Gesture-Driven Cursor Control Interactive Projection System

An Undergraduate Student Research Design Project Presented to the Faculty of

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In Partial Fulfillment of the Requirements for the

Degree of Bachelor of Science in Computer Engineering

and the Degree of Bachelor of Science in Electronics Engineering

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APPROVAL SHEET

In partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Engineering and the degree of Bachelor of Science in Electronics Engineering, this Undergraduate Student Research Design Project entitled "**GESTURE-DRIVEN CURSOR CONTROL INTERACTIVE PROJECTION SYSTEM**", prepared and submitted by **Hernandez, Lance Eman M., Malabuyo, Jhon Lester M., Puso, Rocxel Roi C.,** and **Ofrin, Carl Symon V.,** is hereby examined and recommended for acceptance and approval.

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CERTIFICATION

This is to certify that the undersigned has edited and grammatically proofread the research paper entitled **"GESTURE-DRIVEN CURSOR CONTROL INTERACTIVE PROJECTION SYSTEM"** prepared and submitted by **Hernandez, Lance Eman M., Malabuyo, Jhon Lester M., Puso, Rocxel Roi C.,** and **Ofrin, Carl Symon V.**

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ABSTRACT

The researchers developed a Gesture-Driven Cursor Control Interactive Projection System designed to improve how users interact with digital content through natural body movements. This innovative system combines gesture recognition technology, high-definition cameras, and projectors to enable real-time detection of user gestures, allowing seamless control of presentations or educational content. It effectively replaces traditional remote controls and whiteboards, creating a more engaging and interactive experience in both classroom and professional settings. The system's core strength lies in its ability to deliver precise gesture detection and smooth performance thanks to advanced machine learning algorithms based on Google MediaPipe, combined with high-quality hardware components. Its modular design ensures quick setup, instant response times, and handheld functionality, making it versatile and easy to use across various environments. Cost-effectiveness was a key focus, with extensive testing and refinement addressing challenges related to detection accuracy, system compatibility, and environmental factors. Overall, this gesture interface technology aims to revolutionize presentation methods by promoting immersive, intuitive, and dynamic user interactions, enhancing engagement and effectiveness in diverse interactive sessions.

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CHAPTER I

INTRODUCTION

Background of the Study

In the fast-paced and continuously evolving educational and professional environment, there are changes needed for modernization, engaging solutions to enhance the quality of presentations. Traditional methods, such as the use of projectors and whiteboards, have often led to one-dimensional execution and limited engagement between the presenter and the audience. To address these challenges, researchers have proposed the Gesture-Driven Cursor Control Interactive Projection System, a cutting-edge solution that leverages gesture recognition, sensors, and cameras to create an IoT-enabled interactive interface.

Unlike conventional approaches that rely on physical objects to interact with content on a whiteboard, this innovative system allows users to control a cursor through hand gestures. These gestures are detected by a projector equipped with a camera and sensors, seamlessly integrating the projected content with the user's movements. This technology fosters a more dynamic and interactive presentation experience, enhancing both the presenter’s delivery and the audience's engagement.

Traditional presentation tools like blackboards, whiteboards, and ceiling projectors often underperform to attract audiences and can hinder the effective transmission of knowledge. In contrast, the Gesture-Driven Cursor Control Interactive Projection System offers a solution that enables presenters to manipulate content directly with their hands and fingers, creating a more immersive and memorable experience. This research focuses on the impact of this technology on the quality of presentations, exploring how it can improve the accessibility of information and foster greater audience interaction.

The study also seeks to identify and address technical challenges associated with implementing gesture-based methodologies. Additionally, it will examine how geographical and infrastructural factors may influence the success of this technology in various settings. By emphasizing the real-world benefits of gesture recognition in presentations, this research aims to bridge the gap between current technological limitations and the potential for future practical applications, ultimately leading to enhanced interactivity and presentation quality.

Through the years, there has been a strong advancement in technologies in mean-interaction with machines. Conventional devices that are used in performing computer interaction include questions such as the keyboards and the mouse. With regards to interacting with the operating system and having a form of control on it without necessarily having direct control, specific instructions are employed in different software (Sharma et al, 2016). Human interface machines have gone through a major advancement where humans interact with computers and or devices. Originally limited to keyboards and mouse, these interfaces have begun to look for methods that are more natural. Sophisticated human machine interfaces allow people to virtually turn the world into a device and touch, voice, gesture, and many other methods. These have the purposes of improving usability to provide more direct, efficient control over digital systems, moving on from input modalities to Model, View, Controller approaches and similar for closer to ideal use interactions.

The booming of smart applications and electronic devices encouraged the interest in smart interfaces. The beginning of using natural and intuitive sensors is realized through advanced technological inventions such as application of the Kinect for home use. The analogous trend also encompasses commercial applications and opens the path to natural and user-oriented applications in the next decades. Such people-oriented devices with back-end supported RT computational streams hold the potential to move the interface from the current generation to the next generation that are characterized by natural and frictionless interactions (Huang, Jaiswal & Rai, 2018). Smart applications and primarily electronic devices are pushing the demand for smart interfaces that are natural and easy to use. The latter is encouraged latterly by innovations that integrate the usage of motion-sensing facilities that can detect motions and voice in homes, an example of which is Kinect. The following are not only revolutionizing consumer electronics but are also opening opportunities for unique business use. Most of the simultaneously people-oriented devices with real-time computation capacity are predicted to fundamentally transform the interface design over the near future and improve user system interactions.

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Objectives of the Study

The study aims to develop and implement a Gesture-Driven Cursor Control Interactive Projection System to enhance presentations and user interaction in educational settings. The specific objectives include:

- Make the system captures hand more accurate and responsive
- Integrate in Microsoft PowerPoint in order to use the system in Presentations
- Detects the gesture that is registered in the system done by hand accurately well.

Scope and Limitations of the Project

This research focuses on the development and deployment of a Gesture-Driven Cursor Control Interactive Projection System. The system will leverage advanced gesture recognition technology to control and interact with projected content on displays, aiming to enhance the usability and interactivity of presentations. The project will involve designing a user-friendly interface that allows users to activate and manipulate projected content through hand gestures, providing an intuitive and immersive experience. The scope and limitations of this project includes: The scope and limitations of this project includes:

Gesture Recognition Focus: The subject emphasizes, to the most part, on the identification of the hand movements for operating the projected system. Other types of gesture recognition (for instance, by face or body) is beyond the scope of investigation of this paper.

Indoor Use: This system is targeted towards indoor applications such as classrooms, offices as well as conference halls. Use outdoors like when flashing light is exposed to strictly natural light, or the weather conditions outside are taken into consideration is excluded.

Projection Surface: Unfortunately, the system mostly works best when used on flat and static projection surfaces. It means that irregular or moving surfaces perform not in the same manner as the stationary ones.

User Training: Thus, proper utilization of the aforementioned system demands learning of certain gestures which are to be employed skillfully. The learning curve may account for the level of satisfaction and the system utilization by the users.

Hardware Dependence: The system is dependent on specific organs including the camera and the projector which might prove very costly to install. Perhaps, the last lesson might be compatibility with existing infrastructures, for instance, incorporation into an existing system.

Environmental Sensitivity: Thus, the problem is that the performance of gesture recognition can be different depending on lighting conditions, movement of the background and other factors, which can be considered as the parts of the environment.

Technical Integration: Implementing gesture recognition system into the currently available software and hardware related systems may pose some issues and may entail other developments.

Initial Implementation Costs: The expenses in the acquisition of needed hardware, creation of special software, and educating the consumers can be reasonably steep thus acting as a constraint to those institutions.

Privacy Concerns: The integration of cameras for gesture recognition might be an issue impacting the privacy of the users and hence; proper protection of their data and privacy.

Overlapping Gesture Functionality: The system may encounter limitations when gestures have overlapping functionality or are misinterpreted due to similarities in movement patterns. This could lead to unintended system responses or reduced reliability, particularly in complex interactions.

More Processing Unit: The system requires substantial computational power for real-time gesture recognition and projection. In scenarios where high-speed processing is unavailable, there may be noticeable lags or delays, affecting system responsiveness. Additionally, the cost and availability of such advanced processing units could be a limiting factor for widespread adoption.

Camera Placement: Proper placement of the camera is critical to the system's performance. Poorly positioned cameras can lead to incomplete gesture recognition or inaccuracies, particularly in areas with blind spots or occlusions. Optimal placement often requires careful calibration and testing, which might demand additional time and resources during setup.

Significance of the Study

The innovation of the gesture-based projection system is beneficial in different fields. This work relates to combining and improving recognition techniques to operate a projector system with a view of producing a better and user-friendly interface. Such activities and further gesture detection are very effective, which allows the system to respond to control of the projected content responsibly and effectively. Since gesture recognition applications are continuously evolving, using this technology seems to have tremendous advantages for different presentation and interaction methodologies.

To Students, Researchers, and Presenters. That is why the necessity of implementing a Gesture-Based Projection System is revealed in the context of increasing the level of interactivity during presentations. The system enhances the ease of acquiring the content as well as ease of use since the users are able to manage the presentations without touching it, making the delivery of content efficient in response to natural hand movements. This technological feature helps make the presentation optimal and kinetic to a level that updating the presentation tools and accessories consume less time while the users also concentrate more on their messages and the response of the audience.

