INFRARED-BASED INTERACTIVE PROJECTOR

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Abstract

This study introduced a device that is economical compared to existing technologies while being portable and easy to setup compared to gigantic electronic whiteboards that require to be mounted on a wall. The study entitled Infrared-based Interactive Projector features built-in CPU that eliminates the need to connect a laptop to a projector and touch screen interface that allows the user to touch and control the image displayed on the projected screen through the use of an Infrared Stylus. The device also promotes remote access feature in which the user can control the desktop in real time through a mobile phone or tablet wirelessly without the need to connect to an internet source. It also has the ability to be operated through an embedded battery pack in which the device could be used for a couple of hours without connecting it to an AC outlet. Lastly, all the components are combined and connected within a small case where in, carrying and setting it up from classroom to classroom is hassle free and not time consuming.

Keywords: Interactive Projector, Infrared-based, Touch Screen Interface, remote access.

Nelson Mandela believes that education is the most powerful weapon which you can use to change the world. Each person has to exercise the right to receive quality education as part of his human rights. To effectively implement that right, the integration of educational system, facilities, educators, and teaching aids are of concern. Teaching aids are materials that an educator uses to present a different way of the teaching-learning process and to enhance the quality of education.

Large number of schools in the Philippines still relies on blackboards and whiteboards which demands a number of chalks, whiteboard markers, erasers and refills periodically. Despite higher budget allocations from the government, the state of education in our country still lags compared to other countries in Southeast Asia. (Garcia, 2016)

At the present period of time, technology has made various improvements transforming a traditional classroom into a smart one. The use of projection technology is one of those advancements. Unbeknownst to the millennial, the projection concept has been around as early as the Palaeolithic era through natural camera obscures and shadow plays. The earliest known sketch, capturing the idea of projecting a drawn image onto a surface was created by a man named Giovanni Fontana in 1420. The sketch included a drawing of a monk holding a lantern projecting an image of a winged demon to the surface. This composition became one of the cornerstone and inspiration for numerous engineers over the following centuries to invent various types of projectors such as opaque, filmstrip, slide, overhead, data, computer, multimedia, and pocket projectors. Projectors can be described as an electrically addressable spatial light modulator whose working volume is defined by the frustum of light emanating from the projection lens.

The use of interactive technology in classroom white-boards is another advancement in the education field. Interactive media is a method of communication in which the output from the media comes from the input of the users. The first interactive whiteboard was introduced to the world by David Martin and Nancy Knowlton in 1987. Since then various interactive white-boards have been created by using different genre of sensors, software, and materials. (Springgay, 2015)

The problem on branded interactive whiteboards is that it is expensive while existing projectors still needs to be connected to a laptop then manually adjust the range, position and resolution of the projected image to the board which waste the class hours just by setting up the equipment. The researchers thought of a solution to those problems by constructing a device which has its own operating system like a computer by using a

miniature central processing unit known as the maker-board. The equipment features touch screen interface that allows the user to interact with the images and objects shown on the projected display using a stylus through infrared technology. It is a powerful tool in the classroom that adds interactivity between the professor and students, allowing the integration of media content into the lecture and support collaborative learning.

By unifying various ideas, concepts, and features from existing technologies into a single product, the researchers proposed a study which aims to provide the professors and students of the College of Environmental Design and Engineering of Baliuag University an Infrared-based Interactive Projector.

Problem Statement

The main problem of the study is: how to design and construct an electronic device that will innovate modern day teaching and improve the way information is presented?

The study sought answers to the following questions:

1. What are the current methods and electronic devices used by Baliuag University educators to present lecture and discussion inside a classroom?
2. What are the features of the infrared-based interactive projector that will differentiate it from existing devices and technologies?
3. What are the electronic components required for the infrared-based interactive projector?
4. What are the parameters considered to test and evaluate the proposed device?

Methods

Conceptual Framework

This section provides an organized way of presenting the IPO model through series of block diagrams. IPO stands for Input, Process and Output which signifies the systematic procedure starting from gathering ideas to testing and evaluation of the Interactive Projector.

Conceptual Framework sets the stage for the presentation of the particular research question that drives the investigation being reported based on the problem statement which presents the context and issues that caused the researchers to conduct. (McGaghie et. al, 2001)

The IPO model is divided into 3 elements:

- Input – Includes gathering of data, reviewing of lecture and generalizing the information.
- Process –Analysis, design, construction, testing and evaluation of the components.
- Output – Product of the study which applies the systematic approach done in I and P

