Students might connect sensitive circuit elements such as ICs with power supply falsely, causing these components to get damaged. As such, there is a need to provide the system with a further software component, which protects the system from damage in that it prevents dangerous circuit configurations like short circuits or unwanted high power connections. Since this software component undertakes some activities of a human instructor, it could be designated as e-instructor.

Chapter Five

Hardware of the Implemented ARI Laboratory

5.1 Introduction

As was obvious, in this thesis we are concerned with enabling the student to remotely access a real electrical and electronic experiment through the ARI client user-interface. The student can interactively tele-operate the experiment and after every manipulation step she/he will be fed back about his progress achievement in the experiment. To make this possible, the distributed ARI laboratory system requires hardware and software facilities in order to access the physical laboratory. The laboratory experiment is connected with the server via an interface; the students can remotely control the experiment via sending and receiving command to laboratory server. This chapter illuminates the hardware design and implementation with the all required apparatus and components that enable accessing the ARI lab's kit.

5.2 ARI lab's Kit

The kit is designed in special manner to complete the ARI system; it contains all required components and instruments as is shown in Fig.(5.1). One important component which plays a central role in designing computer-controlled laboratories is a switching matrix, which is made as a grid of lines structured in forms of horizontal and vertical axes. At every crossing point where two lines are meeting, there is a switch, which can be connected by a controlling PC command.

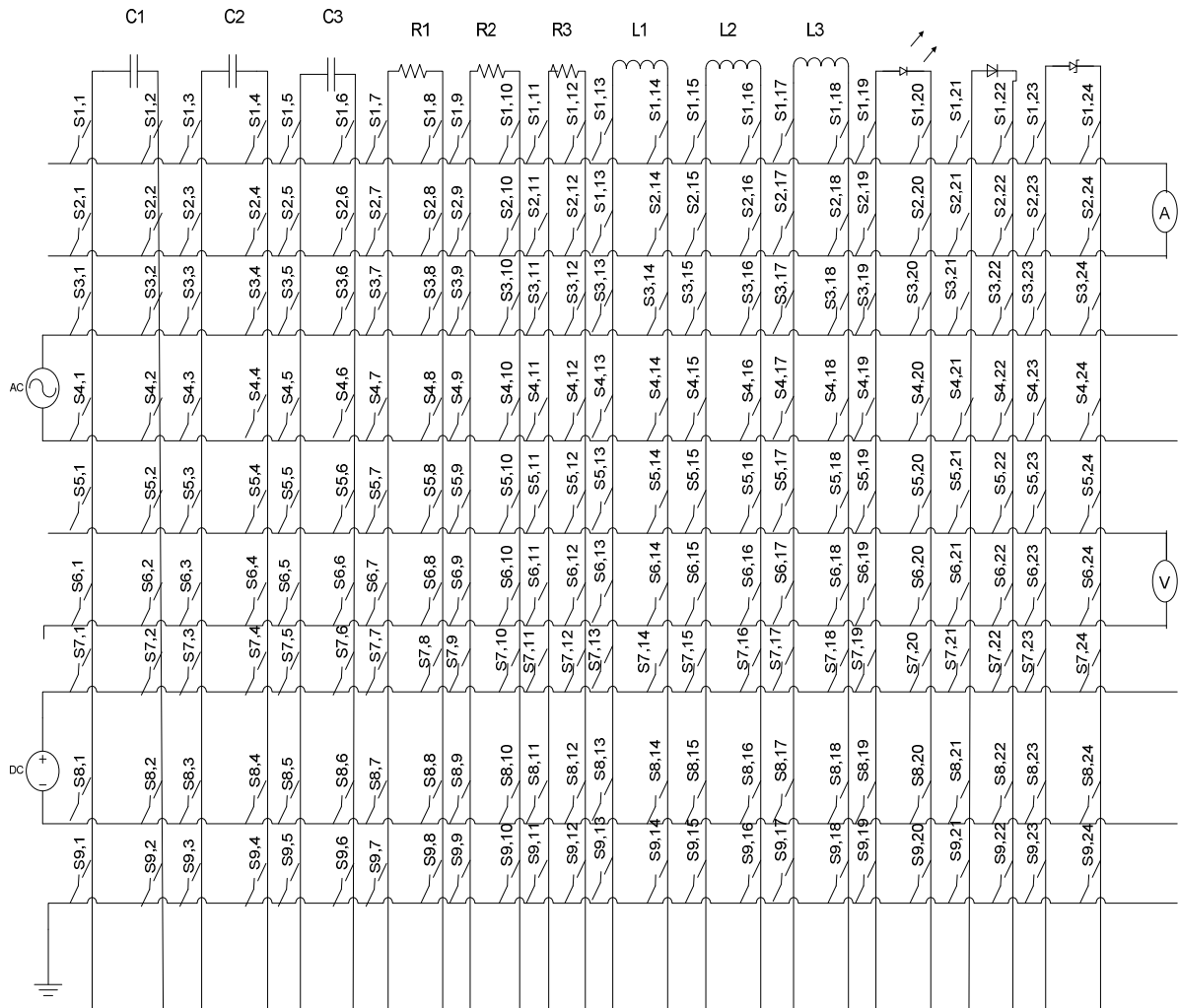


Figure 5.1: General design of ARI lab's Kit in forms of a switching matrix

This design can be applied on various types of electrical and electronic experiments. For a required experiment, every course's lab kit can be provided with particular components.

5.3 Series and Parallel Circuit Experimental Kit

The aim of this thesis is to find out the strengths and weaknesses of using AR in designing remote laboratories; therefore, we used a simple circuit types such as series and parallel circuits. It is of great significance to highlight that in our remote AR laboratory, more complicated circuits can be configured than the two mentioned before. The kit for realizing series and parallel circuits consists of several resistors that can be connected in series or in

parallel manner, depending on the type of the experiment needed. Thereby, two measurement instruments, namely ammeter and voltmeter, can be used in order to take the value of current and voltage of the circuits. The required hardware for constructing a kit is divided in two circuit subsystems: a main circuit, on which a student experiments, and an auxiliary circuit that functions as a protector for the PC, ICs etc. of the kit.

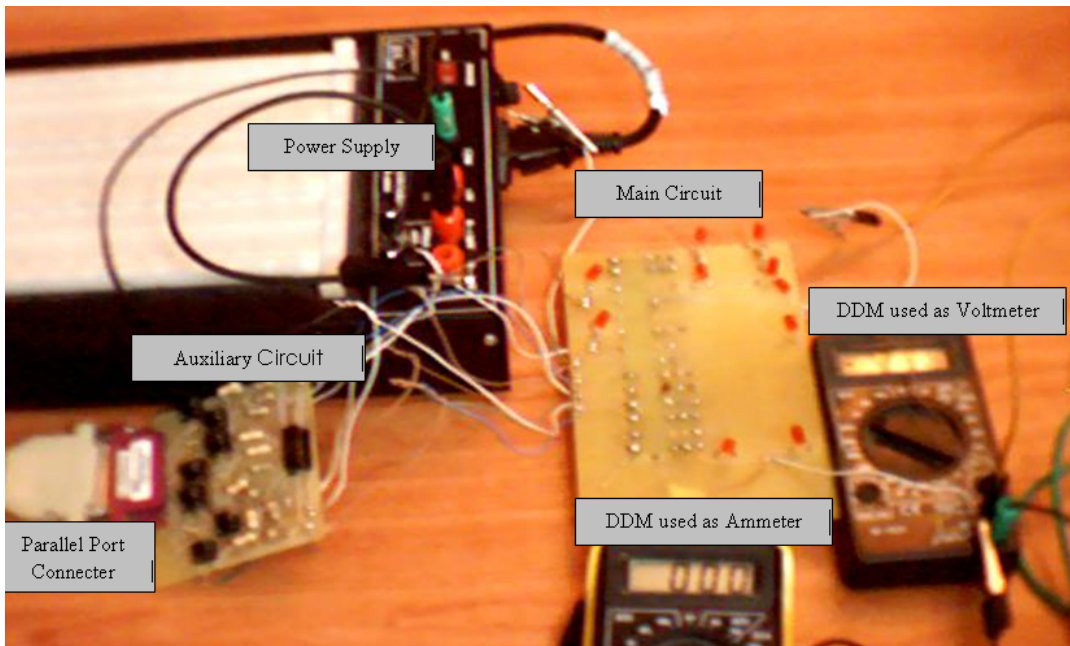


Figure 5.2: The implemented hardware of series and parallel circuit experiment.

5.3.1. Main Circuit:

The main circuit appears on student's computer screen with all required components and instruments to enable him to operate on his experiment interactively. Fig.(5.3) shows the implementation of the experiment's kit that contains two separated circuits, the first circuit is consisting of ten red light emitter diodes that are connected in series with each other; these LEDs are located at the terminals of each component and instrument to be wired. The LEDs circuit is necessary in order to assist the HSL filter, which is implemented in forms of a software program, to determine the positions of node's components and instruments on the captured video photo of the ARI lab's kit that will be described in-depth in chapter six.

The circuit is fed by an external DC power supply voltage with a value of 15 V. As is known, the drop voltage of a red LED is 1.4V and the max current permitted through LEDs is 27mA.

According to previous values, the value of the resistor R3 is determined with respect to the required quantity of brightness and must be not less than 37Ω .

The second circuit contains resistors, an ammeter, a voltmeter, a DC power supply and seven 9V relays. The required connections between the terminals of the circuit are achieved by controlling commands processed on the PC linked with experiment kit.

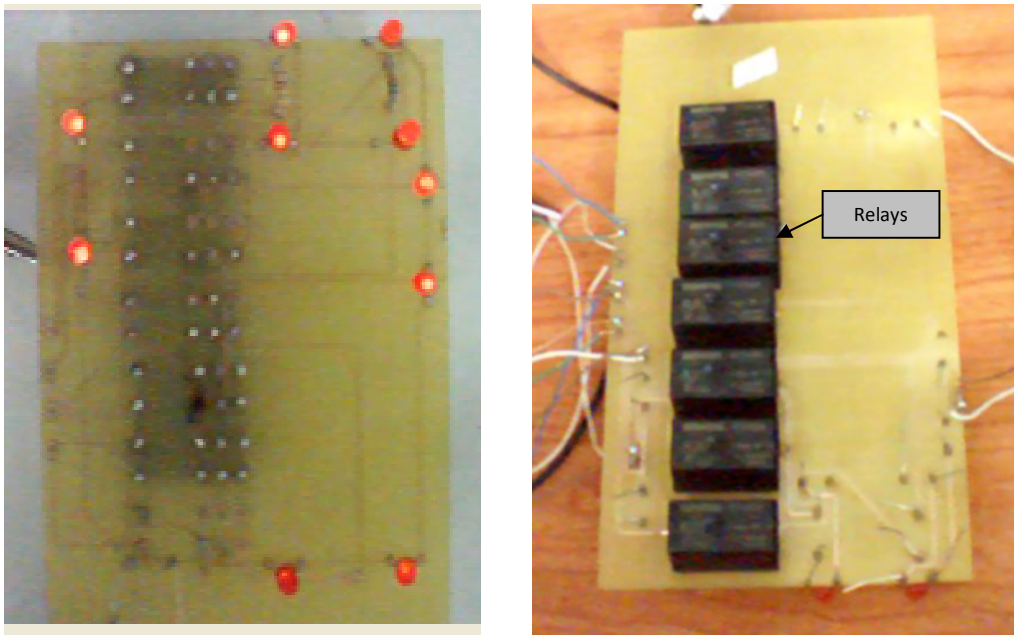


Figure 5.3: The top view and underside of main circuit.

The used relays are necessary to control component's connections in the main circuit. A relay is an electrically operated switch and uses an electromagnet to operate a switching mechanism. When the current flows through the coil of a relay, it creates a magnetic field which attracts a lever, leading to change the state of the switch. In the built circuit, the relays used have two switch positions and designated as double throw switches [40].

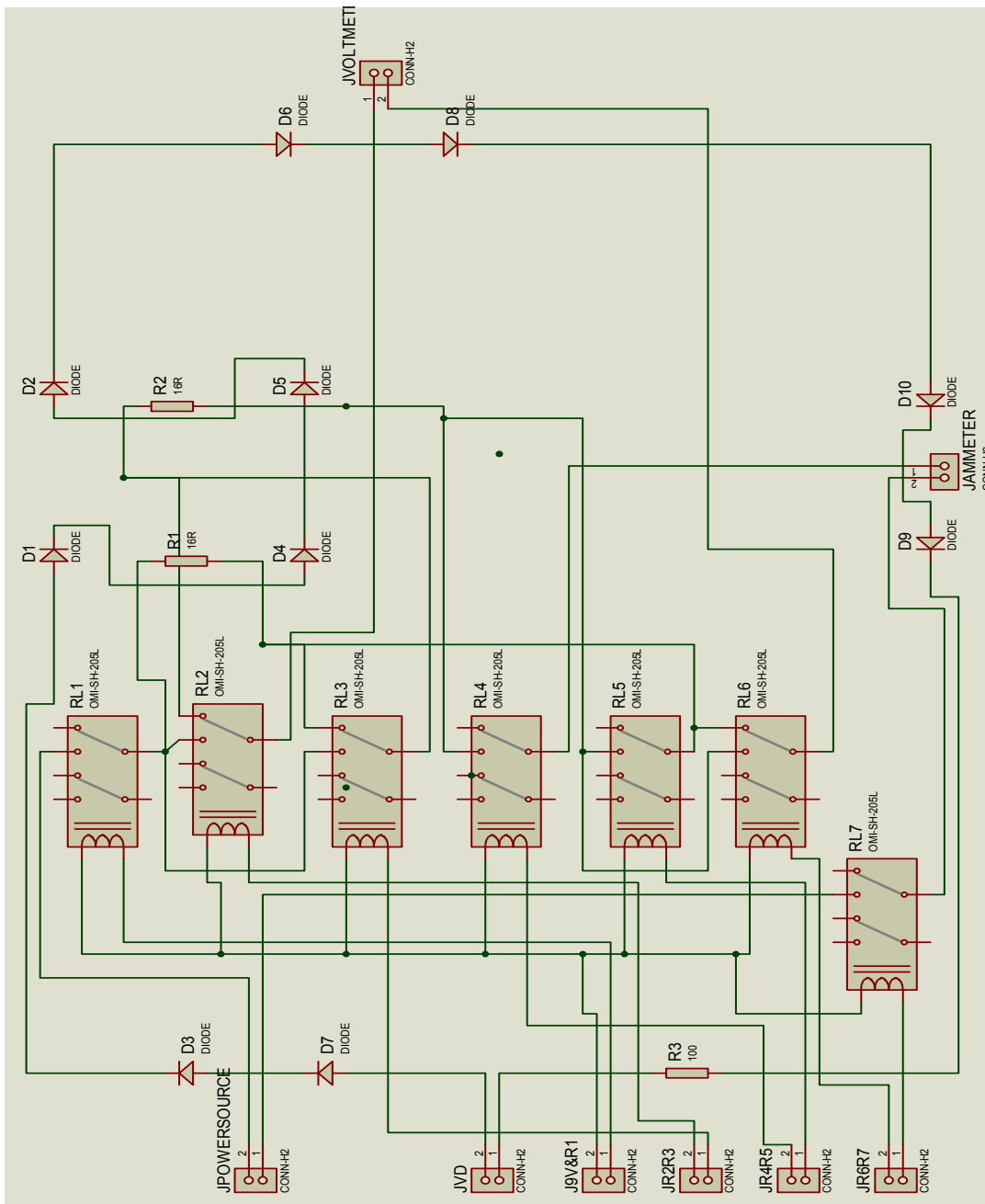


Figure 5.4: The implemented main circuit.

One advantage of a relay is that there is no electrical connection between the control signal and the switch inside the relay. Thus, a relay allows two circuits to be connected with each other that are completely separated because the link between them is caused by a magnetic field leading to close the switch mechanically [40].

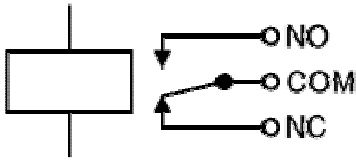


Figure 5.5: A relay with double throw switches.

As is obvious from Fig.(5.5), the relay's switch connections symbolized with COM, NC and NO are defined as follows:

- COM: Common, it is the moving part of the switch; the circuit is always connected with COM.
- NC: Normally Closed; COM is connected with NC when the relay coil is off.
- NO: Normally Open; COM is connected with NO when the relay coil is on.

There are major disadvantages of relays that are listed below:

- Relays need more power due to the current flowing through their coil; thus, they require a driver circuit.
- Relays cannot switch rapidly because they have a slow response and the switch contacts will rapidly wear out due to the sparking.
- Relays have moving parts which makes them more susceptible to failure.
- and, Relays are large.

The real (physical) implementation of the main circuit is invisible for the student. Initially, the visual presentation of the circuit on the client user-interface just contains the resistors without any connections, as the goal of an experiment is to give a student the freedom in manipulating of the experiment, aimed at accomplishing effective learning. Fig.(5.6) and Fig. (5.7) show how the circuit can be configured either in series or in parallel.