To the Academic Community. This system's development creates new horizons in the output of ideas in the academic world. Which becomes a new front-end for the further advancement of the interactive presentation technologies, it offers the basis for developing one's own variants and prototype connected with gesture-based systems. The possibilities of applying such technologies as gesture recognition, real time data processing and designing user interfaces may be incorporated into educational tools, paving the way to innovative teaching techniques and stimulating the usage of modern technology in academic settings.

To the Engineering Field. From a lead generated from gesture recognition research, this project intends to have an engineering Outreach affecting different fields of engineering particularly the electronics and computing disciplines. Applications like real-time gesture detection, interactive buttons/controls on the screen, and real-time changing of the content on the projection screen are possible. This endeavor will exemplify real-life scenarios in the use of sensor technology, real-time data processing and easy to use interfaces to real-world problems hence provoking further advancements and studies in this field.

To Society. This new development in presentation technology will be a bonus to all the people. In the future, gesture-based projection systems have projected their role in society especially in the field of education, business and presentation. As a result, it will have a far-reaching effect on presentations particularly in its ability to provide the clients with a cheap and easy way to control presentations hence encouraging the use of technology in addressing presentation in various circumstances.

Definitions of Terms

For a clearer understanding of the terms used in this research study, below are the meanings of the following:

Gesture-Based Projection System: A hardware application based on gesture recognition mostly involving a projector, a camera and specific sensors.

Gesture Recognition: The primary concept which wraps around the recognition and analysis of human movements using technology.

Sensor Technology: Elements or equipment that integrate features that can identify change in position or other phenomena.

User-Friendly Interface: A concept that encompasses the user's accessibility to features and functions of a software in order to enable the optimum manner of manipulation.

Real-Time Feedback: Actions that the system responds to from a user's input or from the gestures that the user makes.

CHAPTER II

REVIEW OF RELATED LITERATURE

In recent years, significant advancements have been made in the field of gesture-based interaction, particularly in the development of systems that utilize projector technology to create interactive environments. This chapter provides a comprehensive review of the literature related to the mathematical foundations and algorithms that are essential for the implementation of a gesture-based projector system. The focus will be on key techniques in image processing, computer vision, machine learning, and geometric transformations that enable effective gesture recognition and interaction.

Image Processing and Computer Vision

Image identification is increasingly vital in modern problem-solving systems. While numerous approaches exist for image detection, analysis, and classification, the distinctions between these methods remain unclear. It is essential to interpret and analyze the differences between these techniques for effective application (Sharma et al., 2020).

Background Subtraction

According to Torkut(2022), the background subtraction method (BSM) is a computer vision algorithm used to detect objects in video content by comparing the background and foreground of an image. It isolates foreground objects by comparing them to a no-object frame, analyzing the video to detect and isolate these objects. The algorithm then compares frames to identify differences, creating a distance matrix. The presence of objects in a frame, referred to as the threshold value, is determined by analyzing the initial segments of the video.

Foreground Mask=|It−B|

Equation 2.1. Background Subtraction Method Formula

Based on Equation 2. 1, This is done by evaluating the minus absolute difference between ItI_tIt with a background model BBB to get a foreground mask that shows only the object of interest. This step is critical because that lets the system track the moving gesture leaving out any stationary artifacts within the environment.

$$g(x,y) = \begin{cases} 255, & \text{if } f(x,y) > T \\ 0, & \text{otherwise} \end{cases}$$

Equation 2.2 Threshold Formula

Later in the conversion procedure, the function of thresholding is used to transform the foreground mask into a binary picture. In accordance with the discussed Equation 2. 2, This includes setting of a decision threshold (TTT) that assigns pixels with a value of difference larger than TTT to the foreground and those that are lesser to the background. This laid down binary image eases on the identification methods since the difference between the background and the object is well defined.

$$G = \sqrt{G_x^2 + G_y^2}$$

Equation 2.3. Contour Detection Formula

The next significant process is contour detection by which the boundary of the detected object like the hand is determined. Several methods such as the Canny edge detection method is used to locate areas with high gradient values with respect to the image, mainly the boundary of the object. These are very important for defining the outline as well as the extent of the gesturing object.

$$d = \max_{p \in CH} \left(\text{Distance}(p_{start}, p) + \text{Distance}(p_{end}, p) \right)$$

Equation 2.4. Convex Hull and Defects Formula

The convex hull is the outer smallest convex polygon that inclines the contour points (CCC); CVX is the part of the convex hull that deviates from the contour points, such as the region between fingers. These features are paramount for the identification of specific patterns of gestures such as pointing or even waving.

Feature Extraction

According to Geeksforgeeks (2024), feature extraction is a crucial step in image processing and computer vision, as it identifies and represents distinctive structures within an image, transforming raw data into numerical features that preserve essential information. This process is important for dimensionality reduction, improving accuracy in tasks like classification and detection, enhancing performance for real-time applications, and reducing noise by focusing on important aspects and eliminating redundant information.

$$C_x = \frac{M_{10}}{M_{00}}, \quad C_y = \frac{M_{01}}{M_{00}}$$

Equation 2.5. Centroid Calculation

The centroid calculation is another vital approach that is applied to identify the location of the center of the gesturing object. Thus, by averaging the coordinates of the contour points, it is possible to define the so-called ‘centroid’ which will allow us to trace the temporal change in the gesture position.

Gesture Recognition

Gesture recognition is a pivotal technology in human-computer interaction, offering extensive applications in smart homes, medical care, sports training, and other domains. Unlike traditional PC-based interaction using keyboards and mice, gesture recognition allows for more natural, flexible, and intuitive information transmission. This approach has emerged as a significant research focus within the field of human-computer interaction, promising enhanced usability and novel technical possibilities across various applications (Zhou et al., 2023).

$$\mathrm{Match}(G_i, T_j) = \sum_{x,y} |G_i(x,y) - T_j(x,y)|$$

Equation 2.6. Template Matching Formula

Template matching is an image processing method or sub-discipline of the field of computer vision in which a template or a small part of an image is searched in an image. This process entails moving the template on the input image and calculating the degree of resemblance between a given template and a part of the image at that particular place of the template. Usually the similarity measure is based on a filter which may be the normalized cross correlation or sum of squared differences. Numbers are higher if areas of the template match more closely to parts of the large image, and show where the match is strongest. This method is basic in occurrences such as object detection, image recognition, pattern matching in sundry area of studies and practices.

$$d(p,q) = \sqrt{\sum_{i=1}^{n}(p_i - q_i)^2}$$

Equation 2.7. Euclidian Distance Formula

$$DTW[i,j] = \mathrm{cost}(i,j) + \min(DTW[i-1,j], DTW[i,j-1], DTW[i-1,j-1])$$

Equation 2.8. Dynamic Time Warping Formula

Euclidean distance and Dynamic Time Warping (DTW) are ways used to compare the found gesture to certain templates. These methods are increasingly important in the correct determination of gestures according to the shape and sequence in time.

Projection and Geometric Transformation

According to Petrescu (2019), projective geometry is that area of geometry that treats geometric figures from the point of view of the perspective and the horizon line, figures that are considered invariable by projection. Geometric transformations are a class of image data augmentation techniques that alter the geometrical structure of images by shifting image pixels from their original positions to new positions without modifying the pixel values. These transformations are done to modify training data in ways that better describe real-world appearance changes caused by factors such as viewpoint variations, non-rigid deformations, perspective and scale changes (Mumuni and Mumuni,2022).

$$\mathbf{x}' = H\mathbf{x}$$

Equation 2.9. Homography Formula

Mapping of points obtained from the gesture coordinate system to that of the projector screen requires homography. Homography matrix (HHH) helps the system to project the position of the gesture onto the screen with the correct parameters which makes the interaction smooth and precise. This mapping is crucial in ensuring that this user's gestures are mapped with the kind of content being projected.

Signal Processing

According to Chenge et al. (2021), during the gesture operation involving unlocking of a mobile phone, the data matching is determined by such algorithms as the DTW and SVM. DTW is also good in working on time series data that has different speeds to match the gesture as it may be done at different speeds while SVM is good in classification of different gesture patterns based on the extracted features. The effectiveness of gesture authentication is greatly influenced by the pre-processing of the gesture signal which may involve steps such as noise removal, scaling and feature extraction among others. Processing of the signals in the correct manner also assures that

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the data that is input into these algorithms is correct and reflects the intended gestures, thus greatly improving the performance of the gesture based unlocking system.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Equation 2.10. Gaussian Filter Formula

$$\hat{x}_{k|k} = F_k \hat{x}_{k-1|k-1} + B_k u_k + K_k \left(z_k - H_k \left(F_k \hat{x}_{k-1|k-1} + B_k u_k \right) \right)$$

Equation 2.11 Kalman Filter

Smoothing filters and Kalman filters are used to improve the accuracy and estimation of gesture detection and tracking. The Gaussian filter as well as other smoothing filters remove high frequency noise present in the detected gesture trajectory and the Kalman filter anticipates the next position of the gesture and gives the user a smoother user interface feel.