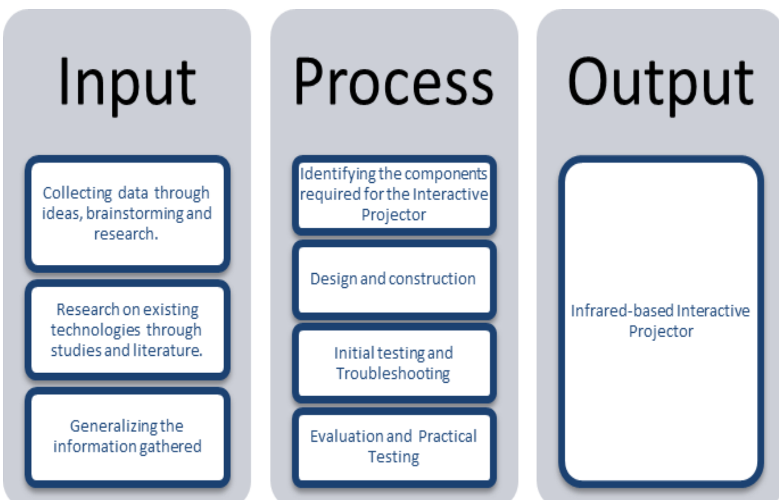

Figure 1. Conceptual Framework – IPO Model

Through observations regarding the effects of technology to make human activity faster and easier, the researchers thought of an idea to apply electronic technology to educational field. The collected data through ideas, brainstorming, and

consultations led to the feasibility on creating a device and through research on existing studies and literature, the idea of Infrared-based Interactive Projector has materialized.

In order to turn the study into an output, the researchers identified the components necessary to design and create the device. The components include projector, infrared camera, single board computer and infrared stylus with the consideration that it is economical compared to existing technologies and inventions, and it should also be light, portable and available in the local market.

With the components ready, the researchers proceeded to the design and construction of the desired output. The device was tested initially as part of beta where internal and external factors were considered. All bugs, issues and problems were troubleshot and repaired in order to ready it for the final outcome. Evaluation was done through surveys from classrooms to classrooms with the College of the Environmental Design and Engineering department, and from professors to students they ranked the parameters depending on their experience in using the device. The following parameters include functionality, usability, reliability, efficiency and maintainability.

By following the input and process of the IPO model along with the plans and guidelines, the researchers were able to transform the study, from a simple idea to the desired output. The Infrared-based Interactive Projector served as an innovative tool for classroom teaching and learning.

Project Design Method

In order to arrive into a conclusion, the researchers followed a set of research design method which ensures that the information obtained is addressed logically and as systematically as possible. Research design refers to the overall strategy that the researchers must choose to integrate the different components of the study in a coherent and logical way which constitutes the blueprint for the collection, measurement, and analysis of data. (Trochim, 2008)

The methods used in this study are the combination of descriptive, action research and meta-analysis design. The researchers gathered the first set of data through observation of the existing problems experienced in the society, then followed descriptive analysis in order to arrive to a conclusion regarding the solutions required to limit or remove the following problems to be researched in the proposed study. Meta-Analysis design was used to systematically evaluate and summarize the results from various individual studies related to the construction of the interactive whiteboard to analyze which components were essential for the system and development of the project.

Population and Sample of the Study

This section includes the systematic procedure on how evaluation of the study was appraised and processed. The results from the survey were used as a set of suggestions in order to further improve the Infrared-based Interactive Projector.

To identify the respondents in the study, the researchers used one stage cluster sampling. The researchers decided to choose the respondents coming from the ECE, CoE and EE department as the applications and documents stored in the device's system are related to the three courses. The population was divided into separate groups, and the cluster samples were obtained through simple random sampling.

A cluster sampling is where the researchers divide the population into groups, called cluster. It is one of the most economical, hassle-free and time-efficient sampling method available. This method is usually used when the loss of precision per individual case is more compensated for the possibility of studying larger samples for the same cost. One-stage is used out of the two types of cluster sampling, where the participants from all the randomly selected clusters are included as sample.

The respondents of the study were composed of three (3) engineering professors and forty three (43) students coming from the College of Environmental Design and Engineering of Baliuag University. Table 1 shows the list of respondents, along with the position, quantity and total of the variables.

Table 1. List of Respondents

Position	Frequency	Percentage
Engineering Professors	3	6.52
Engineering Students	43	93.48
Total	**46**	**100**

Research Instrument

An evaluation through survey was conducted to selected engineering professors and students in the College of Environmental Design and Engineering at Baliuag University to determine the performance of the Infrared-based Interactive Projector. The evaluation table includes the assessment criteria in terms of the functionality, reliability, usability, efficiency, and maintainability of the device.

The form contained series of questions under each assessment criteria that the respondents must appraise with a score from one to five. These ratings signified the participants' judgment on the question, whether they agree or disagree with the statement. The results of evaluation indicated whether the device has been proven worthy to be an exemplary tool in the educational field.

Data Gathering Procedures

In order to gather the information required to obtain the desired output of the study, the researchers considered five methods: 1) Direct observation, 2) Visualization and Conceptual-ization, 3) Requirement analysis, 4) Parameter testing, and 5) Study evaluation.

1. Through observations regarding the current methods used by educators to present information in the classrooms, the researchers thought of an idea to apply electronic technology to the classroom teaching and learning process.