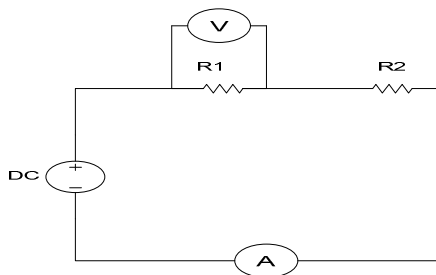


Figure 5.6: The series circuit.

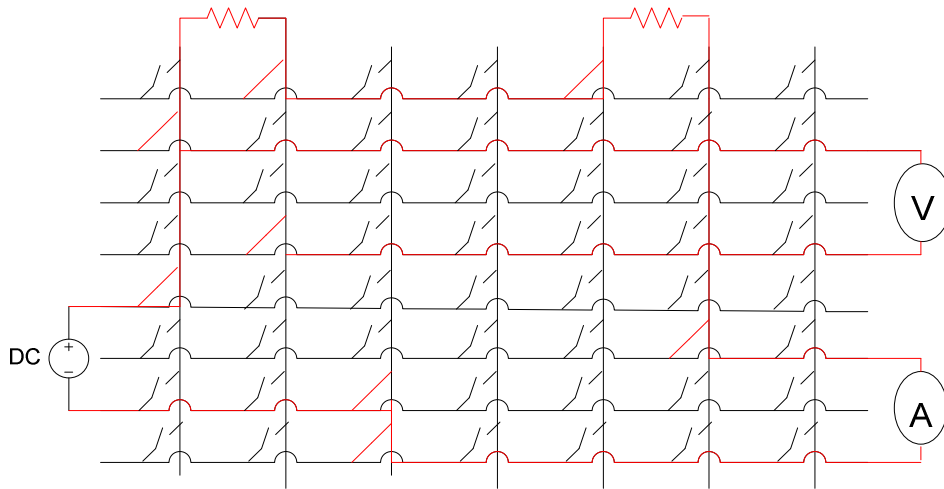


Figure 5.7: The equivalent series circuit of the circuit shown in Fig. (5.6) by using switches.

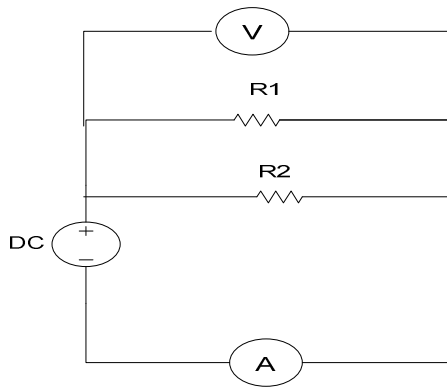


Figure 5.8: The parallel circuit.

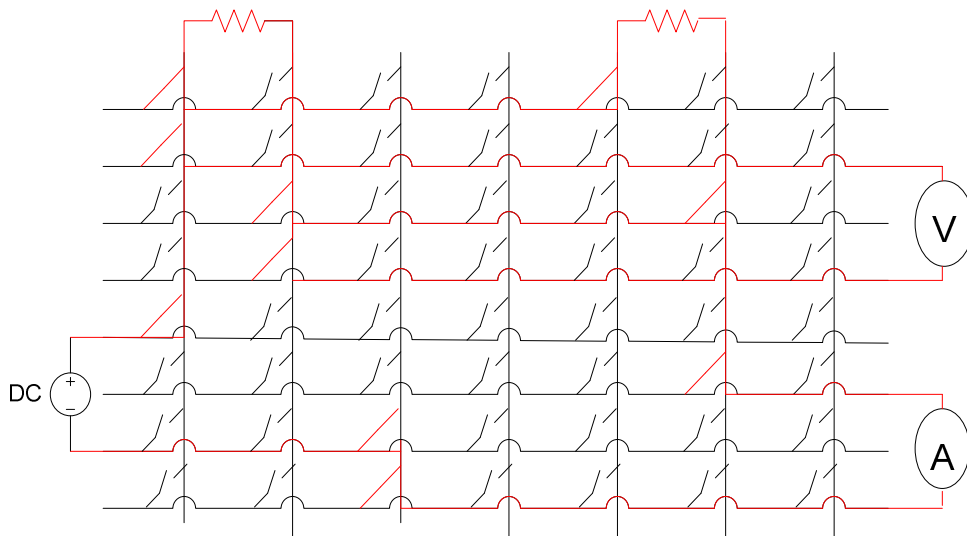


Figure 5.9: The equivalent parallel circuit of the circuit shown in Fig.(5.8) by using switches.

5.3.2. Auxiliary Circuit:

The main circuit has an interface with the laboratory server computer which has an output voltage of 5 V what is not sufficient for driving 9V relays. To drive such relays, we need another circuit, providing further functionalities such as isolation and protection of the laboratory server computer from any error that may occur. The implementation of the auxiliary circuit is show in the Fig. (5.7).

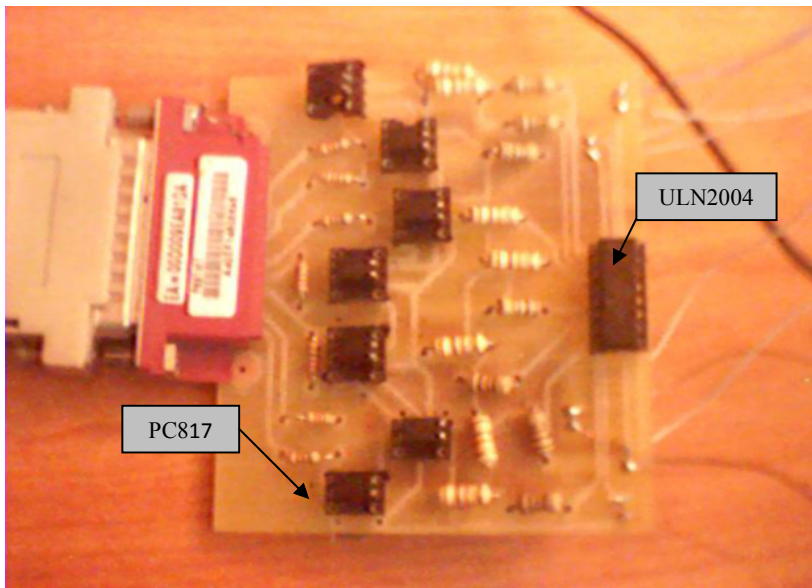


Figure 5.10: Auxiliary circuit.

This auxiliary circuit includes seven photo-couplers of the type PC817 [41], one ULN2004a [42] and resistors, and has two interfaces: one with computer through the PC's parallel port LPT1, and the other with the main circuit.

The ultimate protection uses photo-coupler PC817, which consists of a photo diode as input and a uniform transistor type as output. The isolation is located between the input and output of this IC, and the inputs are connected directly to the parallel port LPTs.

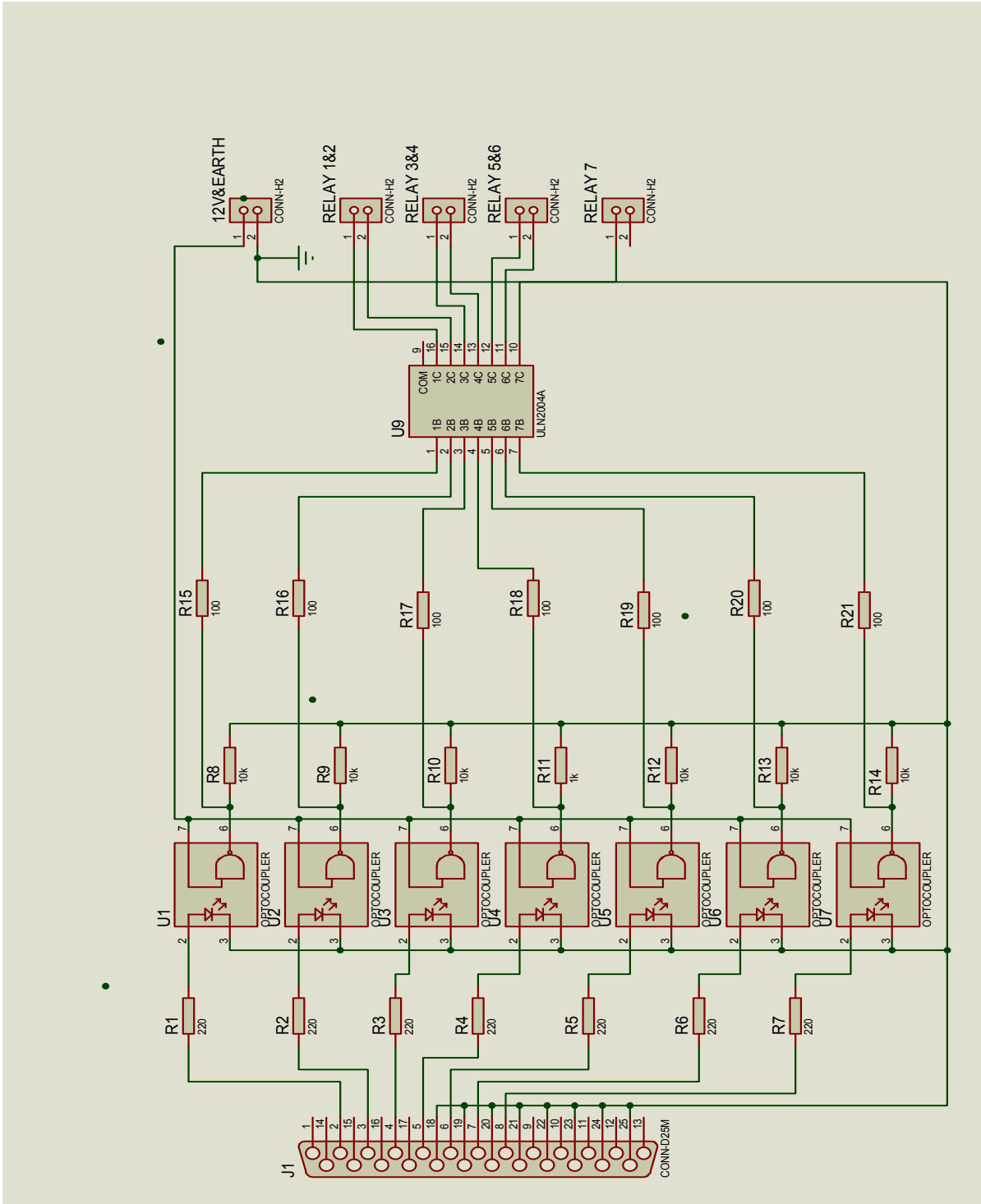


Figure 5.11: The implemented auxiliary circuit.

For providing high current to drive the relays, the integrated driver “ULN2004a” array is used, which has seven separate Darlington transistor drivers. Each driver is capable of supplying

500mA at up to 50V. The inputs of the IC are connected directly with the output of PC817, and the seven outputs are connected directly to the seven relays.

5.3.3. Parallel Port:

The Parallel Port LPT1 is the most commonly used port for computer interfacing to controlled devices. The port is composed of 4 control lines, 5 status lines and 8 data lines. It's found commonly on the back of PC as a D-Type 25 Pin female connector. There may also be a D-type 25 pin male connector; parallel port is assigned a unique I/O address which is mostly 378h [43].

Here, not all 25 pin are needed. Eight output data line pins (2 3 4 5 6 7 8) are used and signal pin 18, 19, 20, 21, 22, 23, 24 and 25 is connected to ground.

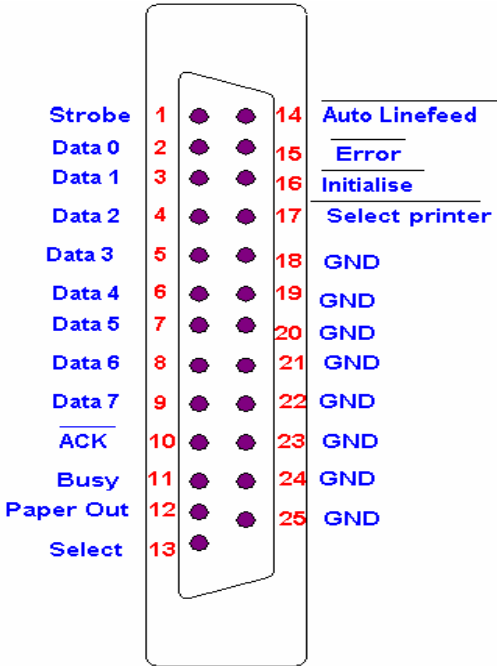


Figure 5.12: Pin configuration of the parallel port of the PC

To control the parallel port through software program, we can use the dynamic link library “inpout32.dll”, which must be copied and saved in the folder “windows\system32”. Afterwards, the libraries “System.Runtime.InteropServices” must be added in the top of codes. By default, in C# uses port 888 for output and 889 for input. The value for output here will be in binary form of 8 bits since 8 bits have to be used for output in a parallel port.

The output of the parallel port is determined in accordance with the student's circuit used in an experiment. The connected nodes of the visually presented circuit on the web-based client UI determine the state of the switches of auxiliary circuit installed in the laboratory server. By referring to a configuration table consisting of the number of the experiment circuit nodes and their corresponding relays that are saved within a database on the laboratory server, we can obtain the specific relays, whose states must be changed Table (5.1). This configuration table contains four columns, namely, *Node1*, *Node2*, *RelayNumber*, and *ValueOfSwitch*. *Node1* and *Node2* indicate the number of the nodes that can be wired, *RelayNumber* is the number of relay that connects between nodes, and *ValueOfSwitch* presents the value of the output of the parallel port that enables the switch to be closed between these nodes.

Table 5.1: The configuration table is saved on server.

NodeSwitch			
Node1	Node2	RelayNumber	ValueOfSwitch
3	1	1	1
4	2	3	0
5	10	4	1
7	9	7	1
1	6	2	1
4	8	6	0
2	6	2	0
5	8	6	1
4	10	4	1
4	5	5	1
1	2	3	1

Some relays need 0 and another need 1 to establish the connection; this difference comes from how a switch is configured in the circuit. In the implemented circuit, we built some safety features to prevent some critical components such as ammeters etc. from getting damage. This

is achieved by letting some relays to be normally closed (NC) and others to be open (NO) because critical nodes are allowed to be connected only once at the same time, that offer further protection functionality by the hardware.

5.4 Summary

This chapter described the hardware design and implementation with the all required apparatus and components that enable controlling the remote laboratory through commands carried out on the client user-interface of the ARI lab's kit. The kit was designed in a special manner, so that the student just sees all components and instruments of laboratory graphically. The laboratory experiment is connected with the server via the parallel port interface; the students can remotely control the experiment via sending and receiving commands to the laboratory server. Moreover, the implementation of the hardware is provided with an additional protection circuit that protects the server and also the ICs of the kit from any unforeseen electrical error. The ARI laboratory system also requires a software facilities in order to complete accessing the physical laboratory that will be discussed in chapter six.

Chapter Six

Software Implementation of the Augmented Reality Internet Laboratory

6.1 Introduction

This chapter provides an overview of the implemented software of the ARI laboratory developed using the programming language C# within the integrated development environment dot NET. The developed software is implemented both for the server and client. In the distributed ARI laboratory system, the client UI is responsible for the graphical presentation of the remote on the user-interface for both controlling and observing the remote components and instruments. The ARI laboratory server manages the requests from client, and accordingly, sends the feeds the client GUI with the necessary information about the status of the experiment to enable the experimenting student to control the real components and instruments that are present in the laboratory.

C# is a new object-oriented and internet centric language that shares some features of Java; Visual Basic, and C++. It is to note that C# is introduced as part of the Microsoft's .NET platform [44].

6.2 Web-based User-Interface

Creating the client GUI as a web application simplifies accessing to the ARI laboratory from any web-browser installed on a terminal computer. The user-interface developed a ASP dot NET web application exchanges data with the ARI server program written also in C# (ASP.Net) based on software packages such as Microsoft SQL Server 2005 and Web Server:

IIS. Eventually, the web-based client UI receives data from the ARI laboratory server to update its content, as well as presents an event-driven application because it receives the actions manipulated by the student and sends it to the server.

6.2.1. Home Page:

As it was previously shown, accessing the ARI system via the Internet provides the freedom from time and place. A student can access the laboratory server through the client GUI realized as a Web page through writing the URL (uniform resource locator) of the remote ARI laboratory in the address bar of the Web browser. The web home page of the ARI laboratory is shown in the Fig. (6.1).

The home pages of the remote ARI laboratory are designed in a such way that they navigate the student while accessing the remote ARI laboratory. The initial page shows a welcome page including a link to a login page.



Figure 6.1: Home page of the remote ARI laboratory system.

6.2.2. Login Page:

The Login page contains two graphical text controls to give the login name and the password of the student intending to execute the experiment. This information (the login name and the

password) will be previously assigned by the lab administrator to every student registered to study that experiment. The login-page prompts the student to enter the login-in and the password to allow him to access the remote ARI laboratory system. Sequently, the remote server compares the entered information with stored object data in a database, and if matched, she/he will be allowed to access the system. Depending on the account type (teacher or student), the appropriate subsequent pages will be presented.