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Chapter III

METHODOLOGY

Preliminary works of creating a Gesture-Driven Cursor Control Interactive Projection System involve establishing specific objectives along with reviewing gesture recognition systems, projection technologies and appropriate software frameworks. Thus this review assists in the identification of the best practices and technologies to adopt or integrate in the selection of quality input, processing and output hardware such as cameras, projectors and processing units. Since this is a very important aspect, it is well planned and properly developed for accurate detection of gestures and projection of content.

There are specific system gestures which are common across most systems and these standard presentation gestures are used to train gesture recognition models using machine learning. A convenient control of the projected content is realized by gestures of the user. The prototype is then built and tested to check the functionality of the system without actually implementing it in the real life environment. Another procedure is the user trial, in which the system is tested and adjusted to achieve the imperatives set for its performance in the real life environment.

The system is then implemented back in real environments where emphasis is placed on appropriate implementation and usage. Some of the inputs that are used to bring enhancement and modification for the software and hardware components include performance checks and users' feedback. Documentation of hardware installation is done alongside documentation of the software development cycle, system design, and the user guide to make the system functional and to be used in future modification and improvement.

Research Design

This research study utilizes a prescriptive design model to develop a gesture-based cursor control touch screen projector system, employing an organized and methodical procedure for achieving the desired outcome. The process begins with problem definition, identifying the need for an intuitive and interactive whiteboard system that enhances user experience through gesture-based control. The next step involves conceptual design, outlining the primary components and functionalities of the system, such as the types of sensors required, the processing unit, and the output display. Preliminary design follows, where initial prototypes are developed and tested to ensure the feasibility of interactions between different system components. This leads to detailed design, refining the prototypes based on preliminary tests to ensure all components work seamlessly together. Finally, design communication involves documenting the design process and communicating the findings and designs to stakeholders for feedback and approval. To better understand the system's components and processes, the Input-Process-Output (IPO) method was employed. For the input stage, the system uses various sensors such as infrared sensors, ultrasonic sensors, and cameras to detect and interpret gestures.

The hardware includes a projector, a processing unit (e.g., a computer or microcontroller), and interactive display surfaces, while the software processes the sensor data and translates gestures into commands. The process stage involves data acquisition, where real-time data from the sensors are collected, followed by data processing using algorithms to interpret the sensor data and recognize specific gestures. Command execution then translates recognized gestures into commands that interact with the projector system, such as changing slides, zooming in/out, and drawing on the whiteboard. The output stage features an interactive display where the projector shows the desired content on the whiteboard surface, responding to user gestures, and provides user feedback through visual or auditory signals to indicate successful command execution or errors.

Additionally, a detailed explanation of the theories behind the research project is presented in the theoretical framework. Functional and constraint analyses were conducted to fully understand and consider the scope and limitations of the project. Technical factors, such as hardware capabilities, software compatibility, and resource constraints, were taken into account. By accounting for these constraints, strategies were developed to optimize the system's performance within the given limitations. Through the application of the prescriptive model research design, IPO method, theoretical framework, functional analysis, and constraint analysis, the researchers successfully developed a robust and efficient system design that met the identified requirements and constraints. These research design methods provided a structured and systematic approach to problem-solving, ensuring a comprehensive understanding of the system's components and processes, ultimately leading to an effective solution for the gesture-based touch screen projector system.

Conceptual Framework

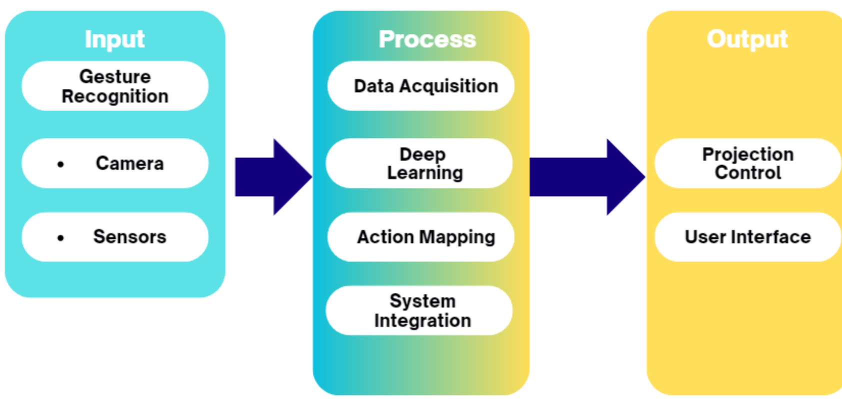

Figure 3.1 Conceptual Framework

Applying the IPO method allows one to have a clear understanding of the components of the gesture-controlled projection system. The use of such a method enables the proper structuring of the system with regard to how it captures the input, appears to process the input, and delivers the outcome. Thus, by dividing the system’s functions into these three steps, we guarantee that each aspect of the development will receive adequate attention, starting with the creation of gesture capture and ending with the visualization of the performed actions on the projection. Schematically, the mentioned elements are illustrated in the following conceptual model, given in Figure 3. 1, provides a brief description where it describes the Input-Process-Output (IPO) flow of the gesture-triggered projection system. They include cameras, sensors, projectors of high quality and the environment is arranged in a way that captures the gestures best. Activities include data and data preprocessing, designing the deep learning models for gesture recognition, system integration, and a graphical user interface. According to the output, it is possible to control the projector through the recognized gestures; offer an engaging user interface and describe the configurations of the hardware and the software that form this system as well as offering users guides about the same. The following is a framework on how to create and evolve a system within such an environment and how to synchronize the parts.

Theoretical Framework

The proposed system is designed to utilize gesture recognition technology for intuitive interaction using various sensor inputs. As shown in Figure 3.2, the inputs include camera data and sensor data inside the system. These sensor inputs are collected and processed by a microcontroller connected to the sensors.

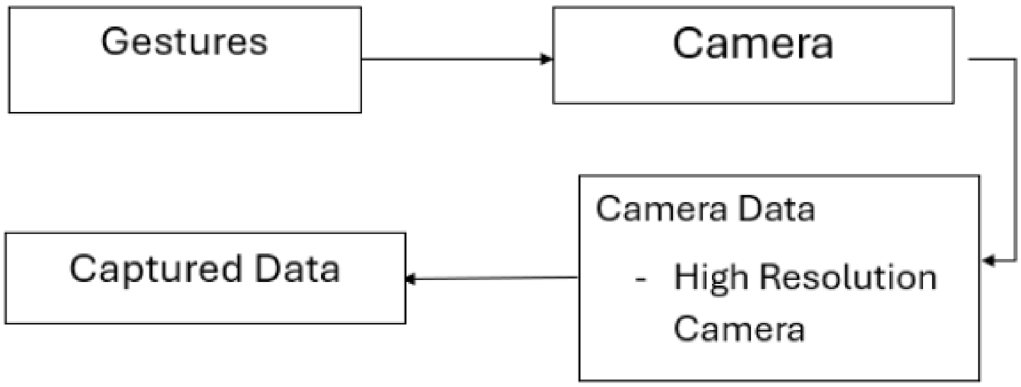

Figure 3.2. Input Diagram

Figure 3.3 outlines a comprehensive process for a data-driven system, which can be directly applied to the concept of the Gesture-Driven Cursor Control Interactive Projection System: Transforming Presentations with Camera and Interactive presentation. Initially, data acquisition takes place where cameras collect gesture data from users interacting.

The gathered data is directly processed within the system. The cameras provide real-time input, and algorithms are applied to this data, performing necessary preprocessing steps such as data cleaning and transformation. These steps are crucial for the subsequent model training phase.

During model training, Deep learning models are developed using the processed data, enabling the system to understand and recognize user gestures. These recognitions are then used in the action mapping stage, where specific gestures are mapped to actions such as changing slides, writing and erasing.

The trained model and action mappings are integrated into the existing presentation system, allowing seamless operation within the infrastructure. Real-time data gathering ensures that the system continuously receives updated gesture inputs from the cameras. This real-time data is processed instantaneously, ensuring that the presentation system responds immediately to user gestures, thus enhancing the overall presentation experience.

By integrating these steps, the Gesture-Driven Cursor Control Interactive Projection System leverages camera technology to transform traditional presentations, making them more interactive and engaging through real-time, data-driven responses to user gestures.