2. The researchers gathered and critically analyzed multiple research studies and literatures in order to visualize and conceptualize the feasibility of the desired outcome of the proposed study. Relevant studies and literatures include graduate dissertations, articles, books, and alumni thesis which have provided information related to the system and development of the project.

3. The researchers narrowed down the specific components that are required for the creation and development of the proposed study. Specifications, features, cost and compatibility of the devices were studied to obtain the desired output of the study.

4. In testing the device, internal and external factors were included. All issues and problems were identified and repaired in order to ready it for actual use. The factors considered in testing includes accuracy and precision of the touch screen interface, effects of distance and height to the device, projected screen size limit, and usage time limit of the device when it is operated through DC source.

5. Through survey and evaluation, the researchers identified the parameters in which the device excels and which are inferior. The following results served as a set of suggestions and opinions to further improve and develop the device.

Design Procedures

In order to create the desired output of the study, the researchers followed a set of systematic procedures which include: 1) Requirement analysis, 2) Design and Construction, 3) Test and Troubleshooting, and 4) Evaluation.

1. The researchers analyzed which of the existing inventions to innovate and what features from existing technologies to integrate into the device. Specific components were then narrowed down by considering the following factors: specifications, features, cost, and compatibility.

2. The researchers designed the Infrared-based Interactive Projector to be portable and light-in-weight where in it is possible to carry it from classrooms to classrooms. The following were considered in the construction of the device: proper placement of components and accessories, easy access on ports and cables, and security.

3. In order for the device to be fully operational and easy to use, the researchers applied several testing procedures for its features and implemented troubleshooting the problems, bugs and issues found within the components and the Raspberry Pi's system.

4. Evaluation through survey was conducted in order to acquire data from the respondents' side based on their experience in using the device. The results were used in order to further improve the device for it to be functional, usable, reliable, efficient and maintainable.

Design Components

The Infrared-based Interactive Projector was built using various components. This section discussed the purpose and function of each part along with its specifications and features.

Raspberry Pi 3 Model B

The Raspberry Pi 3 is a powerful credit-card sized single board computer, nowadays, called maker board. It serves as the central processing unit for the interactive whiteboard. The researchers used the latest model that has higher processor speed and which includes built-in wireless fidelity and Bluetooth connectivity compared to its predecessor.

Figure 2. Raspberry Pi 3 Model B

Table 2. Raspberry Pi 3 Model B Specifications

Specifications	Description
Processor	Broadcom BCM2387 chipset 1.2 Ghz Quad-Core ARM Cortex-A53 802.11 b/g/n Wireless LAN and Bluetooth 4.1 (Bluetooth Classic and LE)
GPU	Dual Core VideoCore IV® Multimedia Co-Processor ES 2.0. hardware-accelerated OpenVG, Capable of 1Gpixel/s, 1.5Gtexel/s or 24GFLOPs with texture filtering and DMA infrastructure
Memory	1 GB LPDDR2
OS	Linux Operating System
Dimensions	85 x 56 x 17 mm
Power Consumption	Micro USB socket 5V1, 2.5A 250 mA (1.2 W)

Table 2 lists the specifications and descriptions of the Raspberry Pi 3 Model.

Table 3. Raspberry Pi 3 Model B Connectors

Specifications	Description
Ethernet	10 / 100 BaseT Ethernet Socket
Video Output	HDMI (rev 1.3 & 1.4) Composite RCA (PAL and NTSC)
Audio Output	Audio Output 3.5 mm jack, HDMI USB 4 x USB 2.0 Connector
GPIO Connector	40-pin 2.54 mm (100 mil) expansion header: 2x20 strip
Camera Connector	15-pin MIPI Camera Serial Interface (CSI-2)

Table 3. Continuation

Specifications	Description
Display Connector	Display Serial Interface (DSI) 15 way flat flex cable connector with two data lanes and a clock lane
Memory Card Slot	Push / pull Micro SDIO

Table 3 defines the specifications and descriptions of the Raspberry Pi 3 Model B Connectors.

Micro USB Power Supply

It is a micro USB plug in power supply for the Raspberry Pi 3. It is possible to use chargers from mobile phones to other handheld devices as long as it runs at 5V and at least at 2A.

Figure 3. Micro USB Power Supply

Table 4. Raspberry Pi Power Supply Input

Specifications	Description
Input Voltage Range	90-264VAC
Input Frequency	47-63Hz
Input Current	0.5A Max
Inrush Current	No damage and IP fuse will not blow
AC Intel	UK, Euro, Aus & US changeable heads

Table 4 describes the specifications and the corresponding descriptions of the Raspberry Pi Power Supply Input.

Table 5. Raspberry Pi Power Supply Output

Specifications	Description
Output Voltage	+5.1 Vdc
Minimum Load Current	0A
Nominal Load Current	2.5A
Nominal Output Power	13W
Output Regulation	+/- 5%
Line Regulation	+/- 2%
Ripple & Noise	120mVp-p Maximum
Rise Time	100mS Maximum at nominal input
Turn-on Delay	3 Seconds Maximum at Nominal Input
Protection	Short circuit, over current, over voltage
Efficiency	80.86%
Output Cable	1500mm Micro USB B 5 Pin

Table 5 describes the specifications and the corresponding descriptions of the Raspberry Pi Power Supply Output.