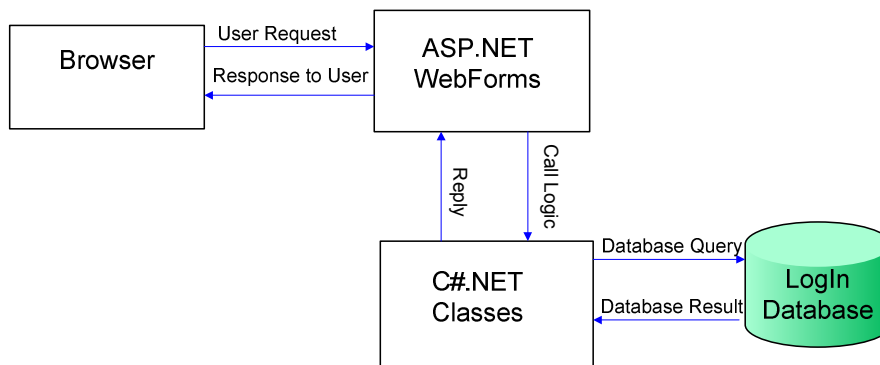


Figure 6.2: ARI lab's access process in forms of block diagrams

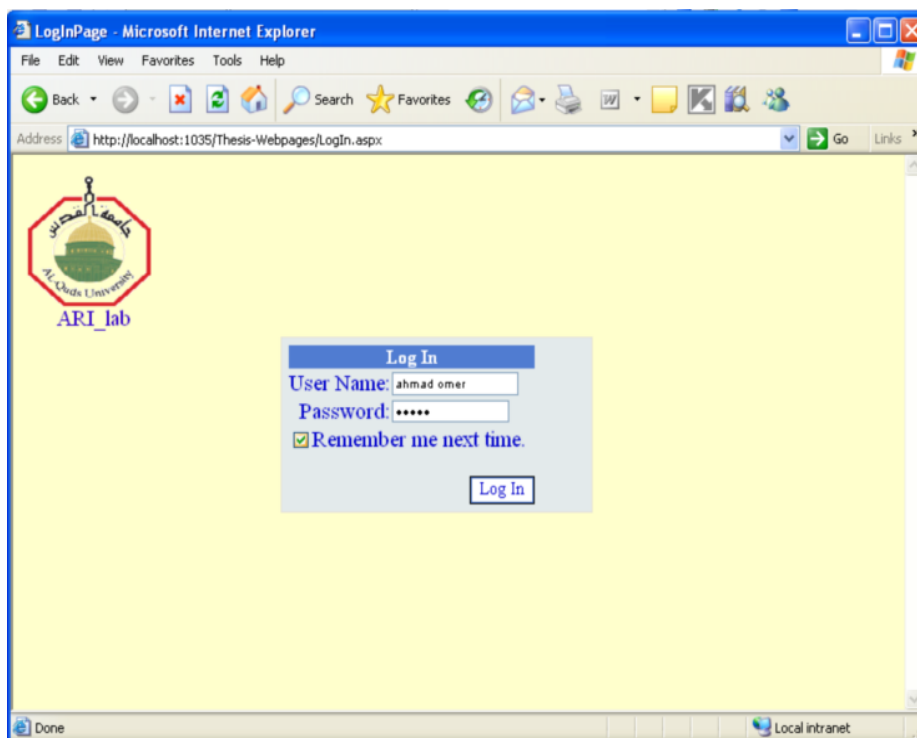


Figure 6.3: The Login page of the ARI system.

A further system designated as scheduling system is responsible for scheduling students' accesses to the experiment. The maximum time available for carrying out an experiment is

limited and can't exceed two hours. While a student carries out an experiment, no other students are allowed to carry out this experiment concurrently, and, thus, avoiding various reservations. A very plausible advantage (and one of its best features) of the implemented ARI lab is the freedom of the user to select suitable time slots.

In any traditional (hand-on) laboratory, after the student sets up the experiment, he must prepare the theory experiment, and, therefore, oriented on this fact, the web-pages of the client GUI are divided regarding these subjects:

- General /basics principles offering a short description on the subject and theory of experiment.
- Section of experiments that includes the experiment and the procedure of the experiment, as well as all tables and diagrams necessary for solving the tasks in the experiment.

After selecting an experiment from a web page, which includes various experiments as a list (see Fig.6.4), the client GUI shows start page of the desired experiment (see Fig. 6.5).

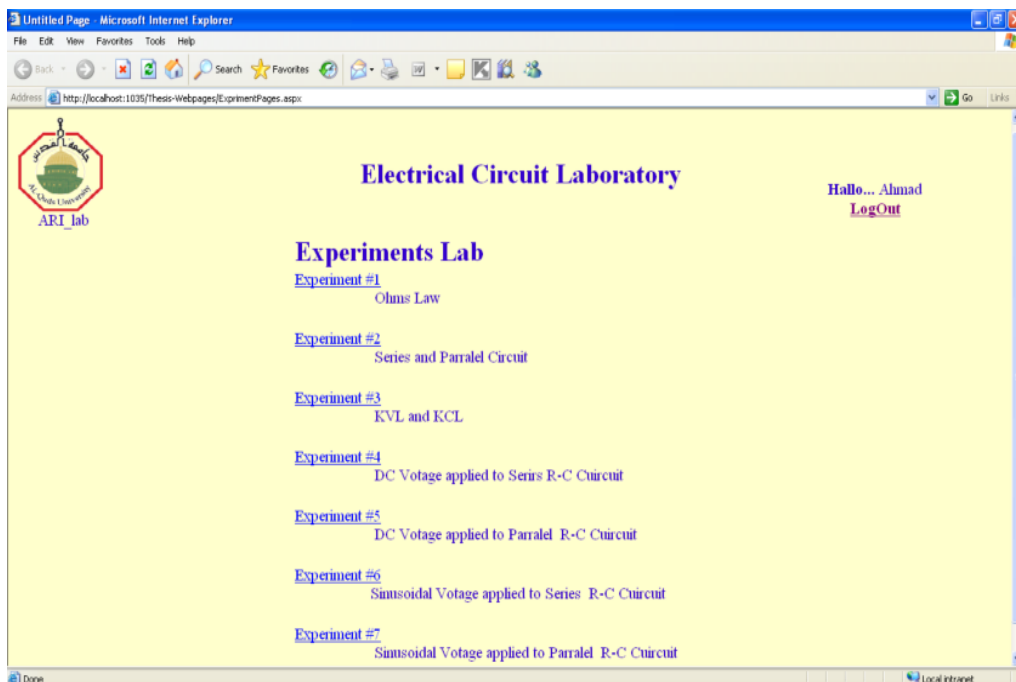


Figure 6.4: A web page listing various experiments.

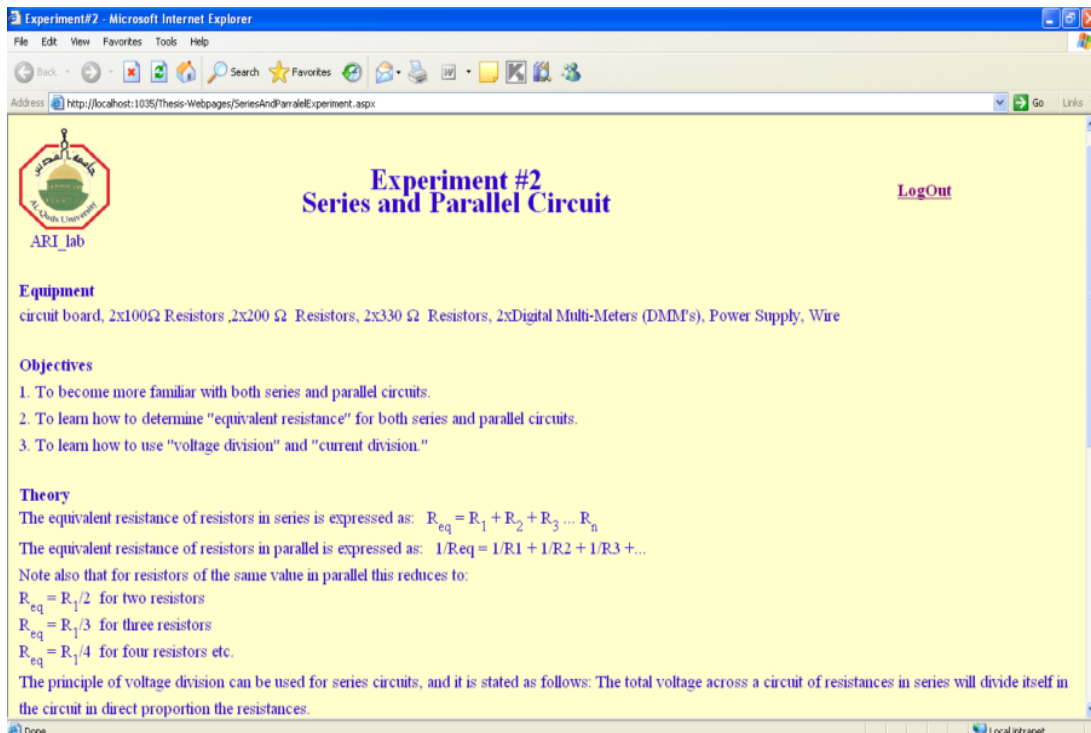


Figure 6.5: The start web page of a specific experiment.

After having gone through these steps, the student has all knowledge and background about experiment, and, accordingly, he is now already to do the practical side.

6.3 API's of the Implemented ARI laboratory

At the bottom of an experiment web page, there is a button called "StartExperiment", which can be clicked to activate a further application using a windows programming interface. One reason this part of the application is realized as a window and not as a web application is that dot NET Framework for web application is thought to be used for creating business applications and, unfortunately, does not support multimedia applications. The development of multimedia applications in the dot NET can be easily done by using Windows Application Programming Interface (API), whose usage reduces development time and complexity because it contains many helpful functions. The API consists of many helpful functions, messages, data structures, data types, statements etc. that may be utilized in creating applications running under Microsoft Windows. Windows APIs are used to directly make a call to a function inside Dynamic Linked Libraries (DLLs). A DLL import is used to specify the DLL location

containing the implementation of an external method, whose parameters specifies desired actions [45].

6.3.1. Setting-up an Experiment:

The graphical user-interface (GUI) as a client of the whole system is the mediator between a student and laboratory server. The GUI consists of a number of displays built using graphical controls with which the user can quickly and easily control the hardware.

Fig.(6.6) shows a window embracing a picture box, which displays a live video of the experiment. Here, a web camera transfers a video stream of the experiment with its required instruments on the computer screen of the student. It is to note that the web camera used is connected with server through the Universal Serial Bus USB port.

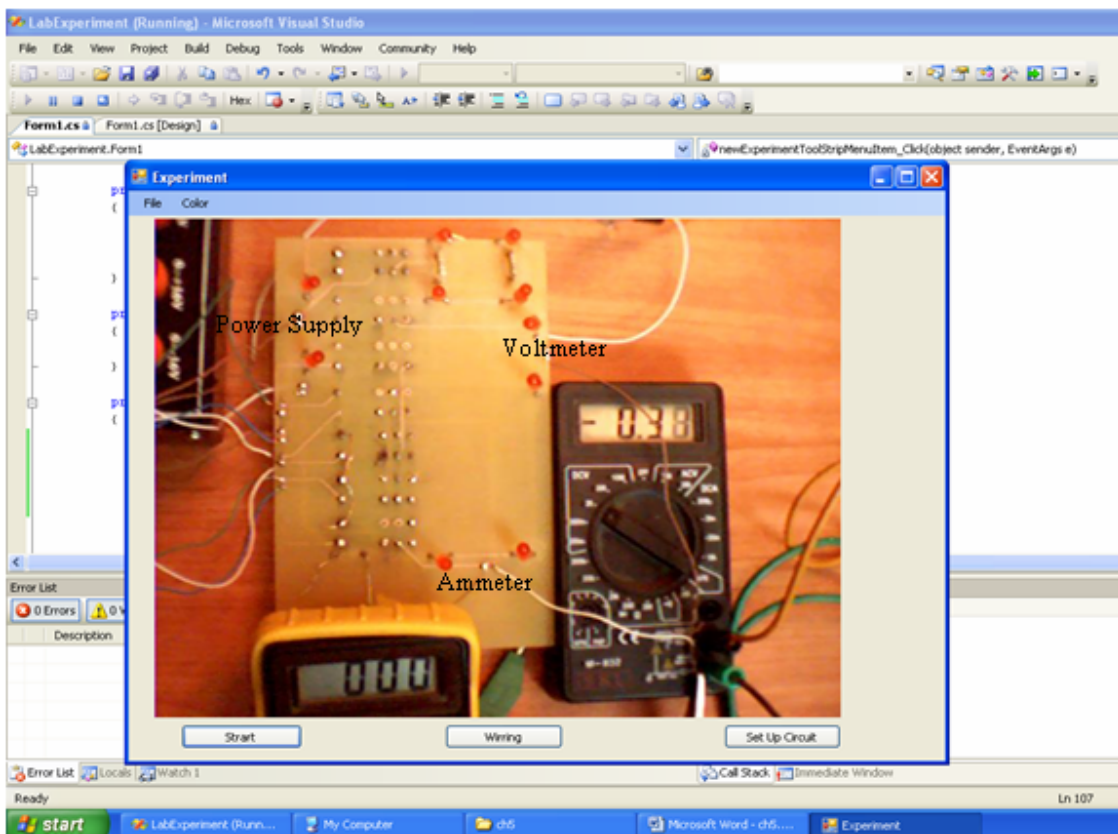


Figure 6.6: Video stream of the experiment displayed on the client GUI.

After starting-up the ARI laboratory server, the initialization process of the web camera takes few seconds, and thus few seconds pass before beginning to capture the video stream of the

laboratory. Doing so avoids exceptions and allows enough time for the camera to be initialized.

By clicking on the “Start” button, the web cam transfers real live pictures of the laboratory experiment to the student carrying out the experiment. The transferred pictures are of the kit with all its components, digital multi meters (DMM) and a power supply. , the student obtain real live image.

As so far discussed , a web-based remote experiment using augmented reality is centered around the idea that students can carry out an engineering experiment represented by real and virtual elements, components and equipments, through overlaying real kits with virtual (graphical) objects. Here, the video stream shows real pictures of the experiment itself and the instruments so that the experimenting student can virtually connect specific nodes of the real objects with each other. This will be discussed at the end of this chapter (see Fig. 5.11). This makes possible the interaction between students and the represented remote experiment to be no longer restricted in a face-to-screen fashion; rather it will be strived to dissolve students in a remotely located real environment laboratory.

In order to highlight the connectable nodes on the experimenting kit (see Fig. 5.7), several LEDs are closely placed near these nodes. Two advantages are achieved through adding the LEDs. On the one hand, the captured images can be easily processed through reducing of unavoidable noises caused by both the webcam and bad lighting; on the other hand, the student is supported to locate the connectable nodes; the latter can be seen from a human-computer interaction perspective as orientation.

Computer vision can be a powerful tool for our system. It is a potential to sense position of some objects that enable the computer to control the experiment connections itself. In ordinary AR systems use computer vision as a solution that provides the necessary understanding of the sense. Computer vision (or *image understanding*) represents a subfield of Artificial Intelligence which tries to analyze and interpret the visual information. Image understanding is a starting process from an image and resulting in a computer-internal (such as symbolic representations) description of the view to enable a system interaction with its environment

[15]. Our ARI system uses image understanding to recognize some objects from a captured image.

The captured pictures will be processed to acquire symbolic computer data that will be used to control switches (relays) of the remote experiment by a software [seen appendix A] . A captured photo of the kit is passed through several sequential processes that will be discussed in the following:

As mentioned, connectable nodes are indicated by red LEDs (Light Emitter Diode); any component or instrument belonging to the experiment kit must have LEDs at its connectable terminals. Using color filters of the image processing techniques, a further image containing only the highlighted red colored pixels can be easily extracted and the rest pixels of the pictures are eliminated.



Figure 6.7: Both terminals of resistor with red LEDs

Because of the facts that we applied a color filter, namely HSL [43], [44] filter in combination of other image processing techniques to extract useful pixels for developing an ARI laboratory, we can see that the major item of our consideration is color [seen appendix B]. The advantage of HSL over RGB is that it is more intuitive, and it is also easier to create sets of matching colors [48], [49].

The following flow chart illustrates the source code for realizing a HSL filter that computes the hue, saturation, and lightness for each pixel in the image using the HSL equations [seen appendix B].