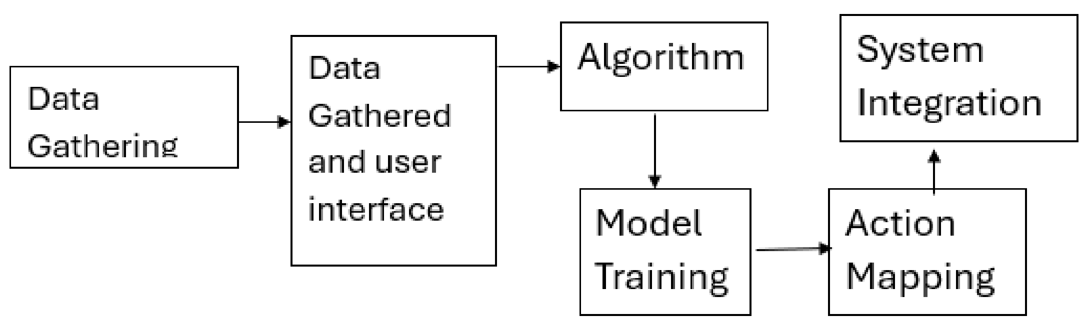

Figure 3.3. Process Diagram

Figure 3.4 illustrates a feedback loop essential for the Gesture-Driven Cursor Control Interactive Projection System, which transforms presentations using a camera that enhances presentations using hand gestures. The process begins with Projection Control, where commands are sent to the projector based on the detected user gestures. This projection control is driven by the Deep learning models trained to recognize and interpret various gestures, such as swiping to change slides or pinching to zoom.

Next, the projector executes these commands to Display Content, making the desired changes visible on the presentations. This real-time display allows presenters and the audience to see the immediate effects of the gestures, ensuring an interactive and dynamic presentation experience.

Finally, the system receives User Feedback through both visual and auditory channels. This feedback loop is crucial for continuous improvement and adjustment of the system. For instance, visual feedback might include changes in the displayed content, while auditory feedback could involve confirmation sounds indicating successful gesture recognition. This user feedback is then used to refine the gesture recognition models and improve the overall accuracy and responsiveness of the system.

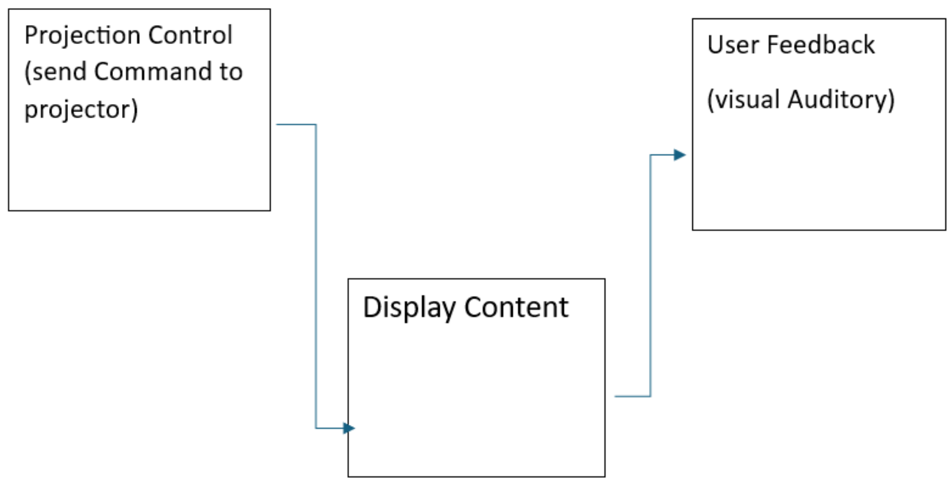

Figure 3.4. Output Diagram

Functional Analysis

The project lies to completely transform presentations through employing gesture technologies, cameras and sensors. The purpose of this is to make a presentation more interesting and interactive. Originally, the system was equipped with the function of gesture recognition; this means that cameras and sensors can identify and later interpret human gestures. Possible actions that can be implemented might be specific calls, hand movement toward a particular location, or sweeping motion to go to the next slide. The machine understands those motions and maps them to instructions to the projector meaning the presenters can manipulate their presentation without having to touch a computer or a remote. Some of these commands include zooming in or out, flipping to the next slide and underlining or writing on the content written on the whiteboard.

In order to facilitate proper interaction, the system gives feedback in the form of visual and audio feedback indicating that the gesture has been processed and/or recognized. It also analyzes data coming from the sensors and cameras in real-time to properly interpret the gestures; it also collects data on usage of gestures to fine-tune the algorithms making the system better and adding to the overall experience of using the interface over time. The graphical user interface shows the output of interaction occurring concurrently, thus making the system easy to embrace. Several processes are involved in the operational workflow of the system that include; system initialization, system control, gesture identification, data processing, command processing, and user feedback in order to facilitate a proper presentation.

Constraints Analysis

The following are the technical limitations that need to be considered for successful implementation of the Gesture-Driven Cursor Control Interactive Projection System. For an efficient and accurate recognition of adequate gestures, cameras and sensors must be positioned and covered sufficiently, which becomes a demanding task when it comes to different presentation scenarios because of possible various obstacles and unfavorable angles. Gestural recognition algorithms or models which are used have high sensitivity on gesture recognition which helps in system reliability but this can be an issue since there may be variations in human gestures, noise and light intensity. Real-time data processing requires fast algorithms, since any time delay impacts the globe's user experience in performing gestures.

However, users are required enough practice time and well-defined guidelines to enable them to use the gesture based system properly. Another criterion is conformability with other systems in case the system is to interface independent software or hardware used for hand gesture capture and projector management. The gestures which need to be interpreted by the machine learning algorithm have to be very accurate, the algorithm works for any action performed by the user and needs to be trained constantly and updated with the real user data. Speed and the clarity of the feedback that the user gets from the system is a major determinant of how the user experiences the system and one has to ensure feedback mechanisms do not interrupt the user or give unnecessary details. Lighting, the size of the environment that is to be presented, and background noise are particularly hard to control, which may exert significant influence on the probes' and cameras' functioning thus making it difficult to apply the system in different environments. Further, in determining these equipments; quality sensors, cameras, and projectors should be selected but this has to fit the financial plan and requirements in order to achieve the best system plan possible.

To overcome these constraints several interventions can be done as follows; Some considerations include extensive testing for identifying the best location for placing the sensors depending on the setting, issues to do with transportability of the systems or the use of adjustable stands for differently shaped presentation areas. Gesture recognition can be made more accurate by retraining and improving machine learning algorithms with raw data on a continuous basis as well as considering the feedback received from the users. Designing algorithms and tuning preprocessing and postprocessing in an efficient manner, as well as deploying high end computational resources, can help keep delays low and real time response possible. An additional approach will be the development of reference documents, tutorials for the convenience of new users to familiarize themselves with the system quickly.

Method of Data Collection

Literature from credible online sources formed the basis of developing the methodology for data collection for the project. In order to guide their study, the researchers conducted a review on the objective, materials and methods, and result of similar studies that were conducted. In order to get even deeper understanding, interviews of structured nature were made with the educators and administrators who often deliver presentations. These interviews intended to find out what are the main issues and needs for the interactive presentation system.

The project adopted several camera and sensor models to obtain the various user gestures that were to be considered. The gesture recognition algorithms used were derived from sources on the internet and the researchers also created their own dataset for the purpose. To gather data the concentration was made on covering multiple types of gestures, done by multiple users in different light and environmental conditions to make the system more stable and precise.

Data was collected from multiple sessions in which the users carried out pre-specified gestures including swipe, point and execute custom commands. The dataset itself contained thousands of gesture samples where the samples were subdivided according to the type of gesture that they represented as well as the conditions under which the gesture was executed. The feature sets, which were collected with the help of Kinectsensor, were also large enough in order to train the gesture recognition system based on machine learning algorithms. Some important indicators documented during data gathering were position, velocity and movement path of the gesture, as well as lighting and noise level of the environment. These parameters were detected and recorded in real-time by the attached sensors and cameras and then AC voltage of the object under test was controlled and analyzed by the onboard microcontroller connected with the cloud server for data storage, further analysis and model training.

With such a systematic data gathering approach into consideration, the researchers facilitated the design and implementation of a concrete gesture-driven projection system that would improve the influence and interactivity of the presentations. The methodology fulfilled the objectives of the project by confirming the system's reliability in different conditions for recognizing and interpreting the user gestures.

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Generation of Alternatives for System

With the use of camera and sensor-enhanced whiteboard technology, the gesture-driven projection system seeks to improve presentations by instantly recognizing and reacting to user motions. System-based and component-based alternatives are the two categories into which the development of alternatives is separated. These two sections will be used to assess and select the optimal system and parts for the implementation of the research project. The systems that are now in use and those that are being considered for use in augmenting presentations via gesture recognition are listed in this section of the research project.

Regular Manual Control System

The traditional manual control method involves controlling presentations with physical devices like keyboards, mouse, and remote controls. This method operates under the presumption that users will manually manipulate the presentation software in order to highlight text, switch between slides, and carry out other tasks. The normal manual control system is a commonly employed approach due to its simplicity and dependability. Direct user input via devices connected to the presentation system is usually required. This approach is used in a lot of business and educational contexts where users control their presentations through physical controls. Although efficient, this approach may restrict the presenter's movement and ability to interact with the audience because it requires personal contact with the control devices.

Gesture-Based Control System:

Presenters can control their presentations without using physical equipment thanks to gesture-based control systems, which use cameras and sensors to recognize and interpret user motions. According to this approach, control actions—like swiping to switch slides or pointing to highlight content—should be carried out in response to particular gestures that the system has identified. Typically, sensors are used to determine spatial coordinates and cameras are used to record user movements in gesture-based control systems. This technique has been used in a number of situations where natural user interfaces improve the user experience, such as virtual reality, gaming, and smart home systems. Gesture-based control, which eliminates the need for physical controllers, can optimize user involvement in presentations by enabling smooth transitions and dynamic content management. This can enhance audience participation and presentation effectiveness even more.