Table 6. Raspberry Pi Power Supply information

Specifications	Description
Dimensions	73.2 (L) * 45.1 (W) * 35.1 (H) mm
Weight	Approx 150g
Operating Temperature	0 °C to 40 °C
Storage Temperature	-20 °C to +60 °C
MTBF	50,000 Hours

Table 6 lists the specifications and the corresponding descriptions of the Raspberry Pi Power Supply information.

Acer C205 Projector

An optical device used to create large flat displays that provide a shared viewing experience for presentations or entertainment applications. In choosing what projector to use, the researchers considered the following factors: It must be portable and yet can produce clear and brighter images.

Figure 4. Acer C205

Table 7. Acer C205 Specifications

Specifications	Description
Brightness (ANSI Lm)	200
Native Resolution	854 x 480
Lamp Type	LED
Lamp Life	20000 hours
Contrast Ratio	1000:1
Lens Type	Manual Focus
Projection size	52 – 240 inches
Throw Ratio	1:1:1 (2082.80 mm @ 2000 mm)
Native Aspect Ratio	16:9
Speaker	Pair of 2 W
I/O	HDMI / USB / Audio Line In

Table 7. Continuation

Specifications	Description
Size (L x W x H cm)	26 x 34 x 12
Weight (g)	4.5
Power Consumption	32 W
Battery Capacity	3980 mAh
Battery Run Time	2 hours

Table 7 lists the specifications and the corresponding descriptions of the Acer C205 Projector.

HDMI Cable

The Raspberry Pi only uses HDMI to connect directly to a monitor or projector. It was possible to connect the Pi to a VGA peripheral through the use of HDMI to VGA adapter. However, the researchers used HDMI as it is digital compared to VGA that is analog. In using HDMI, it provided better video and audio output.

Figure 5. HDMI Cable

- Male HDMI to Male HDMI
- 2.0 Version with Ethernet and Audio return channel
- Nickel plated connectors
- RoHS soft PVC jacket for lifetime protection
- Pure Oxygen-free copper for ultimate conductivity

- Support 3D, 4K*2K, 17.8 Gbps, 2160P/60Hz and X.V. color
- Length : 500 mm

Infrared Pen

An input device which acts as the mouse for the interactive projector. Other terms include infrared stylus and light pen.

Figure 6. Infrared Pen

- Wavelength of 650 nm
- Operated by AAA battery
- Uses momentary push button
- Infrared LED

Infrared Camera

Its purpose in the study is to locate the coordinates of the infrared light on the tip of the light pen and to convert it into mouse movements.

Figure 7. Infrared Camera

- Bluetooth Connection
- 128 x 96 Monochrome camera
- 1024 x 768 Resolution
- Field view of 45°

Sandisk Micro SD Card

The Raspberry Pi does not have a built-in hard disk or storage. Hence, the researchers used a micro SD card in which the operating system, various applications and files were installed.

Figure 8. Sandisk Micro SD Card

- 64 GB Capacity
- Memory Card Type: MicroSDHC
- Speed Class rating: Class 10
- Size (cm) : 1.5 x 1.1 x 0.1
- Weight (kg) – 0.01

SC Model GI.SC209

A portable gadget that can charge electronic devices without connecting through an AC source. It was used in order to provide power to the built-in CPU for 2 hours.

Figure 9. Power Bank

- Capacity : 10000mAh
- Dual USB Output : 5V 1A & 5V 2.1A
- Size (Inches) : 5.5 x 2 x 3

USB to Micro USB Cable

It was used in order to connect the single board computer to the power bank for charging.

Figure 10. USB to Micro USB Cable

System Diagram

In order to provide an insight on how the equipment operates or works, the researchers constructed a block diagram which includes the main components for the study. The diagram showed the connection between the components and how data or information was transferred and received through wired and wireless media. Arrows indicates signal flow, with arrow heads indicating direction.

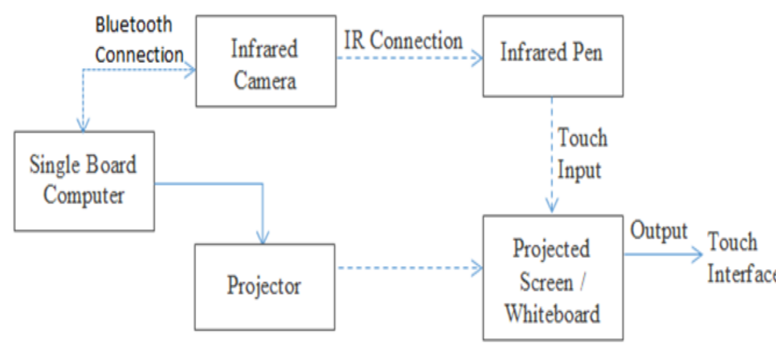

Figure 11. Block Diagram for Infrared-based Interactive Projector

The single board computer served as the hardware bridge for the camera and projector. The projector was connected to the single board computer via HDMI cable, whereas the Infrared Camera was connected via Bluetooth. Once the projector started projecting an image, the Infrared Stylus served as the mouse for the interactive whiteboard. When the momentary switch on the pen was pushed or pressed, the infrared camera detects, tracks and calculates the coordinates of the infrared source and converts it into mouse movements.