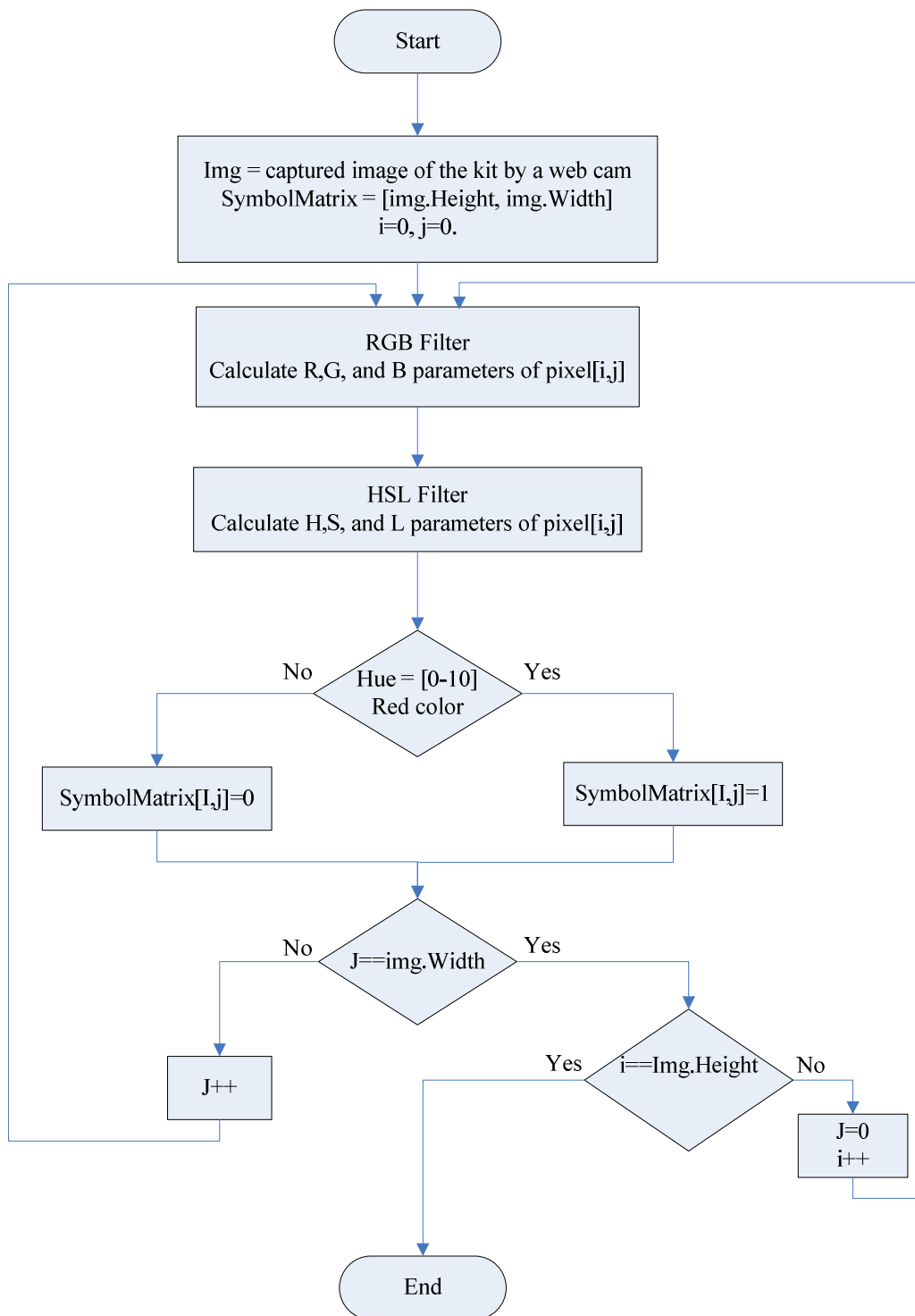


Figure 6.8 : The flow chart of HSL color filter.

Each component of the HSL color model is independent of the others. The hue should never change as their brightness changes. Hue, saturation and luminance is a very good and quickly

mode to approach the desired color. The HSL filter is used when the target object is appreciably differing in color from the rest of the surroundings [46], then compares the resulted hue value with a pre-defined hue value, which equals the red emitted LEDs' light. If the hue of a pixel is within the interval $[0, 10]$, which is an interval for red color, then it will be left on the output image; otherwise the filter makes it black [seen appendix A].

Fig.(6.9) shows two images from which the left one serves as input for the HSL filter and the right is the output of the HSL filter. It is obvious that the right one includes only two colors: black and red; Red symbolizes the nodes of the circuit.

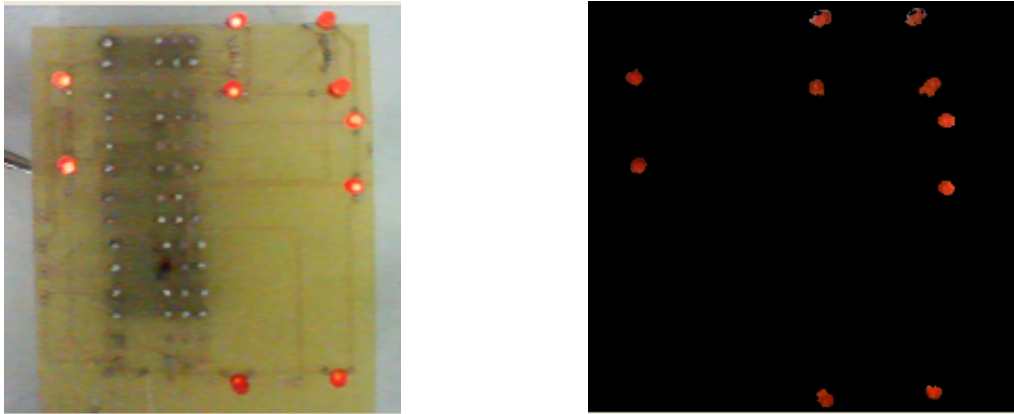


Figure 6.9: Input (left) and output (right) images of the HSL filter.

In a further computing step, the pixels of the image are transformed to a matrix whose entries are 1 for the red color and 0 for others as shown in Fig. (6.10).

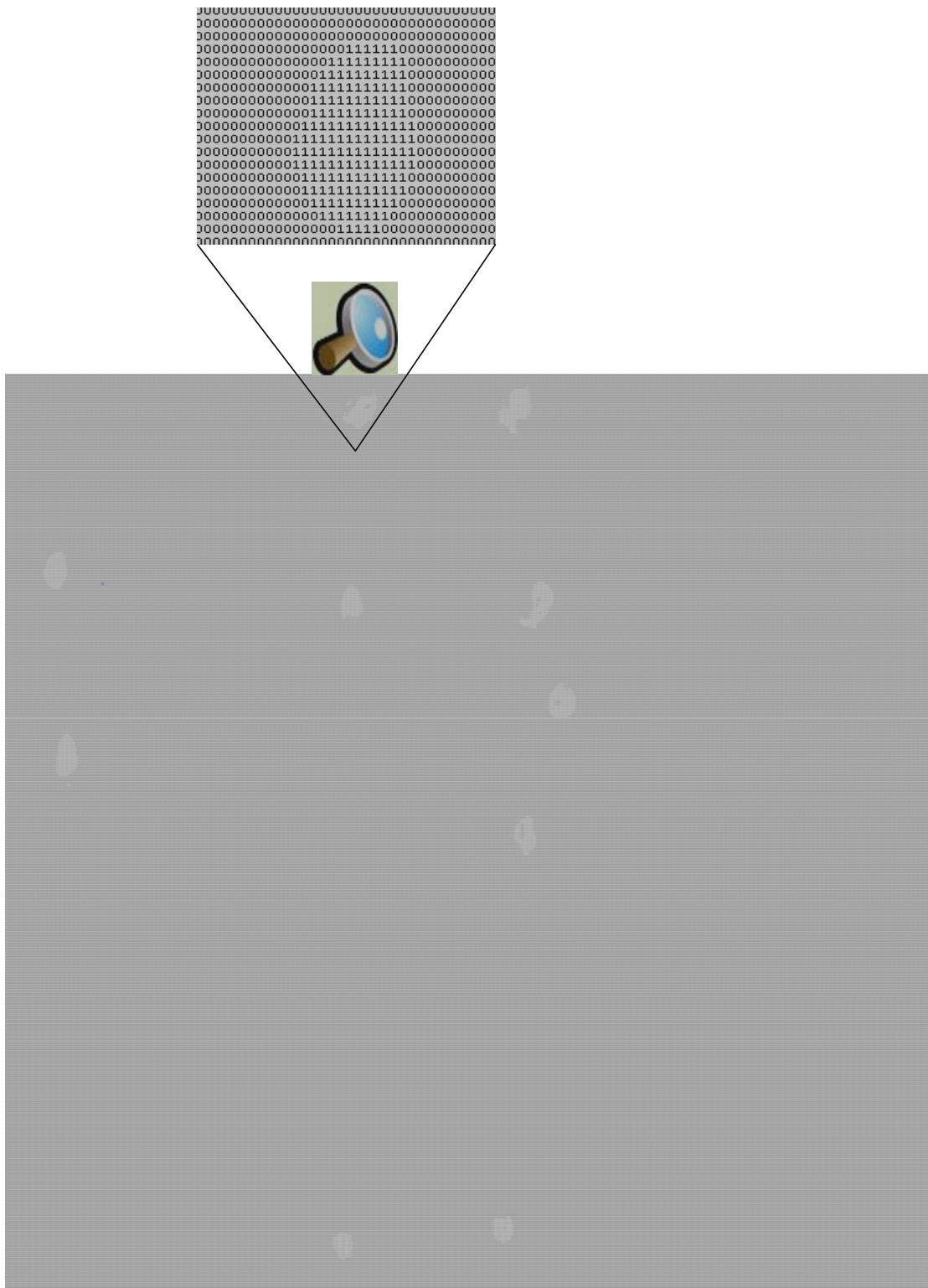


Figure 6.10: The result of transforming the output image of the HSL filter to a matrix of pure symbolic data of the values 1 and 0

she/he sees real resistors and instruments and, therefore, she/he can read its value by either using the color rings on the resistors (color code for the resistor magnitudes), or calculating resistor values through displayed voltages and currents of these resistors.

In this research, wiring of the real represented experiment circuit will be performed based on the augmented reality, where, as previously mentioned, real video pictures are overlapped with virtual wires. A student can wire his circuit by clicking on the button "wiring" as shown in Fig(6.6). At the this moment, the web cam is stopped after the picture is taken and the student can see the experimenting kit of the remote ARI laboratory, which contains all required components and instruments viewed on the screen of the student. By using the mouse and the keyboard, the student can wire his experimental circuit using the last picture taken; this step leads to reduce the distortion of the transferred image that depend on the bandwidth of the internet. A connection between two nodes on the circuit board is implemented by clicking on the first node and then clicking on the second node. This causes that a line between them is drawn (see Fig. 6.12). So when the student wire point1 (x_1, y_1) with point2 (x_2, y_2), the software take the (x, y) coordinates of these points (pixels) and refer for node matrix, then take the entries $N(x_1, y_1)$ that present the node's number of first clicked node and $N(x_2, y_2)$ that present the node's number of second clicked node, put these two elements as a row in matrix, when the student start wiring second wire previous steps again time and put the taken nod's numbers from node matrix in new row and so on....

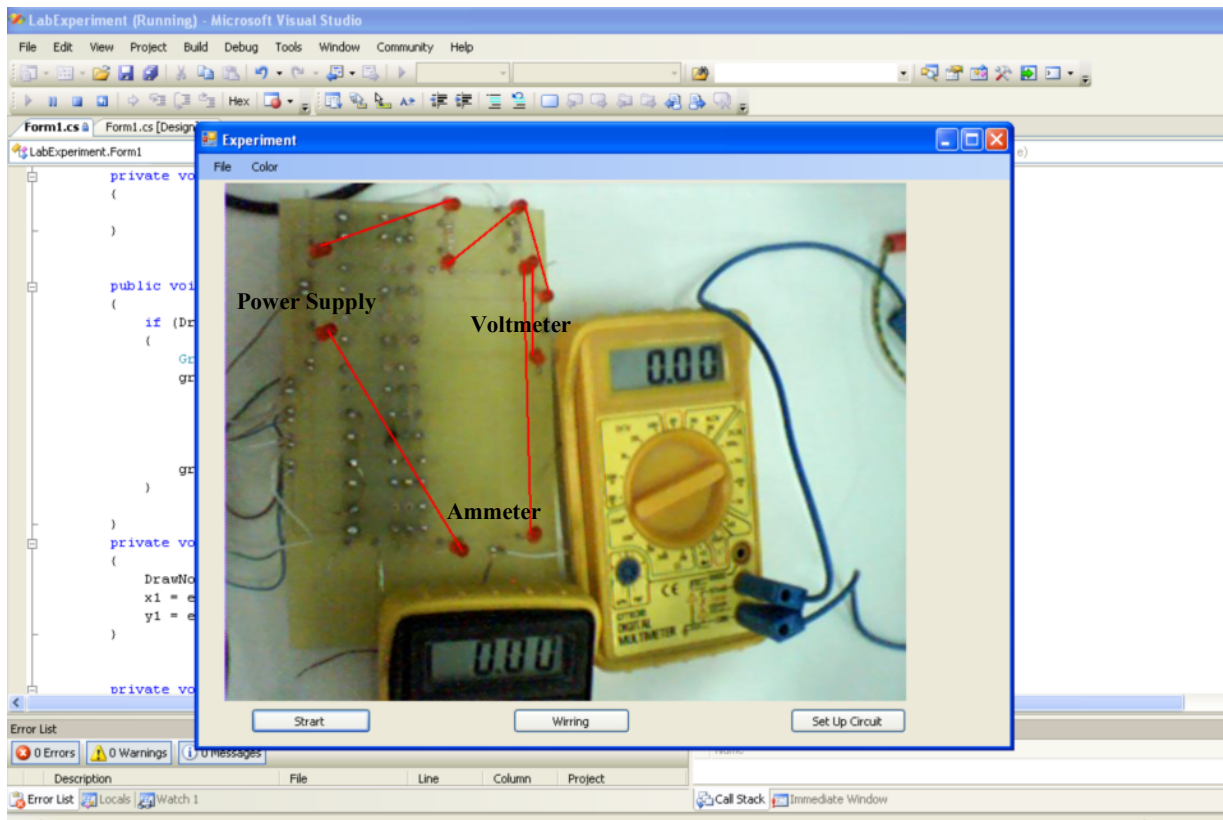


Figure 6.12: A virtually wired real circuit in the remote ARI laboratory leading to augmented reality based visualization.

From Fig. (6.12), the connected nodes of the wired circuit are given by the following matrix:

$$\begin{bmatrix} 3 & 1 \\ 4 & 2 \\ 5 & 10 \\ 7 & 9 \\ 2 & 6 \\ 5 & 8 \end{bmatrix}$$

The column elements in a row reflect the connected nodes, e.g., in the first row, node 1 is connected with node 3, and in the second row, node 2 with node 4 and so on. The content of this matrix is sent to server student by clicking on button "Set up Circuit" as seen in Fig(6.10).

In ordinary in hand-on laboratories, when a student finishes wiring a circuit experiment, the instructor of that experiment must check the connections in order to avoid damaging the components. In the developed ARI laboratory, this fact was adopted and is realized through a

software component designated as e-instructor. To achieve this, there are tables saved in a database containing all possible connections in the kit. The e-instructor like a human instructor validates the manipulated connections to avoid undesired connection combinations such as short circuits, high power values etc. If there is a wrong connection, a message will be sent to the client GUI and then it appears on the student's screen; the student will be alarmed and informed about unacceptable connections.

The acceptable connection combinations of the experiment kit circuit are saved in a table (5.1) as previous mentioned. As an example, if the student connects the circuit in Fig.(6.12), the required nodes of the experiment elements must be connected by the switches of the relays according to the saved table of the experiment in the server, the software will take columns three and four to determine the output of the parallel port as follows:

$$\begin{bmatrix} 3 & 1 & 1 & 1 \\ 4 & 2 & 3 & 0 \\ 5 & 10 & 4 & 1 \\ 7 & 9 & 7 & 1 \\ 2 & 6 & 2 & 0 \\ 5 & 8 & 6 & 1 \end{bmatrix}$$

Since the low-level program for the parallel port, which is implemented in .NET (C#), requires decimal values, we have to transform bit-based control data to a corresponding decimal data. This is necessary because the sequence of the relays in the configuration table is not an ascending order. The output of the parallel port is calculated via the equation $\sum_{i=1}^{i=row} 2^{(a[i][3]-1)} * a[i][4]$. Thus, the output for the previously mentioned is:

$$\sum 2^0 * 1 + 2^2 * 0 + 2^3 * 1 + 2^6 * 1 + 2^1 * 0 + 2^5 * 1 = 105 .$$

For accessing the parallel port, we can use the class called *PortAccess*, which is implemented in the programming language C# (.NET) [see appendix A]. After sending the output data by the server for the LPT1, the specific relays will be turned on, the switches in these relays will be closed, and, the web cam will start transferring the video stream of the completed experimental circuit. Finally, the results will be shown on the instruments' screen, and the

student can observe these data through the transmitted live video of the kit and its instruments on his computer's screen as shown in Fig.(6.13).