Evaluation of Alternatives for System

The review of the alternatives for a Gesture-Driven Projection System has shown that there are actually quite a few reasonable choices that can be taken. Smartboard have developed to have high interactivity and are familiar with teachers and students but the costs are high and cannot be easily transported. Flexible and moderately expensive, portable projectors with gesture recognition may have certain inaccuracy problems and the longer time for setup. The actual physical systems for normal whiteboards are affordable solutions that involve a combination of traditional and digital modes of communication; however, gesture recognition may be challenging. Rotating top-range informative boards sharing all-in-one features deliver an excellent quality at a high price but are poor in terms of expansibility. Techniques such as VR presentation systems expose the audience to invented environments, but are expensive and need time for the audience to familiarize themselves with. Thus, the portable projector with a gesture recognition system can be considered the most versatile and reasonable choice as it offers mobility, moderate price, and the opportunity to turn any surface into a sort of screen, which can be suitable for various and rather dynamic presentations.

Figure 3. 5 presents the objective tree of the study. The most strategic level is the one where the primary objective appears, and the secondary branches protrude, which further break down the main activity. The last three branches on the second row focuses on the working of the proposed system, the hardware and software aspects of the system and usage of the system.

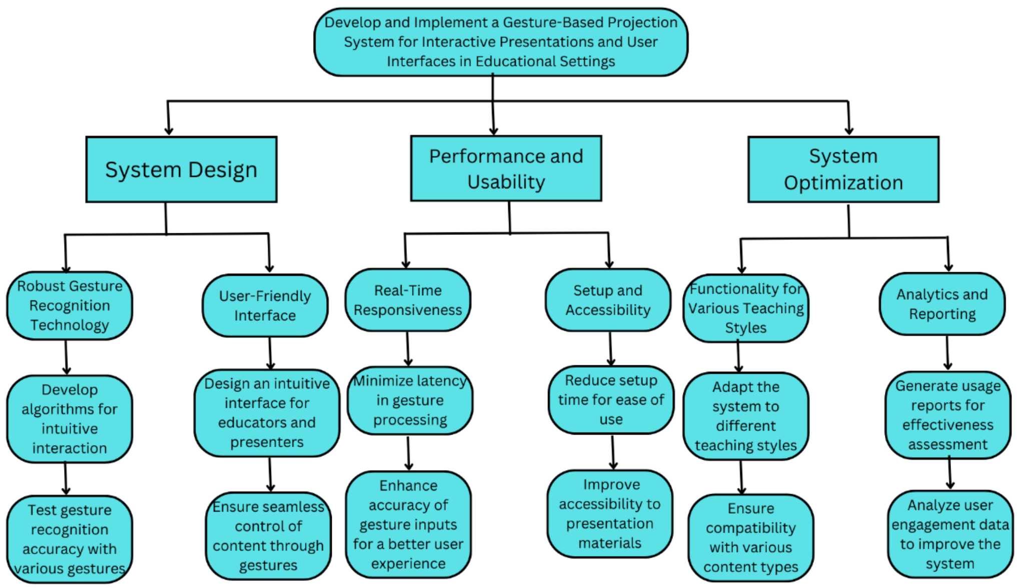

Figure 3.5. Objective Tree of The Study

General metrics were evaluated and ranked, as illustrated in the comparison chart in Table 3.1. Prioritizing preferences was facilitated through a pairwise comparison chart. Metrics were assessed and scored based on their significance to the main study; a score of '1' was assigned if a metric was more important than another, otherwise, it received '0'. The comparison is based on matching rows against columns. Additionally, '0.5' points were awarded if the row and column metrics were of equal importance. After tallying all the points, the metric with the highest score was given the highest priority, followed by other metrics according to their rank.

Metrics	Accuracy	Speed	Convenience	Cost	Total
Accuracy	0.5	1	1	1	3.5
Speed	0	0.5	1	1	2.5
Convenience	0	0	0.5	1	1.5
Cost	0	0	0	0.5	0.5

Table 3.1. Pairwise Comparison Chart for System

Table 3.1 presents the Pairwise Comparison Chart for evaluating different metrics. According to the results, accuracy, which measures the precision of a system's performance, ranked the highest with a total score of 3.5. Speed, indicating the swiftness of the system's operations, is the next most important metric, scoring 2.5. Convenience, assessing how user-friendly and accessible the system is, placed third with a score of 1.5. Cost, reflecting the financial efficiency and affordability of the system, ranked fourth with a total score of 0.5.

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Metrics	Weight	Alternatives	
		Regular Manual Control System	Gesture-Based Control System
Accuracy	3.5	2	1
Speed	2.5	2	1
Convenience	1.5	1	2
Cost	0.5	2	1
Total		14.5	9.5

Table 3.2. Evaluation Metrics for System

Table 3.2 shows the evaluation metric for system-based alternatives, which includes design options and project goals that are interconnected in various ways. The alternatives are ranked from 1 to 2, with 2 being the highest. Scores are then multiplied based on the weight derived from the results in the Pairwise Comparison Chart in Table 3.1. Here, the goal is to choose the best system among the generated alternatives.

The Regular Manual Control System scores the highest with a total score of 14.5. This system ranks highest in accuracy, speed, and cost, indicating its overall effectiveness in these metrics. On the other hand, the Gesture-Based Control System scores 9.5, performing better in convenience but lower in other metrics. Based on this ranking, the Regular Manual Control System is considered the best alternative among the evaluated options.

Generation of Alternatives for Components

The process of developing gesture-based touch screen projector systems involves a variety of critical components that ensure the effective implementation of the project. This section of the research project presents a comprehensive examination of different sensors, microcontrollers, and projection technologies that can be utilized to create a robust gesture-based interface. It explores and contrasts various specifications and features, offering alternative solutions to enhance the functionality and performance of the system. By evaluating these components, the project aims to identify the most suitable technologies for implementing a seamless and intuitive gesture-based touch screen projector system.

Cameras. Cameras are integral components in gesture-based touch screen projector systems. They are utilized to capture hand movements and gestures, which are then processed to interact with the projected interface. High-resolution cameras with fast frame rates ensure accurate and responsive gesture detection, enabling users to control the system seamlessly. By analyzing the captured data, the gesture recognition software can interpret user inputs, providing an intuitive and interactive experience.

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Figure 3.6. A4Tech PK-910H HD

A4Tech PK-910H HD. The camera shown in Figure 3.6 is the A4Tech PK-910H HD. The A4Tech PK-910H HD Webcam is the low-price webcam which can offer high-quality image and record video with high quality respectively. It has Full HD 1080p which ensures that the implemented model offers high-resolution videos. It operates at 30 frames per second (fps), thus enabling the user to watch a smooth video clip. It has an in-built microphone, supports many operating systems, and has auto low light adjustment, making the vision clearer even in low light environments. This webcam is ideal for people who seek a good picture quality/price ratio.

Figure 3.7. Genius WideCam F100

Genius WideCam F100. The camera shown in Figure 3.6 is the Genius WideCam F100. Genius WideCam F100 is a combined webcam with resolution 1080p Full HD and gives good picture and clear image quality. It has a frame rate of 30 fps to capture high performance in video playing. The prominent features are the extreme wide angle of view of 120 degrees, a stereo mic and the focus is also adjustable. The gesture captured area extended watching angle is quite useful when capturing gestures over a large area, for instance, a video call or stream.

Figure 3.8. *Logitech C922x Pro Stream Webcam*

Logitech C922x Pro Stream Webcam. is a high-quality device designed for streaming, video conferencing, and content creation. It supports full HD 1080p video at 30 frames per second and 720p resolution at 60 frames per second, making it ideal for smooth and professional streaming. The webcam features autofocus for sharp image clarity and automatic light correction to ensure clear visuals even in low-light conditions. It also includes dual omnidirectional microphones for capturing clear and natural audio. With a 78-degree field of view, it is well-suited for capturing a broader area, making it versatile for various setups.

Comparison	A4Tech PK-910H HD	Genius WideCam F100	Logitech C922x Pro Stream Webcam
Resolution	1080p Full HD	1080p Full HD	1080p HD
Frame Rate	30fps	30fps	30fps

Field of View	68°	120°	78°
Depth Sensing	No	No	No
Connectivity	USB 2.0	USB 2.0	USB 2.0
Special Features	Autofocus, light correction	Wide-angle lens, 360-degree swivel	Autofocus, light correction, background removal
Best For	Basic video calls and online meetings	Group conferencing and wide-angle setups	Streaming, content creation, and video calls
Ease of Integration	Simple plug-and-play setup	Simple plug-and-play setup	Compatible with OBS, XSplit, Zoom.
Performance in Low Light	Decent, but lacks advanced light correction features	Moderate, depends on external lighting	Excellent, with automatic light correction

Complexity	Easy to use, beginner-friendly	Easy to use, suitable for wide-angle needs	Slightly more advanced features but user-friendly

Table 3.3. Specifications of A4Tech PK-910H HD, Genius WideCam F100, and Logitech C922x Pro Stream Webcam

Projectors. Projectors are the primary output devices in gesture-based touch screen projector systems. They are responsible for displaying the interface onto any surface, transforming it into an interactive touch screen. The choice of projector, including its resolution, brightness, and throw distance, is crucial for creating a clear and responsive display. Advanced projectors with short-throw or ultra-short-throw capabilities can project large images from a short distance, making them ideal for compact spaces.