Flow Chart

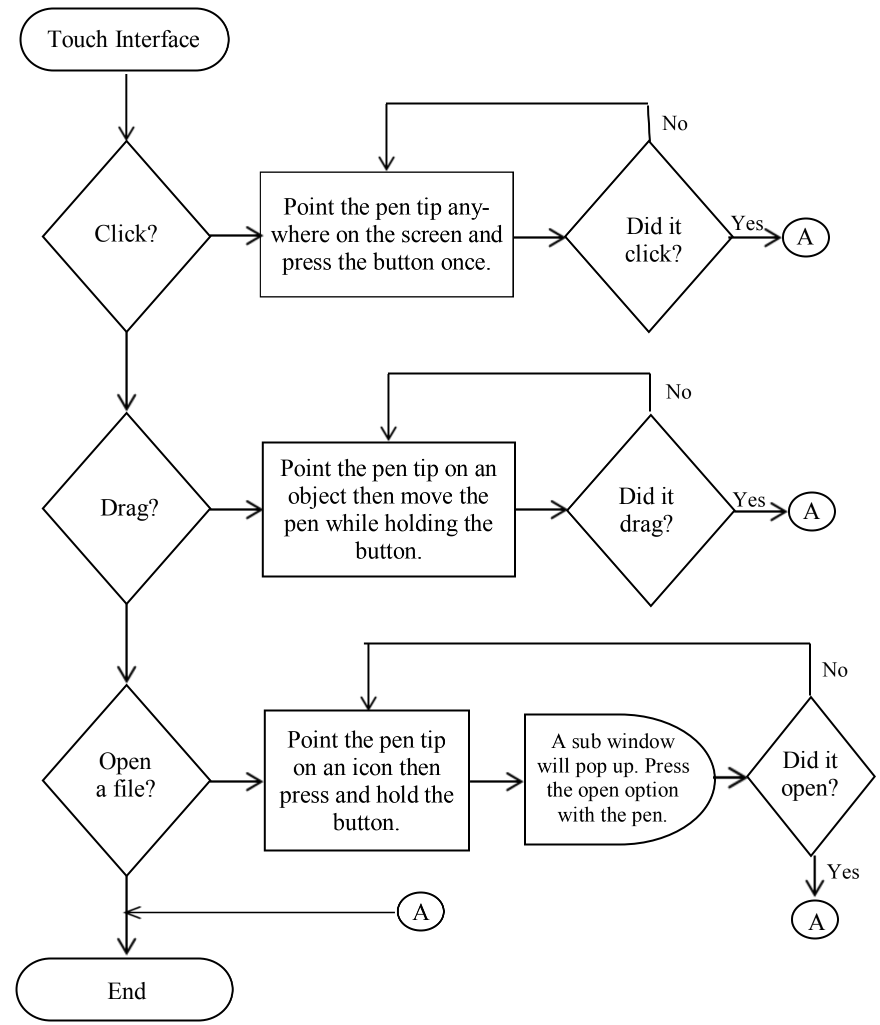

Figure 12. Touch screen interface flow chart

Figure 12 shows the touch screen interface flow chart. This figure summarized the procedure on how to operate the projector in a more illustrative manner.

Touch screen interface followed a set of instructions for the pen to work like a mouse. The user decides in which action to do or make inside the projected screen on whether to click an icon, drag an object or open a desired file for viewing. To click, simply point the pen tip anywhere on the screen and press the momentary button once. To drag, point the pen tip on an object then move the pen while holding the button. Opening a file requires the user to point the pen tip on the desired file icon then press and hold the button, a sub window pops up with a list of various options similar to right clicking in Windows or Mac desktops. Press the open option with the pen to finally open the file.

Cost Analysis

Table 8. Cost of Components

Components	Price	Quantity	Total
Raspberry Pi 3 B	₱ 2,184.73	1	₱ 2184.73
Acer C205	₱ 17,500.00	1	₱ 17,500.00
Infrared Camera	₱ 625.80	1	₱ 625.80
Infrared Pen	₱ 25.00	4	₱ 100.00
USB Power Supply	₱ 446.59	1	₱ 446.59
HDMI Cable	₱ 225.89	1	₱ 225.89
Micro SD Card	₱ 1,388.00	1	₱ 1,388.00
Power Bank	₱ 698.00	1	₱ 698.00
USB to Micro USB Cable	₱ 127.21	1	₱ 127.21
Total			**₱ 23,296.22**

Table 8 summarizes the cost of the components used in the study. It showed that the total costs of the component part is Php 23,296.22

Testing and Evaluation

This section contains information regarding the various tests that the researchers conducted in order to measure the performance of the Infrared-based Interactive Projector in an actual classroom setup. Also, it includes the bugs and issues that were fixed and troubleshot to ready the device in actual use. Furthermore, the results of the evaluation that were appraised by the respondents are presented.