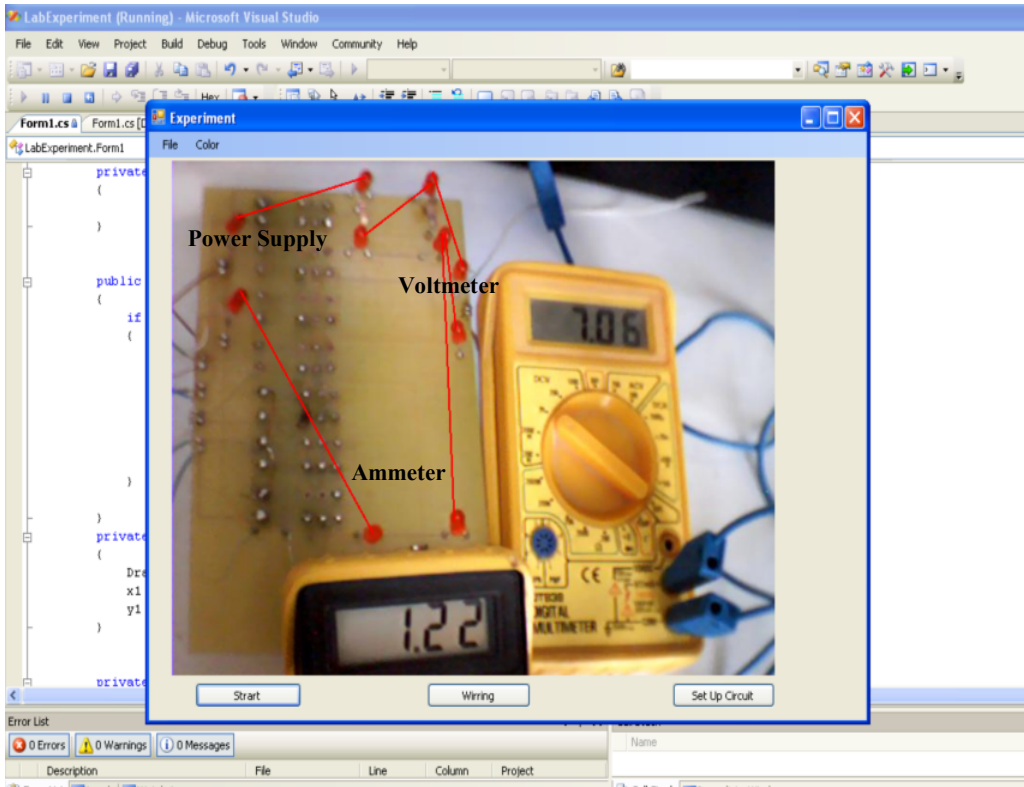


Figure 6.13: The results of ARI laboratory's experiment that the student can observe the transmitted live video of the kit and its instruments on his computer's screen.

If the student wishes to cancel the current experiment and will start a new session, he can do this through a pull-down menu as illustrated in Fig. (6.14). The client software sends a command to the hardware the remote laboratory server in order to cancel all switch connections.

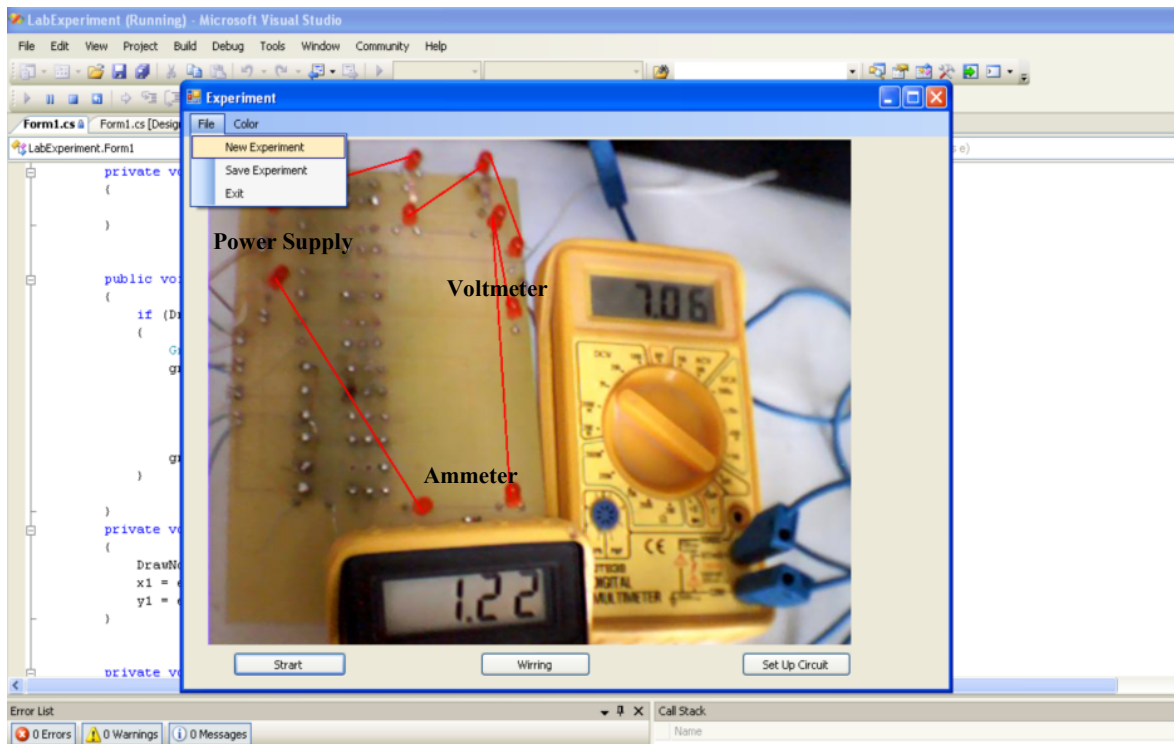


Figure 6.14: Starting a new experiment session through a pull-down menu.

At this step, the server will send the zero values as output of the parallel port to cancel all previous connections to begin new (another) experiment. Now, the student can wire the circuit again and the kit is ready to establish another experiment.

Another example, if the student connects the circuit in Fig.(6.15), the required nodes of the experiment elements must be connected by the switches of the relays as is shown in the following:

3	1
1	2
4	5
2	6
5	8
5	10
9	7

According to the saved table of the experiment in the server, the output of the parallel port is as follows:

$$\begin{bmatrix} 3 & 1 & 1 & 1 \\ 1 & 2 & 3 & 1 \\ 4 & 5 & 5 & 1 \\ 2 & 6 & 2 & 0 \\ 5 & 8 & 6 & 1 \\ 5 & 10 & 4 & 1 \\ 9 & 7 & 7 & 1 \end{bmatrix}$$

The output for the previously mentioned is:

$\sum 2^0 * 1 + 2^2 * 1 + 2^4 * 1 + 2^1 * 0 + 2^5 * 1 + 2^3 * 1 + 2^6 * 1 = 125$, and the results of this ARI laboratory's experiment is shown in Fig(6.15).

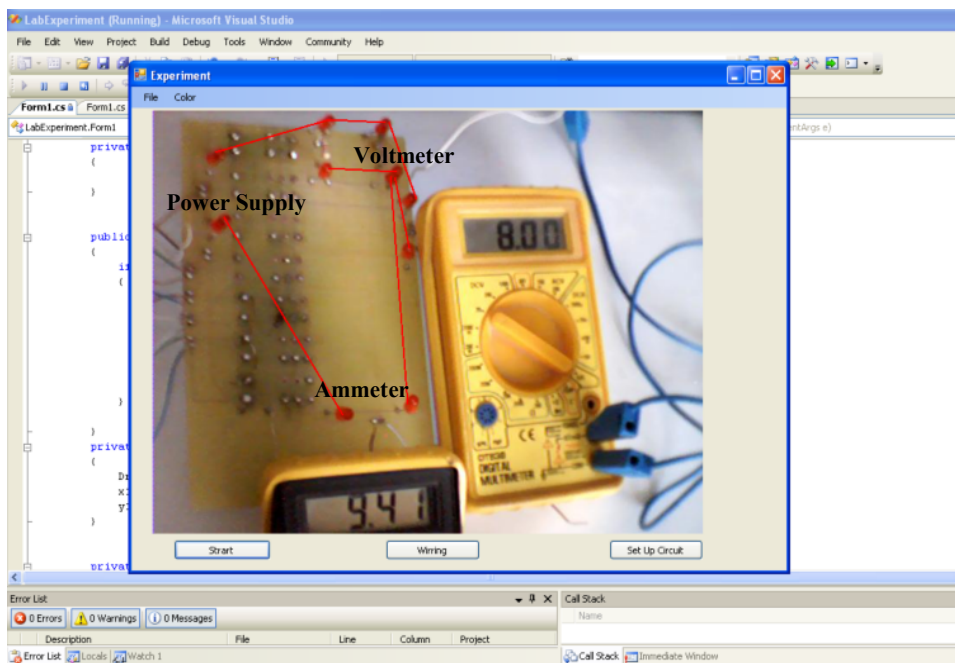


Figure 6.15: The results of ARI laboratory's experiment of a second example.

From the previously mentioned, we can summarize the following features achieved through applying AR technologies in remote laboratories:

- An ARI laboratory presents the real view of components and instruments of a laboratory, along with the real data and results from laboratory's experiment. Other approaches of remote laboratories lack this feature and are worried about imitating real experiments and their results as much as possible, what is missed in most cases. As an

example is the remote laboratory presented in Fig(6.16), which presents the real data of an experiment consisting of physical components and instruments using symbolic and visual graphics [50]

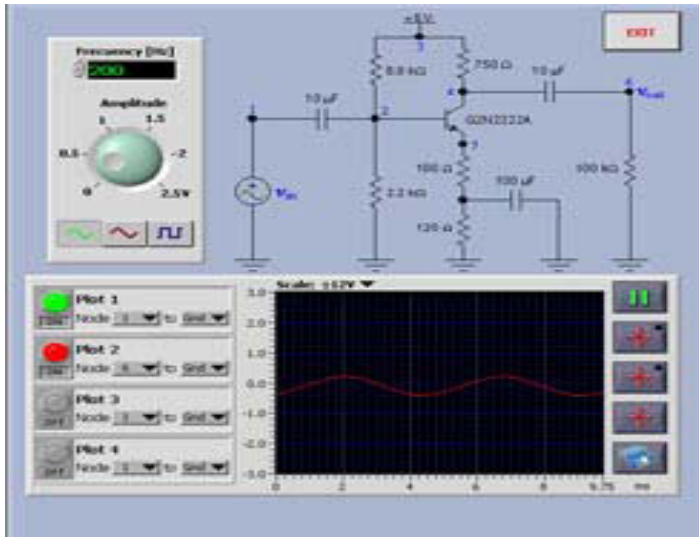


Figure 6.16: A remote laboratory gives actual results but the components and instruments of experiment are symbols or visual graphics.

- ARI laboratory is considered as synchronous interactive graphics system after recognizing and understanding the captured image of the experimental kit. The user can make the allowing connections by using keyboard and mouse. After validating these connections and changing the state of the relays that are responsible for to connect the experiment components with each other by the server, measured data from the experiment is obtained from instrument's screen through the web camera, which transfers a live video stream of the real experiment to the remotely located student's computer screen.

Some students prefer to use different colors while wiring the circuit such as red for positive polarity and black for negative polarity. This opportunity is given to the experimenting student as she/he can change the color of the connecting wire through a color menu (see Fig. 5.17).

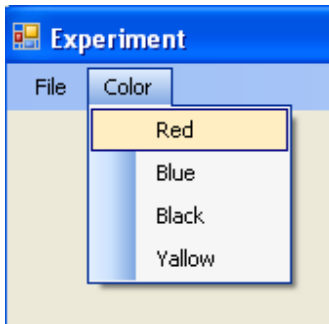


Figure 6.17: Color wire

6.3.3. Saving Results:

Usually, at the end of any a traditional experiment, the instructor sees data and results from the experiment. Also in our ARI laboratory, after executing an experiment, the student can save his results by selecting a menu-item called “Save Experiment” from a pull-down menu as illustrates Fig. (6.18). The system saves not only a snapshot of his/her computer screen, but also the wired connections of the circuit elements as well.

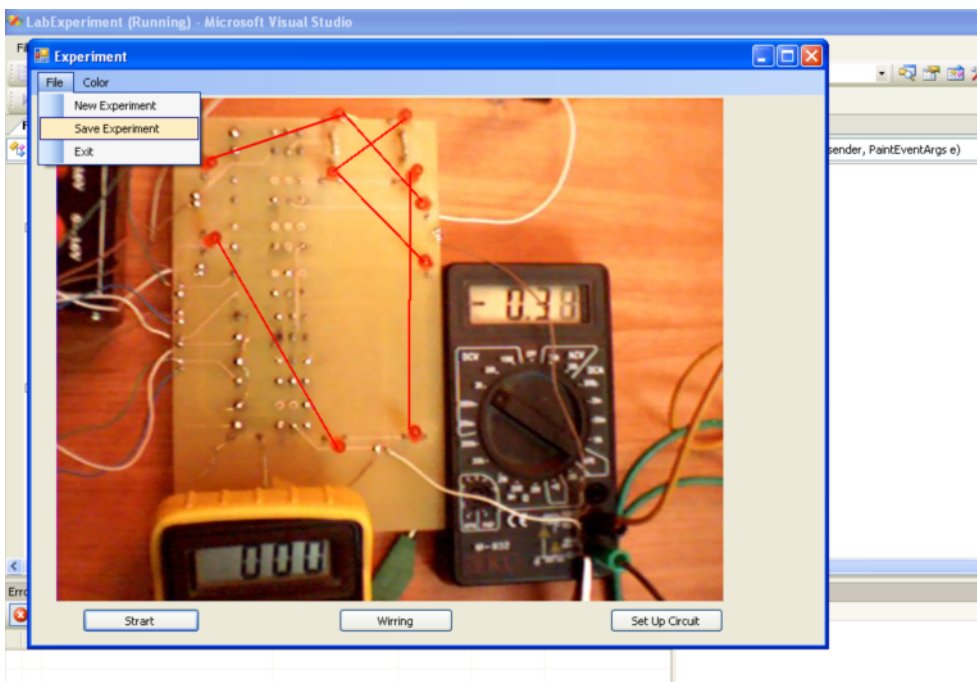


Figure 6.18: Saving an experiment session.

As an example, the source code includes the functionality of capturing the screen of the remote ARI laboratory, which will be saved as jpeg file called “Results.jpeg” [seen appendix A].

6.4 Summary

This chapter illustrated the implemented software of the ARI laboratory developed using the programming language C# within the integrated development environment dot NET. The developed software is implemented both for the server and client.

The graphical user-interface (GUI) as a client of the whole system was the mediator between a student and the laboratory server. The GUI is consisted of a number of displays built using graphical controls with which the user can quickly and easily control the hardware. A web camera transfers a video stream of the experiment with its required instruments on the computer screen of the student. Wiring of the real represented experiment circuit will be performed based on the augmented reality, where, real video pictures were overlapped with virtual wires. A student wired his circuit by using the keyboard and mouse. A connection between two nodes on the circuit board is implemented by clicking on the first node and then clicking on the second node. After wiring the experiment, the student sends his wiring for the server, the E-instructor checks all the connections and prevents unaccepted connections, after that the server sends the required data for the LPT1 to turn on the a specific relays and closes their switches; at this step the experimental circuit is completed and the data was shown on his computer screen.

Through the ARI laboratory, the following features through applying AR technologies in remote laboratories are achieved:

- An ARI laboratory presents the real view of components and instruments of a laboratory, along with the real data and results from the laboratory's experiment more than remote laboratories with pure graphical presentation.
- An ARI laboratory is considered as synchronous interactive graphics system. The student can make his experiment using keyboard and mouse online and the real data of an experiment is visualized simultaneously on his screen.

Chapter Seven

Comparative Evaluation of the Augmented Reality Internet Laboratory

7.1 Introduction

One of our objectives of this thesis study is to find out how much effective augmented reality internet laboratories assist students in understanding and reinforcing their theoretical concepts. An obvious way for doing that would be a comparative evaluation, which compares our system, the ARI laboratory, with hand-on and virtual laboratories. Evaluation of new practical educational systems depends on student surveys to measure the achievement of the required practical skills of the students from these categories of laboratories, compared with other traditional ones.

7.2 Methodology

A survey questionnaire of closed end questions was implemented and the raw data was collected in order to investigate student perceptions of their experiences of hand-on, virtual, and augmented reality laboratories in this case study.

Closed-end questions are questions in which all possible answers are identified and the respondent is asked to choose one of the answers (Strongly disagreement, Disagreement, Neutral, Agreement, Strongly disagreement), Closed-ended questions have advantages [51]:

- Closed-ended questions are generally more straightforward and offer choices for respondents,

- Closed questions guide respondents to specific information needed,
- Closed questions permit to ask more questions in less time, and
- The data (answers) are easy to tabulate, and to analyze.