Figure 3.9. Epson EB-S41 SVGA

Epson EB-S41 SVGA Projector. The Projector shown in Figure 3.9 is Epson EB-S41 SVGA Projector. The graphics display is SVGA which has a screen resolution of 800 x 600 pixels; hence it is very clearer for presentations and common multimedia uses. Having a brightness of 3,300 lumens, which is relatively low when you compare it to other related products, it is ideal for well-lit halls or rooms. The projector has a native contrast ratio of 15,000:1, which improves the quality and sharpness of the picture on the screen. HDMI and VGA inputs contribute to its connectivity which means it can easily be connected to a variety of devices. Furthermore, the projector has a Lamp life of up to 10000 hours in the ecological mode; thus, lowering the cost of maintenance.

Figure 3.10. LG PF50KS

BenQ MS550 SVGA. The Projector shown in Figure 3.10 is BenQ MS550 SVGA The BenQ MS550 SVGA Business Projector is a great projector solution for business people who need high brightness in their projector and want to be assured of good performance out of their projector. It displays SVGA resolution at 800 x 600 pixels, rather ideal for presenting intricate information as well as business oriented related operations. The light output of 3,600 lumens guarantees good picture quality even in lowlight conditions due to the light projected. The projector has a contrast ratio of 20,000:1 a feature that makes images displayed on the projector appear very sharp and clear in terms of coloration. The provided input/output options consist of two HDMI ports as a part of the MS550 setup to support the integration of multiple devices. It has a lamp life that ranges between 10,000 and 15,000 hours on the eco mode, thus is relatively cheaper in the long run.

Figure 3.11. Warpple High brightness true 1080P smart projector LS8 Starlight White/LS8-B Midnight Black

Warpple LS8 projector is a high-performance, true 1080P smart projector. available in two colors: Starlight White and Midnight Black. It boasts impressive features, including a brightness of 700 ANSI lumens, making it suitable for both indoor and outdoor viewing in various lighting conditions. The projector also supports 4K content and has built-in Bluetooth, making it versatile for different multimedia needs.

Comparison	Epson EB-S41 SVGA	BenQ MS550 SVGA	Warpple High brightness true 1080P smart projector LS8 Starlight White/LS8-B Midnight Black
Resolution	SVGA (800 x 600)	SVGA (800 x 600)	True Full HD 1080P (1920 x 1080)
Brightness	3,300 lumens	3,600 lumens	High brightness (exact lumens not specified, likely 2,500+)
Throw Ratio	1.45 to 1.96	1.96 to 2.15	Short throw (specific range not provided)

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Connectivity	HDMI, VGA	Dual HDMI ports, VGA	HDMI, USB, Wi-Fi, Bluetooth (smart connectivity)
Special Features	15,000:1 contrast ratio, long lamp life (up to 10,000 hours in eco mode)	20,000:1 contrast ratio, lamp life up to 15,000 hours in eco mode	Smart features, true 1080P, wireless projection, sleek design
Best For	Basic presentations, office use	Business presentations, high contrast needs	Home theaters, gaming, and streaming content
Ease of Integration	Simple setup, supports standard input devices	Easy setup, supports dual HDMI for more devices	Advanced, supports smart devices with wireless options
Portability	Lightweight, portable	Compact and portable	Sleek and portable, designed for modern use cases

Table 3.4. Specifications for Epson EB-S41 SVGA, BenQ MS550 SVGA, and Warpple High brightness true 1080P smart projector LS8 Starlight White/LS8-B Midnight Black

Gesture Recognition Software. Gesture recognition software is the core component that interprets user gestures captured by cameras. It employs advanced algorithms and machine learning techniques to analyze hand movements and translate them into commands for the projector system. The software's accuracy and efficiency directly impact the user experience, making it vital to choose robust and reliable solutions. Continuous updates and training of the software can enhance its performance, adapting to various gestures and user behaviors.

Figure 3.12. Leap Motion SDK

Leap Motion SDK. The logo shown in Figure 3.12. is Leap Motion SDK. The Leap Motion SDK is designed to offer developers ways to implement hand and finger tracking into the programs. It supports many development languages like C ++, C #, Java, and Python. The SDK provides good tracking data and the recognition of gestures, which allows to develop clear and engaging applications.

Figure 3.13. OpenCV or Open Source Computer Vision Library

OpenCV. The logo shown in Figure 3.13 is OpenCV or Open Source Computer Vision Library. It is a computer vision and machine learning library. It has more than 2500 optimized algorithms for vision applications such as gesture recognition, face detection, object tracking and the rest. OpenCV works on different languages that include C++, python and Java and can be implemented on different platforms.

Figure 3.14. Google MediaPipe

Google MediaPipe. The logo shown in Figure 3.14 is Google MediaPipe. Google MediaPipe is an open source applied machine learning pipeline toolkit for building cross-modal and cross-platform applications. They offer elements for features such as hand tracking, facial recognition, object recognition, etc. Another solver is a cross-platform real-time human pose estimation algorithm MediaPipe which supports C++ and Python programming languages and developed for the mobile-web-cloud triad.

Comparison	Leap Motion SDK	OpenCV	Google MediaPipe
Supported Platforms	Windows, macOS, Linux	Cross-platform	Cross-platform
Programming Languages	C++, C#, Java, Python, Unity, JavaScript	C++, Python, Java	C++, Python
Gesture Types	Hand, Finger, Pinch, Swipe, Tap	Hand, Face, Body, Custom	Hand, Face, Pose, Custom

Special Features	Highly accurate hand tracking, robust API	Open-source, extensive computer vision library	Real-time performance, modular framework
License	Free (hardware purchase required)	Free (open-source)	Free (open-source)

Table 3.5. Specifications for Leap Motion SDK, OpenCV and Google MediaPipe

Coding Software. Coding software refers to tools and applications that developers use to write, edit, debug, and manage computer code. These tools are essential for creating software, websites, mobile apps, and other digital solutions. Coding software comes in various forms, each suited to specific tasks or programming languages.

Figure 3.15. Anaconda

Anaconda. The logo Shown in Figure 3.15 is a powerful open-source distribution designed for data science, machine learning, and scientific computing, particularly for Python and R. It simplifies package management and deployment, making it an ideal tool for researchers, analysts, and developers. One of its key features is conda, a package manager that helps users easily install, update, and manage libraries and dependencies. Anaconda also supports the creation of isolated environments, preventing dependency conflicts between projects. It comes pre-installed with over 1,500 open-source packages, including essential data science libraries like NumPy, Pandas, Matplotlib, and SciPy, providing users with a comprehensive toolkit for data analysis and visualization.

Apache NetBeans

Figure 3.16. NetBeans IDE

NetBeans IDE. The logo shown in Figure 3.16 is NetBeans; it is a powerful open-source Integrated Development Environment (IDE) primarily used for Java development, though it also supports other languages like PHP, JavaScript, and C/C++. It provides a range of features designed to make the development process more efficient, including advanced code editing tools such as syntax highlighting, auto-completion, and refactoring capabilities. These features help developers write cleaner, more efficient code. NetBeans also offers integrated debugging tools that allow developers to step through their code to identify and resolve issues. Additionally, it supports unit testing and integrates with popular testing frameworks like JUnit, which is especially useful for Java developers.

Figure 3.17. Visual Studio Code

Visual Studio Code. The logo shown in Figure 3.17 is a Visual Studio Code (VS Code) is a highly popular, open-source code editor developed by Microsoft. It is known for its speed, versatility, and extensive support for a wide range of programming languages, including JavaScript, Python, C++, and more. One of the standout features of VS Code is its rich ecosystem of extensions, which allow developers to customize the editor to suit their needs, whether they are working on web development, machine learning, or systems programming.

VS Code offers features like syntax highlighting, IntelliSense (auto-completion of code), integrated Git support, debugging tools, and a built-in terminal. Its lightweight design makes it fast and responsive, while its powerful features and extensions make it suitable for both beginner and advanced developers. The editor also supports collaborative coding through Live Share, enabling real-time collaboration with other developers.