Device Testing

The researchers tested the device in terms of (1) effects of distance and height of the infrared camera to the utilization and accuracy percentage of the touch screen interface, (2) projected screen size limit and (3) usage time limit of the device when it is operated through DC source.

1.) Touch Screen Interface Testing

The purpose of this test is to determine the effects of distance and height of the infrared camera to the utilization and accuracy percentage of touch screen interface.

Fixed Variables:

- Height of projector from the ground = 93 cm
- Camera Angle = 90°
- Table height = 81 cm
- Distance of projector lens to the projected screen surface = 101 cm
- Projected screen size = 105 cm x 55 cm

Table 9. Touch Screen Interface Testing

Test #	Distance (cm)	Height (cm)	Utilization %	Accuracy %
1	140	83	57	88
2	130	150	51	97
3	144	138	47	97
4	193	135	26	97
5	249	136	16	98
6	284	135	12	97
7	320	135	8	Unstable
8	50	135	0	0

Table 9 shows that the farther the camera is away from the projected screen, the utilization level decreases dramatically. At 320 cm, the touch screen interface became unstable as the camera at this distance is unable to determine the exact position of the screen with respect to its view, hence the low percentage in utilization. At 50 cm, the utilization and accuracy level are 0% as at this range, the calibration process cannot be completed due to the camera's field of view being too compressed that it cannot see the edges of the screen.

The researchers deduced that the camera must not be positioned too close to the projected screen but also, not too far away. The height of the camera does not affect the accuracy and utilization percentage as long as it is pointed to the center of the screen considering that there is no interruption to its line of sight.

2.) Projected Screen Size Limit

The purpose of this test is to identify the maximum size of the projected screen wherein the touch screen interface is still accurate, smooth and precise. The checks and crosses signified whether the points were successfully marked or not.

Fixed Variables:

- Height of projector from the ground: 82.55 cm
- Camera Angle = 90°

Table 10. Projected Screen Size Limit Testing

Test #	Screen Size (cm)	Point 1	Point 2	Point 3	Point 4
1	121.92 x 64.77	✓	✓	✓	✓
2	132.40 x 68.58	✓	✓	✓	✓
3	140.02 x 73.98	✓	✓	✓	✓
4	163.83 x 86.36	x	x	x	x
5	181.86 x 95.89	x	x	x	x

Table 10 shows that at screen size 163.83 cm by 86.36 cm, the user is unable to mark the four points located in the edges of the screen under calibration process. This signifies that the camera is not capable of capturing all points at this distance.

Even though test 3 was successful in capturing and marking all points, the touch input at this screen size is unstable. Hence, the researchers decided that 132.40 cm by 68.58 cm is the optimal size for the touch screen interface feature.

3) Usage time limit of the device when it is operated through DC source.

The purpose of this test is to identify the usage time limit of the Raspberry Pi and projector when it is operated through their respective DC source. The researchers conducted the test into two parts, (A) to identify whether the Acer C205 can be operated for 2 hours using its internal battery as stated on its specifications and (B) to determine whether the Raspberry Pi can keep up with the projector's battery run time.

(A) Verifying the battery run time of the projector.

Fixed Variables:

- Battery Capacity = 3980 mAh
- Battery Run Time = 2 hours (As stated in the specification)

Table 11. Projector Usage Time Limit Testing

Test#	Date Performed	Time Initiated	Time at 0% Charge	Time Elapsed
1	10 – 8 – 17	7:38 pm	9:48 pm	2 h 10 m
2	10 – 9 – 17	1:23 pm	3:33 pm	2 h 10 m

Table 11 shows that the projector automatically turns off at the exact time of 2 hours and 10 minutes due to the battery being drained. This verifies that the battery run time information on the component's specifications is correct. However, the researchers decided to make the usage time limit up to 2 hours only, as draining the battery frequently may cause damage to the battery.

(B) To determine whether the Raspberry Pi can keep up with the projector's battery run time.

Fixed Variables include:

- Battery Capacity = 10000 mAh (Power bank is at full charge, 4 bars.)
- Output Voltage = 5 V
- Output Current = 2.1 A
- Time Limit = 2 Hours

Table 12. Test on whether the Raspberry Pi can be operated for 2 hours

Test #	Date Performed	Time Initiated	Time Completed	Time Elapsed
1	10 – 7 – 17	10:20 am	12:20 pm	2 h
2	10 – 8 – 17	12:38 pm	2:38 pm	2 h
3	10 – 9 – 17	6:56 pm	8:56 pm	2 h

Table 12 shows that the Raspberry Pi, when powered up through the power bank can keep up with the projector's battery run time. The researchers set a time limit in testing the Raspberry Pi since the time exceeding 2 hours is unnecessary, as the projector can only be used in that duration.