A total of 10 engineering students (4 females and 6 males) from al Khadoori University at Electrical Engineering Department were participated in the survey questions. The laboratory experiments included electrical and electronic components and instrument such as resistors, power supply, ammeters. Students carried out the same experiment (series and parallel circuit) using the hand-on laboratory, virtually using an electronic workbench program, and by using the implemented ARI laboratory. After completing the three sessions, every student answered the survey questions. The used survey questionnaire consisted of eight questions for evaluating the student perception of hand-on, virtual and ARI laboratories, and five other general questions on the usage of the ARI laboratory, using a five point (where scores of 1-5 were used to indicate levels of agreement with the statements). The results of the survey questionnaire are discussed in the following section.

7.3 Discussion of the Results

After the students finished his experiment on three types of laboratories, they answered a list of common questions. These data is collected and analyzed. Table (7.1) and Fig.(7.1) display a comparison of the laboratories regarding the students' perceptions and responses.

Table 7.1: Survey results on hand-on, virtual, and ARI laboratories.

#	Survey item	Hand-on lab.	Virtual lab.	ARI lab.
1	Easy to use	72%	68%	86%
2	Easy to understand the concept theory	80%	76%	78%
3	Available for enough time	44%	82%	84%
4	Satisfying the knowledge theory	80%	68%	80%
5	Safe environmental for student.	52%	90%	90%
6	Progress new skills	76%	74%	80%

7	Teamwork's lab. is encouraged	76%	50%	56%
8	Comfortable physical place	66%	82%	86%
Average		68.3%	73.8%	80%

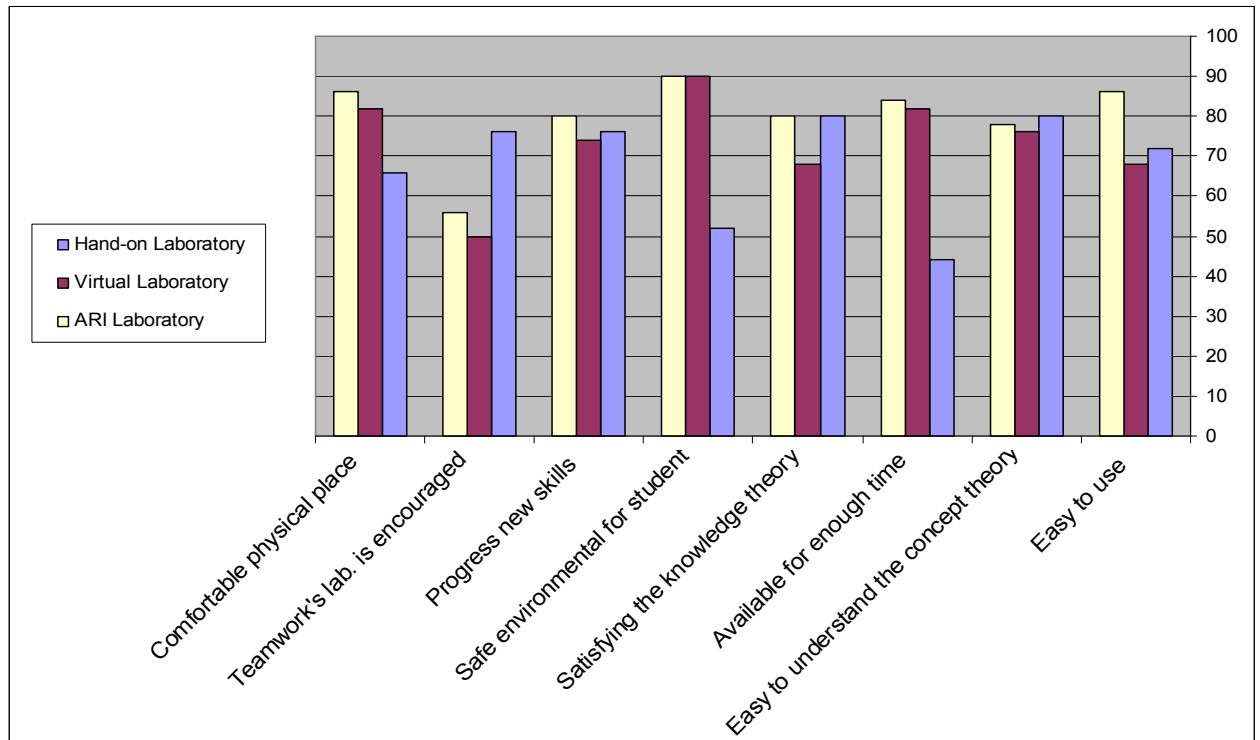


Figure 7.1: Survey results on hand-on, virtual, and ARI laboratories.

The analysis of the survey results gives these indicators as shown in the following:

- Easy to use: The survey data indicates that while carrying using the hand-on laboratory, the student faces some difficulties in the experimental work like wiring the circuit that must be isolated between wires in order to avoid any touch between them. In the virtual laboratory, the students need additional effort to learn how using the software program of the virtual laboratory. In the ARI laboratory, the design of the kit assists the student in the experimental work as all the components and instrument present on his screen. Thus, the student just needs to wire the required components in correct way to take the results from his screen through the webcam.

- Easy to understand the concept theory: As is obvious, the survey data of the three laboratory categories gives nearly the same degree in this question because all of these laboratories are established to demonstrate the theories, providing the students with additional skills of how to deal with these components and instruments in order to prove the concepts.
- Available for enough time: The hand-on laboratory is not available for enough time for that huge numbers of students to become familiarized with the electrical laboratory instruments and its components. On the contrary, virtual and ARI laboratories are available for students. Using the virtual laboratory, which is realized a software program running on a PC. In the case of the ARI laboratory, the students interact with the ARI lab from any terminal computer that is connected to the Internet. The student can choice his experiment and its time through schedule time of the experiment to preserve his experimental time. An ARI laboratory offers more enough time than hands-on to enable more training and understanding of the problematic.
- Satisfying the knowledge theory: carrying the experiment using the hand-on and ARI laboratories, the students deal with real components and instrument so they obtain real results in their environment of the laboratory. But in the virtual laboratory, students interact with a simulated experiment realized on a computer and take the results from a mathematical model. In a simulated experiment, there are many errors that may be occurred are ignored such as tolerance errors from manufactories or surrounding temperature of components and instruments, that cause some actual experiments (hand-on) not to work properly.
- Safety environment: In the hand-on laboratory, the students directly deal with electrical instrument, so the instructor must review the student's connections before executing his experiment, especially for high voltage connections, that need more attention from students and instructor for avoiding any critical error. These errors may harm the students or damage the instruments. In the virtual laboratory, the students deal with a mathematical model where it represents a safely environment for the students, and thus, we do not need to frighten from any occurring error. In the ARI, the students

work their experiment away from the electrical instrument, eliminating the students to be frightened from directly dealing with dangerous instruments. Additionally, by using the implemented e-instructor in the ARI laboratory, sensitive instruments and components are protected against damage. We can conclude that the ARI laboratory offers a safely environment for both the students and instruments.

- Progress new skills: the survey data show nearly equal results of these laboratories because of the facts that these laboratories are created to satisfy the electrical and electronic engineering theory through dealing with electrical components and instruments to prove theses concepts of new practical skill.
- Teamwork's lab. is encouraged : Team-work and communication skills can often be found in hand-on laboratory training. The virtual and ARI laboratories, if are not designated for this purpose, could discourage direct collaboration and communication skills. Further work is required in the design of ARI laboratories to incorporate collaborative assignments and discussions that may enhance students' transferable skills. Abdelghani [52] investigated the collaboration of students along with a tutor while carrying out engineering experiments via remote laboratories.
- Comfortable physical place: The results from this questions indicated that the virtual and ARI laboratories offers relaxed feeling while a student performs his experiment from his computer and at his wanted time and away from electrical instruments. On the contrary, the hand-on laboratory is not only restricted in time and place, but the students, instruments and instructors must be presented at the same place, making frighten feeling from tedious wiring and measurements that might damage the electrical instruments.
- Experimental time: The required time for carrying out the experimental work for the same experiment in each laboratory is different as is shown in Table (7.2). This is caused according to the different environments of the experimented laboratories. In the hand-on laboratory, the students, instruments and instructor must be at the same

physical place; the experimental work needs instructor's supplement, which requires additional time, to verify the correctness of experimental connections before feeding the circuit with power supply to avoid possible damaging errors. In the virtual laboratory the student takes the experiment results of his experimental circuit directly from the mathematical model applied. During the experiment, the student just spends the experimenting time with choosing the components and with connecting the virtually modeled circuit via a computer.

Table 7.2: The experimental time needed in the three different laboratories.

	Hand -on	Virtual	ARI
Experimental time (min)	31	17	43

In the ARI laboratory, the student accesses his experiment through the Internet, and he is permitted to access the ARI laboratory if he has a login name and a password to execute the experiment. It is undeniable that the bandwidth of the Internet influences the experimental time. For small internet bandwidths, we are enforced to increase the time between two taken successive frames of the web cam in order to avoid the delays occurring due to the speed of transfer data in Internet. This is allowed in our ARI laboratory because the actions of the students relative to the response time of the circuit and the instruments, whose states and outputs are sent to the client as a live video stream, are very slow.

Table (7.3) shows the survey results of the five general questions on the usage of the ARI., the following discussion and charts show the acquired results for each survey item in table (7.3) .

Table 7.3: Results of the survey of five general questions regarding the usage of the ARI laboratory.

Survey Item	Strongly agreed	Agreed	Natural	Disagreed	Strongly disagreed
I think that the augmented reality internet lab is more real than a virtual lab	30 %	70%	-	-	-

I think that I learn and understand more in an augmented reality internet lab than a virtual lab	20 %	80 %	-	-	-
I can use augmented reality internet laboratory over the Internet instead of a physical hand-on lab.	-	10 %	20 %	30 %	40 %
I can use augmented reality internet laboratory over the Internet as supplementary to a physical hand-on lab.	20 %	70 %	-	10 %	-
I think that the augmented reality internet lab offers more relaxation than a hand-on because participants are away from electrical instruments and the instructor.	40 %	40 %	20 %	-	-

Regarding the criterion “I think that the augmented reality internet lab is more real than a virtual lab” (see Table (7.3)), Virtual laboratories are an assistive complementary in engineering education. In a virtual laboratory, students deal with symbols and virtual presentation of the instruments and components of the experiment, leading to discourage students from becoming well-known with physical instruments and real devices. In the ARI laboratory, the web cam transfers visual information of the real components and instruments of the hand-on laboratory to their computer's screen on the client side (see Fig.(7.2)).

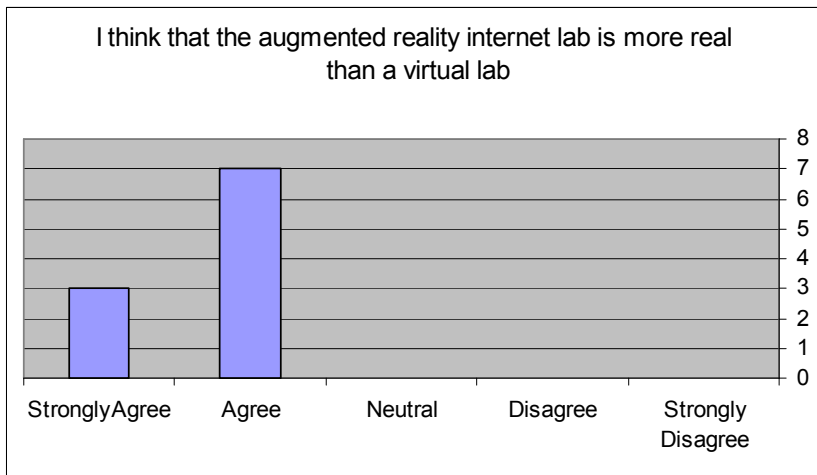


Figure 7.2: Bar chart of the survey result of the question “I think that the augmented reality internet lab is more real than a virtual lab”.

For the survey item “I think that I learn and understand more in an augmented reality internet lab than a virtual lab”, one of the students commented that *"In the virtual laboratory, many experimented electrical or electronic circuits function properly but when we built them physically (with real components and instruments) they don't work"*. This is according to the facts that in a virtual laboratory, students can conduct experiments via a computer and take the results from a mathematical model; the errors that may occur such as tolerance errors from manufactories or surrounding temperature of components and instruments are ignored. But in ARI laboratory, there is no simulation, and a student performs his experiment with real components and instruments, and the real results are captured by the webcam from the screens of the instruments, and then are sent via the Internet to his computer's screen. it is not surprising that some of the survey results show that the education in the ARI laboratory is more real than the virtual laboratory (see Fig.(7.3)).

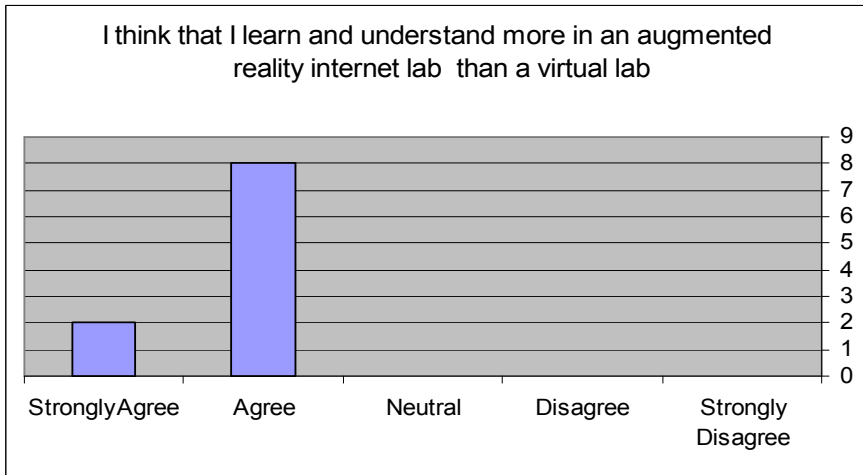


Figure 7.3: Bar chart of the survey result of the question “I think that I learn and understand more in an augmented reality internet lab than a virtual lab”.

The survey question “I can use augmented reality internet laboratory over the Internet instead of a physical hand-on lab” shows the students still favorite the hand-on lab over any category of laboratories, and any category of laboratories will not replace hand-on laboratories because they know that in their future work they must deal with real components and instruments directly without any distance between them (see Figure 7.4).

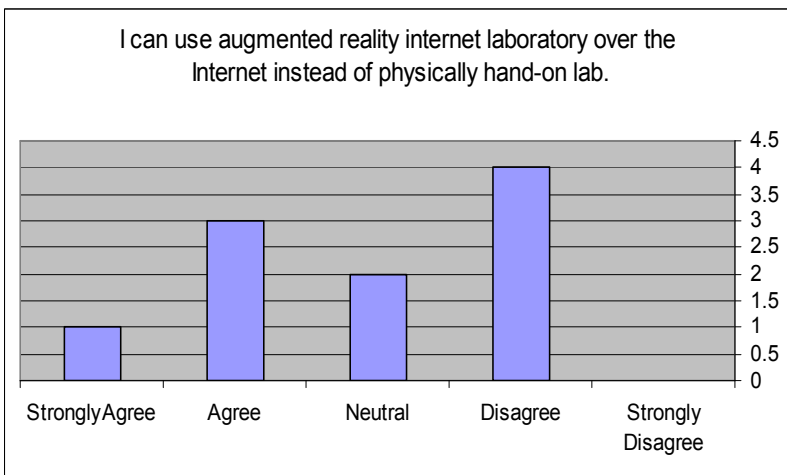


Figure 7.4: Bar chart of the survey result of the question “I can use augmented reality internet laboratory over the Internet instead of a physical hand-on lab”.

The survey question “I can use augmented reality internet laboratory over the Internet as supplementary the physical hand-on lab” gives an idea that the ARI laboratory assists engineering students in understanding and reinforcing their theoretical concepts beside the

hand-on laboratory. Using augmented reality technique in ARI laboratory supports the distance learning in effective way by adding some virtual objects over the real live video of components and instruments which give real experimental and real results for students. Moreover, the students have the possibility to repeat the experiment more than one time. Engineering students can use the ARI as a supplementary to the hand-on laboratories which are available only for a limited time for that huge number of students, and its instruments and components are scarce and expensive (see Figure 7.5).