Feature	**Anaconda**	**NetBeans IDE**	**Visual Studio Code**
Type	Open-source distribution for data science, machine learning, and scientific computing	Open-source Integrated Development Environment (IDE) for Java and other languages	Open-source code editor
Primary Use	Data science, machine learning, scientific computing (Python and R)	Java development (supports PHP, JavaScript, C/C++)	General-purpose code editing (supports multiple languages)

Key Features	Conda package manager, pre-installed with 1,500+ open-source packages (NumPy, Pandas, Matplotlib.)	Advanced code editing (syntax highlighting, auto-completion, refactoring), integrated debugging tools	Rich extension ecosystem, IntelliSense (auto-completion), integrated Git, built-in terminal, Live Share
Supported Languages	Python, R	Java (primary), PHP, JavaScript, C/C++	JavaScript, Python, C++, and many others via extensions
Package Management	Conda package manager for easy installation and management of libraries and dependencies	Not applicable (focuses on code editing and development)	Supports extensions and integrates with package managers like npm, pip.
Environment Management	Supports isolated environments to prevent dependency conflicts	Not applicable (focuses on project development in a single environment)	Not applicable (focuses on code editing and supports external tools

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			for environment management)
Debugging Tools	Not built-in, but can integrate with external debuggers and tools	Integrated debugging tools for stepping through code and resolving issues	Built-in debugging tools, integrates with various debuggers
Testing Support	Includes support for libraries like NumPy, SciPy, Matplotlib for data analysis (not specific to testing)	Supports unit testing, integrates with JUnit for Java development	Supports unit testing via extensions, integrates with popular testing frameworks
Collaboration	Not focused on collaboration but can integrate with version control tools like Git	Not focused on collaboration but can integrate with version control tools like Git	Live Share feature for real-time collaborative coding
Platform Support	Windows, macOS, Linux	Windows, macOS, Linux	Windows, macOS, Linux

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Best For	Data scientists, researchers, analysts, developers working with Python and R	Java developers and those working in PHP, JavaScript, C/C++	Developers working on web, machine learning, or systems programming, suitable for both beginners and pros

Table 3.6. Specifications for Anaconda, Netbeans IDE, and Visual Studio Code

Evaluation of Alternatives of Components

This section evaluates various alternatives by considering and assessing multiple parameters crucial to the device's functionality. It includes pairwise comparison charts and evaluation metrics for each component. These tools enable the researchers to select the best alternatives for the implementation phase of the project.

General metrics for sensors were considered and ranked, as illustrated in the comparison chart in Table 3.7. Metrics are compared and scored based on their importance to the main study: a score of ‘1’ is given if a metric is more important than another, otherwise it receives a ‘0’. If a row and column are equally important, they each receive a score of ‘0.5’. The metric with the highest total score is given the highest priority, followed by others in descending order of their scores.

Metrics	Reliability	Accuracy	Compatibility	Speed	Cost	Total
Reliability	0.5	1	1	1	0	3.5
Accuracy	0	0.5	1	1	0	2.5
Compatibility	0	0	0.5	1	0	1.5
Speed	0	0	0	0.5	0	0.5
Cost	1	1	1	1	0.5	4.5

Table 3.7. Cameras Pairwise Comparison Chart

For cameras, reliability is paramount since a dependable device ensures consistent performance and longevity, outweighing all other factors. Accuracy is crucial for capturing clear, precise images, making it the second most important metric. Compatibility is significant for integrating with various lenses, mounts, and software, ensuring the camera can work in diverse settings. Speed is necessary for capturing fast-moving subjects, but a slower camera can still be effective if it meets the first three criteria. Cost is the least critical since investing in a reliable, accurate, and compatible camera that meets speed requirements justifies the expense.

Components	Alternatives	Metrics					
		Reliability (3.5)	Accuracy (2.5)	Compatibility (1.5)	Speed (0.5)	Cost (4.5)	Total
	A4Tech PK-910H HD	1	0.5	1	1	1	11.25
	Genius WideCam F100	1	0.5	1	1	0.5	9
	Logitech C922x pro stream	0.5	0.5	1	1	1	9.5

Table 3.8. Evaluation Metrics for Cameras

A4Tech PK-910H HD for notebook, Genius WideCam F100 for Nettop, and Logitech C922x pro stream. This results in the reliability of the cameras to function, the accuracy to capture the images, compatibility of the camera with other systems within the network, speed with which the images are processed and the cost of the cameras. Reliability provides the guarantee that the camera will function properly without breakdown and accuracy guarantees that images captured are as they are without distortions. Speed depicts the capacity of the camera to work faster and compatibility speaks of the ability to connect to other parts. Cost is important in relation to effort to control the budget of the project. In the case of the cameras, A4Tech PK-910H HD has the highest aggregate score and is therefore most appropriate for the project. This should agree with cost, speed, compatibility, accuracy, and reliability while ensuring that it fulfills the project's specifications.

Metrics	Reliability	Accuracy	Compatibility	Speed	Cost	Total
Reliability	0.5	1	1	1	0	3.5
Accuracy	0	0.5	1	1	0	2.5
Compatibility	0	0	0.5	1	0	1.5
Speed	0	0	0	0.5	0	0.5
Cost	1	1	1	1	0.5	4.5

Table 3.9. Projectors Pairwise Comparison Chart

In projectors, reliability is the most critical factor, ensuring that the device operates consistently without failures during presentations or screenings. Accuracy, particularly in color reproduction and image clarity, is essential for delivering high-quality visuals. Compatibility with different input sources and display technologies is also important to ensure the projector can be used in various environments. Speed, in terms of response time and setup, is less critical but still relevant. Cost, while important, is the least prioritized metric since a more expensive but reliable, accurate, and compatible projector offers better long-term value.

Components	Alternatives	Metrics					
		Reliability (3.5)	Accuracy (2.5)	Compatibility(1.5)	Speed (0.5)	Cost (4.5)	Total
	Epson EB-S41 SVGA	0.5	0.5	1	0.5	1	9.25
	BenQ MS550 SVGA	0.5	0.5	1	0.5	0.5	7
	Warpple High Brightness True 1080P Smart Projector LS8 Starlight White / LS8-B Midnight Black projector	0.5	0.5	1	0.5	1	9.25

Table 3.10. Evaluation Metrics for Projectors

The table displays a decision matrix for evaluating three projector models: Epson EB-S41 SVGA, BenQ MS550 SVGA, and Warpple High Brightness True 1080P Smart Projector LS8 Starlight White / LS8-B Midnight Black projector. The evaluation criteria include five metrics: Reliability (weighted 3.5), Accuracy (2.5), Compatibility (1.5), Speed (0.5), and Cost (4.5). Each projector receives a score for these metrics, multiplied by their respective weights to calculate a total score. For Reliability and Accuracy, each projector scores 0.5, and for Compatibility, all score 1. For Speed, each scores 0.5, and for Cost, Epson and Warpple score 1, while BenQ scores 0.5. The total weighted scores are 9.25 for both Epson and Warpple, and 7 for BenQ.

Metrics	**Reliability**	**Accuracy**	**Compatibility**	**Speed**	**Cost**	**Total**
Reliability	**0.5**	**1**	**1**	**1**	**0**	**3.5**
Accuracy	**0**	**0.5**	**1**	**1**	**0**	**2.5**
Compatibility	**0**	**0**	**0.5**	**1**	**0**	**1.5**
Speed	**0**	**0**	**0**	**0.5**	**0**	**0.5**
Cost	**1**	**1**	**1**	**1**	**0.5**	**4.5**

Table 3.11. Gesture Recognition Software Pairwise Comparison Chart

For gesture recognition software, reliability is the top priority to ensure it consistently interprets gestures correctly without errors. Accuracy is also extremely important as it directly impacts the software's ability to recognize and respond to user inputs precisely. Compatibility with various hardware and software platforms is essential for broad usability. Speed, in terms of processing and response time, is important but less so than reliability and accuracy. Cost is the least significant metric, as investing in reliable, accurate, and compatible gesture recognition software provides better performance and user satisfaction, justifying a higher price.

Components	Alternatives	Metrics					
		Reliability (2.5)	Accuracy (3.5)	Compatibility(4.5)	Speed (1.5)	Cost (0.5)	Total
	Leap Motion SDK	1	1	1	1	0.5	12.25
	OpenCV	0.5	0.5	0.5	0.5	1	6.5
	Google MediaPipe	1	1	1	1	1	12.5

Table 3.12. Evaluation Metrics for Gesture Recognition System

The performance measure of the gesture recognition software includes the reliability, accuracy, compatibility, speed and cost and contributes with certain weight which signify their significance. Reliability deals more with effectiveness, accuracy focuses more on efficiency in the execution of the gesture recognition system, compatibility deals with the capacity to work in synergy with other systems, speed looks more into the time to perform the function, and cost concerns the financial aspect. Hence, Leap Motion SDK has a high score in the reliability, accuracy, compatibility, and speed parameters, with medium score in cost, totaling to 12.25. In general, OpenCV has lower rank in reliability, accuracy, compatibility and its speedy performance but has bigger rates in cost factors ranking it with a total 6. 5. Google MediaPipe outperforms all the competitors and receives the best score of 12. 5. Therefore, based on this description and comprehensive comparison shown in the table, Google MediaPipe turns out to be the most suitable tool for the project while providing an overall high and balanced gesture recognition rate.