The researchers decided to set the usage time limit of the Infrared-based Interactive Projector, a maximum of 2 hours when it is operated through DC source. This duration is enough for an educator to present lectures and discussions inside a classroom.

Troubleshooting

In setting up the Raspberry Pi, various bugs and issues were encountered by the researchers. This section contains how the following problems were fixed and troubleshot.

1) Keyboard and Mouse no longer functional after Raspbian boots.

- This happens when the version of the operating system has failed at installation. To fix the issue, the researchers reinstalled Raspbian in the micro SD card.

2) Remote access feature creates a virtual desktop instead of remote desktop.

- The researchers fixed the problem by properly installing the same version of VNC application in the Raspberry Pi and mobile device.

3) The Raspberry Pi and projector is switched on but the projector still shows "no signal."

- This happens when the Raspberry Pi is turned on before the projector. The Raspbian operating system was designed to output a HDMI signal, but if it did not detect a HDMI device connected to the single board computer, it would default to generating a composite signal on the A/V jack. Hence, in setting up the device, make sure that the projector is turned on first before plugging the power for the Raspberry Pi.

4.) An application or software fails to open or crashes.

- To fix issues like this, the application or software must be reinstalled.

Evaluation Results

Table 13. Overall Mean and Verbal Interpretation of the Device's Acceptability

Evaluation Criteria	Average Mean	Verbal Interpretation
Functionality	4.49	Strongly Agree
Reliability	4.7	Strongly Agree
Usability	4.59	Strongly Agree
Efficiency	4.54	Strongly Agree
Maintainability	4.64	Strongly Agree
Overall Mean	**4.59**	**Strongly Agree**

Table 13 shows that the results of evaluation were interpreted as "Strongly agree" in categories: functionality, reliability, usability, efficiency and maintainability. Overall, the evaluation gained an average mean of 4.59 which signifies that the respondents strongly agree with the statements listed in the survey.

The participants believed that the Infrared-based Interactive Projector can be a sophisticated replacement next to the traditional blackboards and standard projectors; that the device assisted professors in disseminating information inside a classroom. It was also proven that the device is user friendly and easy to use, as the various features such as the touch screen interface and remote access were accurate, precise and smooth. From these results, the researchers had successfully cleared the objectives conceptualized in the study.

Infrared Stylus Construction

Figure 13: Assembling the Infrared Stylus

Figure 14: Soldering the stylus' electronic components

Device Testing

Figure 15: Projection Size Limit Testing

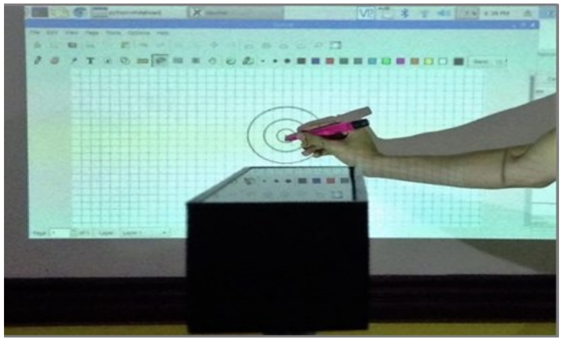

Figure 16. Touch Screen Accuracy & Precision Testing

Actual Testing

Figure 17. Presentation of the device to the respondents

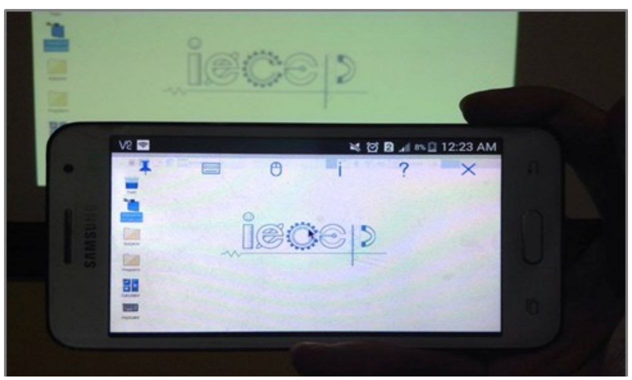

Figure 18. Remote Access Demonstration

Summary

The main objective of the study is to assist educators in presenting information inside the classrooms. The researchers aim to design and construct a device that is economical compared to existing technologies while being portable and easy to setup and which is composed of various features that are beneficial for teaching. Below are the findings of the study.

1.) What are the current methods and electronic devices used by an educator to disseminate information inside a classroom?

Despite the advancement of technology in the field of education, most schools in the Philippines still rely on the traditional blackboards and whiteboards which waste a number of chalks, markers and erasers. While projectors are available to some, the need to connect a laptop is still required and setting up the device from classroom to classroom greatly lessen the class hours just by adjusting the position, range and resolution of the projector. One of the advanced technology used in classroom teaching is called the interactive whiteboard, however this tends to be expensive and requires to be mounted on a wall.