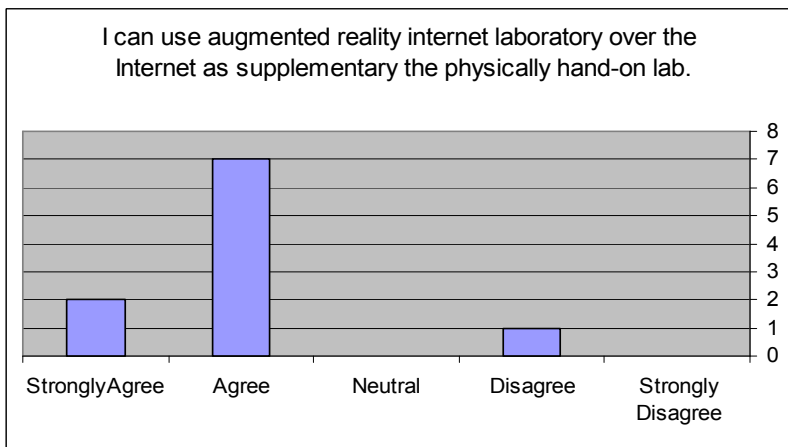


Figure 7.5: Bar chart of the survey result of the question “I can use augmented reality internet laboratory over the Internet as supplementary to a physical hand-on lab”

The results from the question “I think that the augmented reality internet lab offers more relaxation than a hand-on because participants are away from electrical instruments and the instructor” indicated that the ARI laboratory offered relaxed feeling while the student performs his experiment from his computer and at his wanted time, and is a safe away from electrical instruments. In the ARI laboratory, the students are concentrated on understanding fundamental concepts and not frighten from tedious wiring and measurements because they are familiar that the measuring instruments are protected against accidental damage due to wrong wiring (see Figure 7.6).

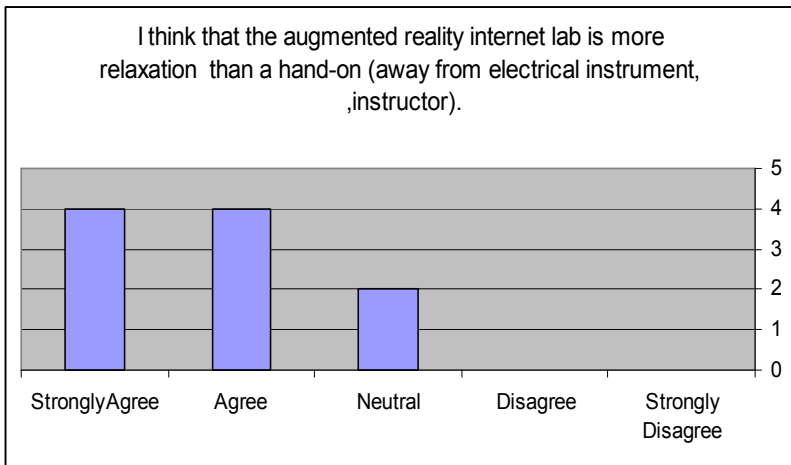


Figure 7.6: Bar chart of the survey result of the question “I think that the augmented reality internet lab offers more relaxation than a hand-on because participants are away from electrical instruments and the instructor”

7.4 Summary

The results obtained from the comparative evaluation shows that the ARI laboratory was generally well accepted from the students. However, the feedback from students' answers indicated that students perceived ARI laboratory as easy to use, easy to understand the concept theory, flexible to use in relation to time and place, safety environment and satisfying than virtual labs overall.

Students agreed that the ARI laboratory experiment assists for illustrating concepts learned in class. In addition, they feel that the ARI laboratory is an effective system for enhancing their knowledge of their understanding of the lectures. They have an improved ability to identify the inaccuracies and uncertainties between experimental and theoretical results because there is no simulation in an ARI laboratory, indicating the ARI laboratory environment experience closer to a hands-on experiment. This is mostly achieved through overlaying real kits (stream video) with virtual (graphical) objects. We can summarize that the students are immersed in their activity while carrying out experiments through the ARI laboratory. As the term of immersion examines the strengths of real world and virtual world in the manufactured environment, the average value of the survey results of the ARI laboratory (Table 7.1), which is superior to Hand-on and virtual laboratories, exposes that the students are “strongly” immersed in their activity of carrying out experiments through the ARI laboratory.

Chapter Eight

Conclusion and Recommendations for Future Works

8.1 Conclusion

It has been discussed how remote internet laboratories can be developed through using augmented reality technology, which combines the live real world with an overlay of virtual objects that become visible as one world. Captured photos of a live video stream of the kit with its components will be overlaid with graphical (virtual) objects of electronic components. Therefore, ARI laboratories bypass problems of virtual laboratories where students do not feel the reality of the components and instruments in engineering experiment.

The main goal of an augmented reality internet lab is to help students understanding applications of electrical and electric circuits. As our aim is to show and to implement AR technology in remote laboratories, the experiment selected here is simple consisting of passive components such as resistors, inductors, capacitors.

An augmented reality internet (ARI) lab can be accessed through a conventional web browser at any time and from any place, and students can remotely perform their required experiments. The representation of the experiments uses real live picture along with graphics that somehow samples hand-on laboratories. A login and scheduling systems are implemented to let the users carrying out their experiments in a flexible manner without conflicting with other students.

Developing the software for the web-based of augmented reality internet laboratory, contemporary development environments such as .NET are used; thus, the software can be easily adapted to other platforms. Placing of graphical objects such as electronic elements and

modules on the experimenting field of the user-interface causes connectors of the corresponding physical elements to become closed.

After completing building and implementing the ARI lab, various results are achieved such as: offering the laboratory at any time on all day, moving the real environment laboratories at any place where students present, protecting equipments from getting damaged, providing safer experimental environments for students, saving money through reducing the numbers of instructors and equipments, saving an instructor's time and simplifying their task.

A comparative evaluation, which compares our system, the ARI laboratory, with hand-on and virtual laboratories is carried out to show how much effective augmented reality internet laboratories assist students in understanding and reinforcing their theoretical concepts. The results of the comparative evaluation was carried out using student surveys to measure the achievement of the essential practical skills of the students from these categories of laboratories. However, the feedback from students' answers indicated that students perceived ARI laboratory as easy to use, easy to understand the concept theory, flexible to use in relation to time and place, safety environment and satisfying than virtual labs overall. In addition, they feel that the ARI laboratory is a useful system for enhancing their knowledge of their understanding of the lectures, the main reason for these positive results that there is no simulation in an ARI laboratory, indicating the ARI laboratory environment experience closer to a hands-on experiment. This is mostly achieved through using augmented reality technique that overlay real kits (stream video) with virtual (graphical) objects.

In thesis, we showed that the students will be immersed in their activity of carrying out experiments through the ARI laboratory, as the term of immersion examines the strengths of real world and virtual world in the manufactured environment. Through the previously discussed, we can see that the immersion type achieved in our system is more mental than physical, which is created through the factors: the real-visualized experimenting circuit (meaningful world), the LEDs (where the user can interact with computer), and the high resolution images offered and the high-speed internet bandwidths that, nowadays, are available. As mentioned in former chapters, small internet bandwidths are not a concern for our ARI laboratory, because of the facts that the time between two taken successive frames of

the web cam is increased for avoiding the delays occurring due to the speed of transferring data through the Internet. This is allowed, as the actions of the students relative to the response time of the circuit and the instruments, whose states and outputs are sent to the client as a live video stream, are very slow.

8.2 Recommendations for Future Works

The work described in this thesis has been developed and implemented based on augmented reality; however, there are still other improvements that can be made to make ARI laboratories more flexible and versatile such as:

- The GUI of the ARI laboratory can be more comprehensible by divided the video image in to multipicture box. In each picture box, the client can show the video image of one electrical apparatus, such as one represents DDM and another power supply and so on; this suggestion requires using more than one web cam.
- Designing the power supply that can be controlled from the client GUI using the mouse and the keyboard; this design includes power supply, potentiometer and stepper motor. To achieve such functionality, the potentiometer must be wired with the power supply, the output voltage is taken from the variable resistors of the potentiometer, and the motor is connected with knob of potentiometer. By using the mouse, the student can increase or decrease the output voltage by sending a command to a motor, which will be rotated to the right or to the left for changing the potentiometer resistor value.
- Controlling DDMs and oscilloscopes by a student from his computer's screen using mouse and keyboard. For example; the student can increase or decrease the scales of oscilloscopes (Volt/DIV or TIME/DIV) by rotating the mouse to the right or to the left.

References:

- [1] S. Dormido, H.Vargas, J. Sánchez, N. Duro, R. Dormido, S. Dormido-Canto, and F. Esquembre: "Using Web-Based Laboratories for Control Engineering Education", International Conference on Engineering Education, Coimbra, Portugal, September, 2007.
- [2] Z.Nedic, J. Machotka, and A.Nafalski: "Remote laboratories versus virtual and real laboratories", Proc. 33rd ASEE/IEEE Frontiers in Education Conference, Boulder, Colorado, USA, November, 2003.
- [3] Z. Nedic, J. Machotka, and A. Nafalski: "Remote Laboratory NetLab for Effective Interaction with Real Equipment over the Internet", Proc. 2008 IEEE Conference on Human Systems Interaction (HSI), Krakow, Poland, pp.846-851, May, 2008.
- [4] L. D. Feise,l and A. J. Rosa: "The Role of the Laboratory in Undergraduate Engineering Education", Journal of Engineering Education, Vol. 94, pp. 121-130, January, 2005.
- [5] J. Y. Ma, and J. S. Choi: "The Virtuality and Reality of Augmented Reality", Journal of Multimedia, Vol. 2, No.1, pp.32-37, February, 2007.
- [6] M. Sairio: "Augmented Reality", 2001.
- [7] R. Silva, J. C. Oliveira, and G. A. Giraldi.: "Introduction to Augmented Reality", Technical report, LNCC, Brazil, 2003.
- [8] J. Juhnke, T. Mills, and J. Hoppenrath: "Designing for augmented cognition - problem solving for complex environments", Foundations of Augmented Cognition, Berlin: Springer-Verlag, pp. 424-433 ,2007.
- [9] C. E. Hughes, C. B. Stapleton, D. E. Hughes, and E. M. Smith: "Mixed Reality in Education, Entertainment, and Training", IEEE Computer Graphics & Applications, Vol. 25 Issue 6, pp. 24-30, 2005.
- [10] N. Navab: "Developing killer apps for industrial augmented reality", IEEE Computer Graphics & Applications, Vol. 24 Issue 3, pp. 16-20 ,2004.
- [11] H. WU: "Virtual Reality – Improving the Fidelity of Architectural visualization", Thesis in architecture, Master of scoence, Texas Tech University, may 2006.
- [12] T. Nilsen, S. Linton, and J. Looser: " Motivations for Augmented Reality Gaming", Proceeding of Fuse '04, New Zealan Game Developer Conferences, pp. 86-93, 2004.
- [13] B. Takacs: "Cognitive, Mental and Physical Rehabilitation Using a Configurable Virtual Reality System" , The International Journal of Virtual RealityVol.5 ,PP 1-12, 2006.

- [14] P.I Milgram, and F. Kishino: "A Taxonomy of Mixed Reality Visual Displays", IEICE Transactions on Information Systems, vol. E77-D,no.12, 1994.
- [15] W. T. Freeman, D. B. Anderson, P. A. Beardsley, C. N. Dodge, M. Roth, C. D. Weissman, W. S. Yerazunis, H. Kage, K. Kyuma, Y. Miyake, and K. Tanaka: "Computer Vision for Interactive Computer Graphics", IEEE Computer Graphics and Applications, vol. 18, No. 3, pp. 42-53, May 1998.
- [16] T. Nilsen, and S. Linton, and J. Looser: "Motivations for augmented reality gaming", Proc. the New Zealand Game Developers Conference, New Zealand, pp. 86-93 ,2004.
- [17] J. R. Vallino: "Interactive Augmented Reality", doctoral diss., University of Rochester, New York ,1998.
- [18] LearnFrame: "Facts, Figures and Forces Behind e-Learning", www.learnframe.com New York,pp4-81, 2000.
- [19] HEEPF deliverables: "E-learning and simulation labs", <http://www.heepf.org.eg>.
- [20] Aleksandrova and N. Nancheva: "Electromagnetism-Interaction of Simulation and Real Lab Experiment", Information Technologies and Knowledge, Vol.1, 2007.
- [21] J. Ma And J. Nickerson: Hands-On, Simulated, and Remote Laboratories: A Comparative Literature Review. ACM Computer Survey , Vol.38, Issue 3, Article No.7, 2006.
- [22] ASTD/NGA :”A Vision of E-Learning for America's Workforce”. Report on the Commission on Technology and Adult learning, 2001, www.nga.org/cda/files/elearningreport.pdf.
- [23] S. Naidu: “E-Learning, A Guidebook of Principles, Procedures and Practices” (2nd edition), CEMCA, 2006.
- [24] D. Huffaker: “The e-Learning Design Challenge Technology ,Models and Design”, E-learning in Higher education,2003.
- [25] J. Rosa, and L. D. Feisel: "The Role of the Laboratory in Undergraduate Engineering Education", Journal of Engineering Education, 94(1), PP.121-130 January 2005.
- [26] D. Hajda: “Implementing a Remote Laboratory”, Report for School of Computer Science and Software Engineering, The University of Western Australia, 2004.
- [27] S. Das, L. Sharma, and A. Gogoi: “Remote Communication Engineering Experiments Through Internet”, iJOE International Journal on Online Engineering - www.i-joe.org, 2006.

- [28] L. Creanor: "E-Learning Guides", Introduction to E-Learning at Glaskow Caldonian University, 2004, www.nga.org/cda/files/elearningreport.pdf.
- [29] Leleve, H. Benomohamad, P. Prevot, and C Meyer: "Remote Laboratory towards an Integrated Training System", Proceedings of the IEEE 4th International Conference on Information Technology Based Higher Education and Training (ITHET03), Marrakech, Morocco, July-2003.
- [30] L.Razmerita, and R. Keyser: "Virtual Laboratory for Simulation and Control Engineering: A Design Perspective".
- [31] Abbas, J. Orellana, P. Rolandi, and J. Romagnoli: "Experiential Engineering E-learning: The Concept of Soft Reaction", World Transactions on Engineering and Technology Education, Vol.4, No.2, pp. 171-176, 2005.
- [32] E. Valentin, A. Verbraeck, and H. Sol: Advantages and Disadvantages of Building Blocks in Simulation Studies: Laboratory Experiment with Simulation Experts, Simulation in Industry 15th European Simulation Symposium, SCS-European Publishing House, 2003.
- [33] B.Guimaraes, A. Souza, H. Gosmann, and A. Bauchspiess: "Internet Based Remote Laboratory: The Level Control of three coupled water Reservoirs", ACCA, Santiago de Chile, 2002.
- [34] Bischoff, and C. Rohrig: "Remote Experimentation in Collaborative Virtual Environment, rep., Department of Electrical Engineering, University of Hagen, Germany, 2001.
- [35] N. A. Streitz: "Cognitive compatibility as a central issue in human-computer interaction: Theoretical framework and empirical findings", Cognitive engineering in the design of human-computer interaction and expert systems, in G. Salvendy (Ed.), Amsterdam: Elsevier, pp. 75-82, 1987.
- [36] B. Shneiderman, and C. Plaisant: "Designing the User Interface: Strategies for Effective Human-Computer Interaction" (4th Edition). Addison Wesley Longman, 2004.
- [37] H. M. Deitel, and P. J. Deitel: "C# for programmers" (2nd edition). Prentice Hall , 2006.
- [38] CEC, CEC 488 programming and reference, Part number 370966A-01, 2003.
- [39] B. Shneiderman, and C. Plaisant: "Designing the User Interface: Strategies for Effective Human-Computer Interaction" (4th Edition). Addison Wesley Longman, 2004.
- [40] K. R. Sullivan: "Understanding Relays", www.autoshop101.com.

- [41] "PC817 Series", www.datasheetcatalog.com.
- [42] "ULN200xA - ULN200xD1 Seven Darlington Array", August 2007, www.st.com.
- [43] J. Axelson: "Parallel Port Complete, Programming, Interfacing, & Using the PC's Parallel Printer Port", Lakeview Research, 2000.
- [44] K. Yehia: "The iLab Service Broker : A Software Infrastructure Providing Common Services in Support of Internet Accessible Laboratories", Thesis, Dept. of civil and environmental engineering, Master of science at the Massachusetts Institute of Technology, 2004.
- [45] C. Darie, and Z. Ruvalcaba: "Build Your Own ASP.NET 2.0 Web Site Using C# & VB" (2nd edition). SitePoint Pty. Ltd, 2006.
- [46] D. A. Kerr: "The HSV and HSL Color Models and the Infamous Hexcones" Issue 3, 2008.
- [47] Y. Wang, N. L. Nihan, R. P. Avery, and G. Zhang: "Improving Truck and Speed Data Using Paired Video and Single-Loop Sensors", Thesis, Washington State Department of Transportation Technical Monitor, 2006.
- [48] L. Z. Krikor, S. E. I. Baba, and M. Z. Krikor: "Palette-Based Image Segmentation of 256-Color images using HSL Space", Journal of Digital Information Management, 2007.
- [49] L. Mornailla, T. G. Pekar, C. G. Solymosi, and Z. Vamossy: "Mobile Robot Navigation Using Omnidirectional Vision", In Proceedings of the 3rd Irish Machine Vision and Image Processing Conference (IMVIP'99), Dublin, Ireland, 1999.
- [50] M. E. Macias, and I. Mendez: " eLab - Remote Electronics Lab in Real Time", 37th AEEE/IEEE Frontiers in Education Conference, pp. S3G-12 - S3G-17, October 2007.
- [51] U. Reja, K. L. Manfreda, V. Hlebec, and V. Vehovar1: "Open-ended vs. Close-ended Questions in Web Questionnaires", Advances in Methodology and Statistics (Metodološki zvezki), 19, pp.159-177, 2003.
- [52] Abdelghani: "E. Collaborative working environments for web-based remote experimentation", Thesis, M. Sc, Al-Quds Univeristy, Palestine, 2009.

Appendix:

Appendix A

The Implemented Code in programming language C#

The source code for transfers real live pictures by using a USB web cam:

The dynamic link library “avicap32.dll” is used for creating a window child embracing a graphical control of the type “Picture Box”, in which the video will be displayed. The source code for importing the library and for creating the window is listed below:

```
[DllImport("avicap32.dll",
EntryPoint="capCreateCaptureWindowA")]

    public static extern int capCreateCaptureWindowA(string
lpzWindowName, int dwStyle, int X, int Y, int nWidth, int nHeight, int
hwndParent, int nID);
```

Using the dynamic library link “user32.dll” enables programmers to access the clipboard for both using and saving of images. The implementation of this software using “C#” clarifies the following source code:

```
[DllImport("user32", EntryPoint="SendMessage")]

    public static extern int SendMessage(int hWnd, uint Msg, int
wParam, int lParam);

[DllImport("user32", EntryPoint="OpenClipboard")]

    public static extern int OpenClipboard(int hWnd);

[DllImport("user32", EntryPoint="EmptyClipboard")]

    public static extern int EmptyClipboard();
```

```

[DllImport("user32", EntryPoint="CloseClipboard")]
    public static extern int CloseClipboard();
public void Start(ulong FrameNum)
    {
        try
        {
            // for safety, call stop, just in case we are already running
            this.Stop();

            // setup a capture window
            mCapHwnd = capCreateCaptureWindowA("WebCap", 0, 0, 0, m_Width, m_Height,
            this.Handle.ToInt32(), 0);

            // connect to the capture device
            Application.DoEvents();
            SendMessage(mCapHwnd, WM_CAP_CONNECT, 0, 0);
            SendMessage(mCapHwnd, WM_CAP_SET_PREVIEW, 0, 0);
            // set the frame number
            m_FrameNumber = FrameNum;
            // set the timer information
            this.timer1.Interval = m_TimeToCapture_milliseconds;
            bStopped = false;
            this.timer1.Start();
        }
        catch (Exception excep)
        {
            MessageBox.Show("An error ocurred while starting the
            video capture..\r\n\n" + excep.Message);
            this.Stop();
        }
    }

```



```
    }  
}
```

The source code of HSL filter:

```
for (int i = 0; i < img.Width; i++)  
{  
    for (int j = 0; j < img.Height; j++)  
    { // get RGB color  
        double r = img.GetPixel(i,j).R ;  
        double g = img.GetPixel(i, j).G;  
        double b = img.GetPixel(i, j).B;  
  
        //start calculate HSL componenets  
        double max = Math.Max(b, Math.Max(r, g));  
        double min = Math.Min(b, Math.Min(r, g));  
  
        double rr = (max - r) / (max - min);  
        double gg = (max - g) / (max - min);  
        double bb = (max - b) / (max - min);  
        if (r == max)  
            hue = (g - b) / (max - min);  
        else if (g == max)  
            hue = 2.0 + (b - r) / (max - min);  
        else  
            hue = 4.0 + (r - g) / (max - min);  
        hue *= 60;  
        if (hue < 0)  
            hue += 360;  
        lum = .5 * (max + min);
```

```

if (max == min)
{
    sat = 0;
}
else if (lum <= .5)
{
    sat = (max - min) / (2 * lum);
}
else if (lum > .5)
{
    sat = (max - min) / (2 - 2 * lum);
}
if (hue < 10) // Select the red color
{
    Node[i,j] = 1;
}
else
{
    Node[i,j] = 0;
}
// set all color to black except red color
if (hue>10)
{
    Color newColor = Color.FromArgb(0, 0, 0);
    img.SetPixel(i,j, newColor);
}
}

```

The variables r, g, b, h, s, l are declared as floating point numbers. Internally, the function works with floating point numbers between 0.0 and 1.0 for achieving precisely results. At the

end of the function, the results can be very easily converted back to integers from 0-360 for hue values.

The code for numbering the node on the kit's picture that captured:

```
nummernode = 1;

    for (int ii = 0; ii < img.Height; ii++)
    {
        count1 = 0;
        count0 = 0;

        for (int jj = 0; jj < img.Width; jj++)
        { // seeking a ones's collection

            if (NT[ii, jj] == 1)
                count1++;

            else
                count0++;

            // finding a ones's collection

            if (count1 >10)
            {

                count1 = 0;
                count0 = 0;

                int cc = 0;
                int c = 0;

                for (int iN = ii-7; iN < ii + 17; iN++)
                {

                    cc++;

                    if (cc <= 12)
                        c++;

                    else
                        c--;

                    for (int jN = jj - c ; jN < jj + c - 1; jN++)
```



```
        public static extern void Output(int address, int value);  
    }  
}
```

The piece of program responsible for calculating the decimal data for the parallel port looks as follows:

```
for (Row=0; Row<r; Row++)  
    OutPutPral=OutPutPral+ Math.Pow(2, (O[Row][3])-1)*O[Row][4];  
PortAccess.Output(888, OutPutPral);
```

Appendix B

RGB and HSL Color Model

Color is the property of visible light by which some light may be differentiated from another. The color is a three-dimensional property, which means that we need three magnitudes to describe a state of color. Color models are developed to describe a particular color in three parameters in coordinate systems such as RGB and HSL color model[43], [44].

The RGB color model:

The basic color model is the so-called RGB model. A pixel's color of an image can be represented by using the three color channels in the RGB color space. These three channels representing the three axes in the color space are red (R), green (G), and blue (B). The color represents proportional the quantity of each of values of R, G, and B. It's also called the additive color model because any color form is accomplished by adding the three color components together. In 24-bit color system, each of the three components R, G and B is an 8-bit variable that can be an integer number between 0 and 255. The absent of color component means 0 (black), while 255 means full intensity. The RGB may be used for the computer representation of colors or for displaying them on other peripheral display devices. Early RGB color space is used in computer graphics to represent colors in computer memory and graphic files. To use a filter based on this model, the stored photo must be passed through it; every pixel of the photo is decomposed in its R, G and B components. Filtering based on this model is not typically perfect for choosing some colors by specifying its RGB model, It is preferable to use the HSL color model over RGB model, because of differences in the ways the models emulate how humans perceive color. RGB is additive models, respectively, modeling the way that primary color lights combine to form new colors when mixed.

The HSL model:

HSL (Hue, Saturation, and Lightness) is a model for describing colors. There are several models resembling the HSL model such as HLS and HIS. It is to note that the L component in the HSL model can be referred to luminosity or luminance rather than light. The HSL color model is graphically represented by a double cone as represents Fig. (1). The top and base ends of the cone are the colors black and white that also called apexes. In this model, the hue is indicated by the angular perimeter. The saturation component of the HSL model is graphically observed by varying distances of the axes placed in the center of the graph in the vertical direction. Luminance is the distance between the two apexes and represents the light of the color model.

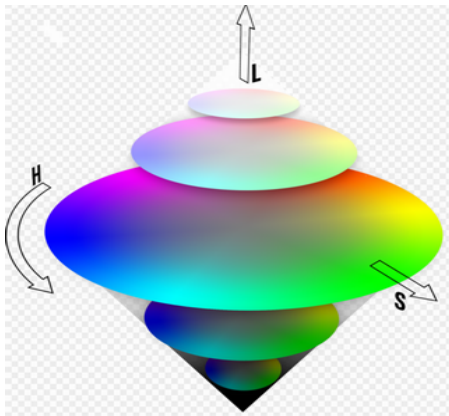


Figure 1: HSL model represented as a double cone

RGB color components are used to calculate the corresponding HSL components: hue, saturation, and luminance and vice versa. The meaning of the HSL color components is listed in the following [45], [46]:

- Hue (H): Hue indicates the color that is equal to the ratio of each primary (RGB) color which can be red, yellow, green, cyan, blue, magenta etc. Hue is referenced by an angle in the interval [0-360] on a color wheel as shown in Fig.(2); this demonstration appears nearly the same as the visible spectrum of light .

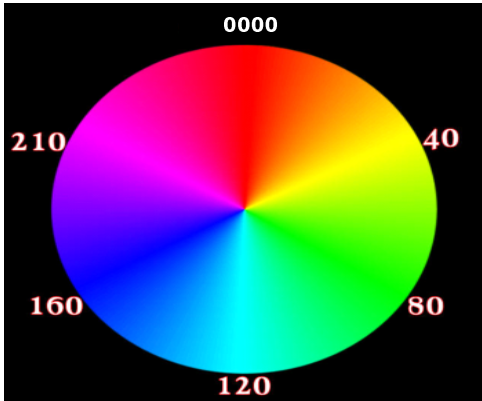


Figure 2: Hue represent as angle on a color wheel

- Saturation (S): Saturation indicates the quantity of intense or gray in the color. Saturation takes a value from 0-1; the value 0 is no color, lowering saturation explains the ratio between each of the primary RGB colors resulting in lower contrast and at its extreme a gray color. In contrast, one is the whole saturation of a given hue at a particular percentage of illumination. Increasing saturation increases the ratio between the major primary color and the lower primary color resulting in increased contrast.
- Luminance or luminosity (L): Luminance indicates the amount of light of the color. Luminance takes a value from 0-1, where at 0, the color is totally black, at 0.5 the color is pure, and at 1, it becomes white. In the HSL model, a color with maximum luminance (L=1) is always white, regardless of what the hue or saturation components are.

As the following equations state, the standard definitions of HSL coordinates are given through equations that begin from the R, G, and B coordinates of particular color.

$$L = \frac{\max(R, G, B) + \min(R, G, B)}{2}$$

$$S = \left\{ \begin{array}{l} \frac{\max(R, G, B) - \min(R, G, B)}{\max(R, G, B) + \min(R, G, B)}, L \leq 0.5 \\ \frac{\max(R, G, B) + \min(R, G, B)}{2 - (\max(R, G, B) + \min(R, G, B))}, L > 0.5 \end{array} \right\}$$

$$H = \left\{ \begin{array}{l} 0, \max = 0 \\ (60x \frac{G - B}{\max(R, G, B) - \min(R, G, B)} + 360) \bmod 360, \max = R \\ 60x \frac{B - R}{\max(R, G, B) - \min(R, G, B)} + 120, \max = G \\ 60x \frac{R - G}{\max(R, G, B) - \min(R, G, B)} + 240, \max = B \end{array} \right\}$$

The $\min(R, G, B)$ is smallest value of the color component of RGB models, and $\max(R, G, B)$ is the largest value of the color component. If $\min(R, G, B)$ equals $\max(R, G, B)$, that means $R=G=B$ and thus the color is a shade of gray. This is a trivial case, hue can be set to anything, saturation has to be set to 0.

تطوير و بناء في مختبرات الهندسة عن بعد على شبكة الإنترنت باستخدام تقنية الحقيقة المعززة "Augmented Reality"

إعداد: شذى صائل ابوشنب

إشراف: د. صلاح الدين عودة

ملخص

هذا البحث يهتم بشكل عام بمختبرات تدريس التجارب الهندسية والعلمية التي يتم التحكم بها عن بعد عبر الإنترنت ، ويهدف بشكل خاص إلى دراسة وتجريب ملائمة الحقيقة المعززة (Augmented Reality) لتسخيرها في جعل تلك المختبرات أكثر ملائمة للطلاب تعليميا ، مع تسهيل استخدامها والتحكم بها عن بعد من خلال واجهة الاستخدام . تعتبر المختبرات جزءا أساسيا في التعليم الهندسي والعلمي ، لأنها توفر المعرفة العملية للطلاب . للأسف ، حتى الآن فإن المختبرات التقليدية والتي يجب على الطلاب التواجد فيها جسديا والتفاعل معها متوفرة لفترات قليلة ومحدودة غير قادرة لتغطية عدد كبير من الطلاب . التقييد بعدد من التجارب المختبرة تحتاج إلى معدات مكلفة كأجهزة القياس الإلكترونية بالإضافة إلى تكلفة الأدوات المطلوبة لهذا النوع من المختبرات . هناك طريقة لتجاوز المشاكل المذكورة آنفاً من خلال استخدام نظام المختبرات عن بعد ، مع تمثيل وعرض أجهزة المختبرات وأدواتها عن طريق الرسومات في الحاسب ، والتي ستؤدي الى عرض المعلومات بشكل افتراضي . العرض الافتراضي لا شك بأنه سيساعد الطلبة في تطوير مهاراتهم العملية ، إلا أنه معلوم بأن هذا الطريقة ستشكل عائقا أمام تصور الطلبة الصحيح لأجهزة وأدوات المختبر الحقيقية ، وستؤدي إلى معاناة الطلاب في تمثيلهم للواقع لعدم استخدام المعدات الحقيقية للتجربة بشكل واقعي .

في هذه الأطروحة ، سنقوم بتقديم نظام مقترح الهدف منه تحسين المختبرات عن بعد عبر شبكة الانترنت باستخدام تقنية الحقيقة المعززة "Augmented Reality" . نظرا لاعتباره نموذجا أوليا كان لا بد من تقييمه من خلال إجراء تجارب في المختبرات التقليدية و مختبر الحقيقة المعززة.

لتحقيق الهدف المذكور سابقا ، كان من الضروري مناقشة تطبيقات تكنولوجيات AR في المجالات الأخرى و فهم الأفكار والتقنيات المستخدمة في مثل هذه التطبيقات التي ساهمت في استحداثنا أفكار

للتحكم بمختبر الحقيقة المُعززة . وعلاوة على ذلك ، من أجل تصنيف بحثنا من نظام المختبرات عن بعد ، من المهم أن نكون على دراية بالنوع الآخر من نظام المختبرات عن بعد ، وكذلك نظرية التعلم الإلكتروني التي تقع خلف هذه التقنيات.

في هذه الأطروحة ، كان لأسلوب بناء و إنجاز مختبر الحقيقة المُعززة الدور الرئيسي في تحقيق الأهداف التي نوقشت أعلاه ، وكان لتطبيق هذا النظام أن يعكس بعض جوانبه التقنية. عرض التجربة في هذا النظام يستند على صور فيديو حقيقة مكسوة بعناصر افتراضية تعزز الشفافية للتجربة وكذلك تجسر هوة التصور التي تنشأ لدى الطلاب عند تفاعلهم مع أنظمة افتراضية بحتة . النظام المحقق يمكن الوصول إليه من أي متصفح ويب تقليدي يحتوي على واجهة مستخدم خاصة بشبكة الانترنت ، مما يتيح للطلاب إعداد التجارب المطلوبة في أي وقت ومن أي مكان . إن واجهة المستخدم لنظام المختبر عن بعد التي قمنا بتطويرها في هذه الرسالة قائمة على أساس مختبر الحقيقة المُعززة وتحتوي على جميع العناصر المطلوبة ، الحقيقية والظاهرية ، التي يحتاجها الطلاب للقيام بتجربة محددة . في هذا النظام تم الحصول على دفق فيديو للتجربة المعنية من خلال كاميرا ويب ، وإنشاء صوره أساسية خاصة بمختبر الحقيقة المُعززة مستندة إلى واجهة المستخدم التي سيتم تغذيتها ببيانات مصورة للتجربة الفعلية على جانب الخادم ، والتي تمثل مصدر اهتمام رسالة الماجستير هذه . الطالب يتفاعل مع النظام عن بعد من خلال استخدام أجهزة الماوس ولوحة المفاتيح وجهاز العرض . في البدء لدورة التجربة ، يقوم الطالب بتأسيس اتصال بمختبر الحقيقة المُعززة المعد عن بعد ، حيث يقوم هذا النظام بتقديم عرض حقيقي لدوائر التجربة مكسوة بصورة جرافيكية أو نص . بمجرد أن يتم إنشاء الاتصال ، يستطيع الطالب أن يبدأ في التعامل مع هذه التجربة و تنفيذها .

بعد ما أن يقوم الطالب بتوصيل نقاط أدوات الدائرة الإلكترونية الممثلة بتقنية الحقيقة المُعززة على شاشة النظام العميل التي تجمع بين الجانب الافتراضي والواقعي المحقق ، فإن البرنامج العميل يحدد العقد المرتبطة مع بعضها باستخدام وسيلة تصفية تستند إلى تقنيات معالجة الصورة الرقمية (HSL filter) . ثم يرسل العميل المعلومات المكتسبة إلى الملقم الخاص بخادم التجربة ، الذي يقوم بدوره التحقق من صحة هذه الوصلات من أجل تجنب إتلاف معدات المختبرات ؛ بعد ذلك يقوم خادم المختبر بربط التبديل المطابق للمفاتيح الخاصة بدائرة التجربة.

Publication