2.) What are the features of the infrared-based interactive projector that will differentiate it from existing devices and technologies?

Its main difference to the existing technologies such as standard projectors and interactive whiteboards is that the need to connect a laptop was removed as the Infrared-based Interactive Projector featured built-in CPU through the installation of latest model of Raspberry Pi. The single board computer has WiFi and Bluetooth module embedded on the circuit; hence, transferring of files is much faster and easier as connecting dongles are not required anymore. Also, the user has the ability to touch the image displayed on the surface through infrared technology by using a stylus which acts as a mouse. Alternatively, the user can control the device's interface through a mobile device wirelessly without the need to connect to an internet source. The device can also be operated for 2 hours without connecting it to an AC outlet through the power bank; hence it can be used even when there's no electricity, as long as there is a flat surface and the lighting is dim enough. Lastly, the components used in the study were combined and connected within a small case making it portable, easy to setup and carry from room to room.

3.) What are the electronic components required for the infrared-based interactive projector?

To construct the Infrared-based Interactive Projector, the researchers chose the following components through requirement analysis. This includes the projector, single board computer, infrared camera, micro SD card, power bank, and infrared stylus. The researchers studied and analyzed the components' specifications, features, and compatibility in order to provide the maximum performance of the device.

4.) What are the parameters to test and evaluate the infrared-based interactive projector?

Test and evaluation is the set of practices and processes used in order to determine if the Infrared-based Interactive Projector correctly reflects the functional requirements and whether the device satisfies the usability needs of the intended users who are the professors and students. Also, its performance in an actual setting was considered and if the objectives of the study were properly met.

The researchers tested the device in terms of accuracy of the touch screen interface, effects of distance and height to the utilization level of the camera, optimal projected screen size, and usage time limit in using the device through DC source. These tests provided sufficient data in order to adjust and improve the device into the desired output. All bugs, issues and problems found within the internal and external sections of the device were troubleshot, repaired and enhanced.

To undergo the evaluation process, the researchers used one stage cluster sampling to determine the respondents in the study. The participants, consisting of engineering professors and students from the College of Environmental Design and

Engineering of Baliuag University rated the following assessment criteria: functionality, reliability, usability, efficiency, and maintainability. The ratings signify the participants' judgement on the questions, whether they agree or disagree with the statement. The data collected from the results were used to further enhance the device in criterion that were rated low or neutral.

Conclusion

By unifying beneficial features from existing technologies, the researchers constructed the Infrared-based Interactive Projector which features built-in CPU and touch screen interface. From the results of evaluation, the device has been proven to be a great asset in classroom teaching improvement. It can be a reliable replacement to the traditional whiteboards and projectors that maximizes the teaching capability of professors to disseminate information. The device passed in functionality, reliability, usability, efficiency, and maintainability from various respondents which proved that it was ready to be operated or used in an actual classroom setup.

The device with the total cost of ₱23,296.22 was economical compared to existing technologies like interactive whiteboards and projectors which range from ₱50,000 to ₱100,000. It was portable and easy to setup compared to gigantic electronic whiteboards that require to be mounted on a wall. The device had an embedded CPU which removed the need to connect a laptop to a projector. Its primary feature, the touch screen interface allowed the user to touch and control the image displayed on the projected screen through the use of an infrared stylus. An alternative to using pen was to use a mobile device to control the desktop in real time wirelessly without the need to connect to an internet source unlike other types of remote access. Since the device had built-in DC source through a power bank, it could be used in case of brownout for a limited amount of time. All the components were combined and connected within a small case where in, carrying and setting up the device from classroom to classroom proved to be less hassle and not time consuming.

Recommendations

The Infrared-based Interactive Projector was made through economical, portable and accessible components and accessories that time. The researchers' listed notable ideas below that could further enhance the device but requires investment on time, research, and financial aspects.

- Create a program or application that can connect 2 infrared cameras to the Raspberry Pi. The secondary camera shall act as a backup to the primary camera. This gives the advantage at which when the line of sight of the first camera is being blocked, the second camera will immediately take over the function of the primary camera. This will ensure continuous tracking when the Infrared pen is not detected by one of the cameras.
- Create a pen with longer Infrared LED wavelength than 650 nm. This will make the touch screen interface more accurate than the existing pen used in the project.
- Provide a DC source with higher rating than 10000 (mAh) but with the same output of 5(V) and 2.5(A). This will make the device last longer with continuous flow of power.
- Provide a projector with higher lumens and has an aspect ratio of 4:3. Using a screen size with the same aspect ratio as the camera will ensure that the camera view can cover all the sides of the projected screen.
- Construct a durable camera stand / rod that can move through X and Y axis. This will make sure that the camera can always point to the center of the projected screen.
- Invent a new type or integrate an existing touch screen technology that is different than Infrared. A type wherein it will remove the limitations covered in using Infrared technology. Next in line touch screen technology includes holographic application.
- Provide a micro SD card with higher storage capacity than 64 GB. This will provide more space for application and document installation.

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