Metrics	Cost	Security	Scalability	Availability	Total
Cost	**0.5**	**0**	**0**	**0**	**0.5**
Security	**1**	**0.5**	**0**	**0**	**1.5**
Scalability	**1**	**1**	**0.5**	**0**	**2.5**
Availability	**1**	**1**	**1**	**0.5**	**3.5**

Table 3.13. Gesture Recognition Software Pairwise Comparison Chart

The pairwise comparison table for Cloud Storage reveals that Availability is the most critical metric, scoring the highest (3.5), as it ensures continuous access to data, which is the primary purpose of cloud storage. Scalability follows (2.5), emphasizing the need for the storage solution to grow with user needs. Security (1.5) is also vital, reflecting the importance of protecting data from breaches. Cost (0.5) is considered the least critical, as businesses often prioritize the other three metrics over expense, willing to invest more for better availability, scalability, and security. This prioritization aids in selecting a cloud storage provider that best meets organizational requirements.

Components	Alternatives	Metrics				
		Cost (0.5)	Securit (1.5)	Scability (2.5)	Availability (3.5)	Total
	Anaconda	0.5	1	1	1	7.75
	Netbeans IDE	0	0.5	1	1	6.75
	Virtual Studio Code	1	0.5	1	1	7.25

Table 3.14. Coding Software Pairwise Comparison Chart

The pairwise comparison table for Coding Software shows the most critical metric is Availability at 3.5 signifying regular access to tools and the second most important is Scalability at 2.5 for managing project growth requirements. Security (1.5) and Cost (0.5) though these two are not very significant, they are considered essential. In the same alternatives, Anaconda gets the highest overall score of 7.75. Visual Studio Code has the highest functional score with 7.25 and it shows that Netbeans IDE is the least favored with a total functional score of 6.75. This comparison shows that, according to the weightage factor, the best package is again found in Anaconda.

Chapter IV

TECHNICAL STUDY

This chapter offers a detailed and extensive overview of the project, encompassing a description of its objectives and goals, followed by the design specifications, which outline the technical requirements and component functionalities. It includes a block diagram to illustrate the system's architecture and interconnections, as well as a flow chart to map out the step-by-step process and decision points involved in the system's operation. Additionally, the chapter presents a 3D model to provide a visual representation of the system's physical layout and component arrangement, alongside a graphical user interface (GUI) that demonstrates the user-friendly design and interactive features. Lastly, it outlines the verification plan, detailing the testing and validation strategies employed to ensure the system meets its specifications and performs reliably. This comprehensive chapter serves as a thorough guide to understanding the project's design, functionality, and validation processes.

Project Description

The "Gesture-Driven Cursor Control" project is an innovative system designed to revolutionize presentations by integrating camera and sensor-enhanced whiteboard technology. This advanced setup allows for seamless interaction and dynamic content delivery through gesture-based controls, utilizing key components such as an Arduino Uno microcontroller, Logitech C922x Pro Stream Webcam, Warpple High Brightness

True 1080P Smart Projector LS8 Starlight White / LS8-B Midnight Black projector, Google MediaPipe, and Google Drive.

At the heart of the system is the Arduino Uno, which manages data flow and control signals among the various components. Its reliable processing capabilities make it ideal for handling the real-time data necessary for gesture recognition. The Logitech C922x Pro Stream Webcam captures high-definition video inputs, focusing particularly on the presenter's hand gestures. These gestures are crucial for the system's functionality, as they are processed and recognized by Google MediaPipe, which uses machine learning models to interpret the gestures and convert them into commands for controlling the projected content.

The Warpple High Brightness True 1080P Smart Projector LS8 Starlight White / LS8-B Midnight Black projector is an essential component, delivering bright and clear visual displays on a whiteboard or screen. This ensures that the presentation content is visible and engaging for the audience. Complementing this hardware setup, Google MediaPipe provides the necessary algorithms for accurate gesture recognition, while Google Drive offers cloud-based storage solutions for managing and accessing presentation files. This integration allows presenters to conveniently store and retrieve their materials from anywhere, adding a layer of flexibility to the system.

One of the standout features of the Gesture-Driven Projection system is its gesture-based control mechanism, which provides a natural and intuitive way for presenters to interact with their content without physical contact. This capability is especially valuable in educational and professional environments, enhancing engagement and streamlining the flow of presentations. Additionally, the system's portability and ease of setup, facilitated by the compact Arduino Uno and lightweight webcam, make it suitable for various venues, including classrooms and conference rooms. The use of Google MediaPipe ensures high accuracy in gesture recognition, while Google Drive offers secure and convenient access to presentation materials.

Category	**Specification**
Coding Software	Visual Studio Code
Platform support	Windows, macOS, Linux
File Types Supported	Multiple (e.g., .js, .py, .cpp, .html, .css, .json, .md, etc.)
Extensions	10,000+ extensions (languages, debuggers, themes, etc.)
Editor Features	IntelliSense, Syntax Highlighting, Code Folding, Bracket Matching

Version Control	Git Integration (GitHub, GitLab, Azure Repos)
Debugging	Built-in Debugger for multiple languages
Customization	Themes, Keybindings, Snippets, Settings Sync
Language Support	JavaScript, Python, C++, Java, HTML, CSS, Go, Rust, and more
Memory Usage	~400 MB (depending on extensions and project size)
Installation Size	~250 MB
Plugins	Marketplace for Extensions
Integrated Terminal	Yes (supports multiple shells: Bash, PowerShell, Command Prompt)
Updates	Regular updates (monthly)
License	MIT License (free to use)
Release Date	April 2015
Developer	Microsoft

Table 4.1. *Design Specification Virtual Studio Code*

Category	Specification
Projector	Warpple High Brightness True 1080P Smart Projector LS8 Starlight White / LS8-B Midnight Black
Resolution	True 1080P Full HD (1920 x 1080)
Brightness	8,000 lumens
Throw Ratio	1.35:1
Connectivity	HDMI, USB, Bluetooth, Wi-Fi, VGA
Special Features	10,000:1 contrast ratio, smart OS, wireless screen mirroring, dual-band Wi-Fi, built-in stereo speakers, long lamp life (up to 50,000 hours)

Table 4.2. *Design Specification of Warpple High Brightness True 1080P Smart Projector LS8 Starlight White / LS8-B Midnight Black*

Category	Specification
Camera	Logitech C922x Pro Stream Webcam
Resolution	1080p Full HD / 720p HD
Frame Rate	30fps at 1080p / 60fps at 720p
Field of View	78°
Depth Sensing	No
Connectivity	USB 2.0
Special Features	Built-in stereo microphones, auto low-light correction, background removal, tripod included
Best For	Streaming, video calls, content creation with smooth HD quality
Ease of Integration	High
Performance in Low Light	Excellent (with automatic low-light correction)
Complexity	Low

Table 4.3. *Design Specification of Logitech C922x Pro Stream Webcam*

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Category	Specification
Gesture Recognition system	**Google MediaPipe**
Supported Platforms	Cross-platform
Programming Languages	C++, Python
Gesture Types	Hand, Face, Pose, Custom
Special Features	Real-time performance, modular framework
License	Free (open-source)

Table 4.4. *Design Specification of Google MediaPipe*

Category	Specification
Gesture Recognition system	**OpenCV**
Supported Platforms	Cross-platform
Programming Languages	C++, Python, Java, JavaScript
Gesture Types	Hand, Face, Object Detection, Motion Tracking
Special Features	Comprehensive library, extensive image-processing tools
License	Free (open-source, BSD License)

Table 4.5. *Design Specification of OpenCV*

Block Diagram

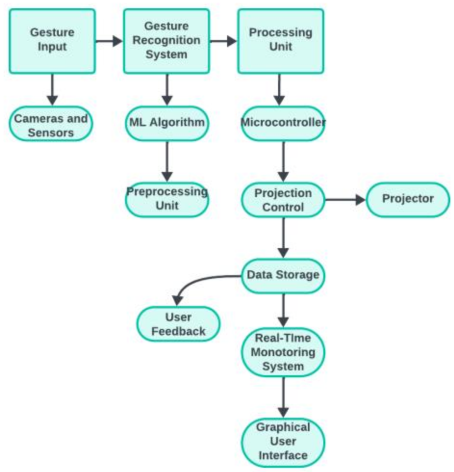

Figure 4.1 *Block Diagram*

The block diagram illustrates a sophisticated gesture-based interaction system that integrates gesture recognition with projection technology. Initially, gesture input is captured by cameras and sensors that record visual and motion data. This data is then processed by the Gesture Recognition System, where a machine learning (ML) algorithm analyzes and identifies specific gestures. Before this analysis, a preprocessing unit filters and normalizes the data to enhance accuracy. The recognized gestures are sent to the Processing Unit, which features a microcontroller responsible for coordinating system responses. The microcontroller directs the Projection Control unit, determining how the projector should display visual content based on the interpreted gestures. The projector then visualizes the appropriate output, such as user interfaces or instructional visuals.

Simultaneously, the system utilizes Data Storage to save gesture data and user interactions for further analysis and improvement of the gesture recognition algorithms. A Real-Time Monitoring System continuously oversees the system's performance, making necessary adjustments to ensure smooth operation. Users interact with the system through a Graphical User Interface (GUI), which provides real-time feedback, status updates, and relevant information or options. Additionally, user feedback is collected to enhance the system, allowing it to learn and refine the gesture recognition process and overall user experience. This integrated system captures and processes gestures to control a projector, ensuring an efficient and responsive interaction through real-time monitoring and user feedback mechanisms.

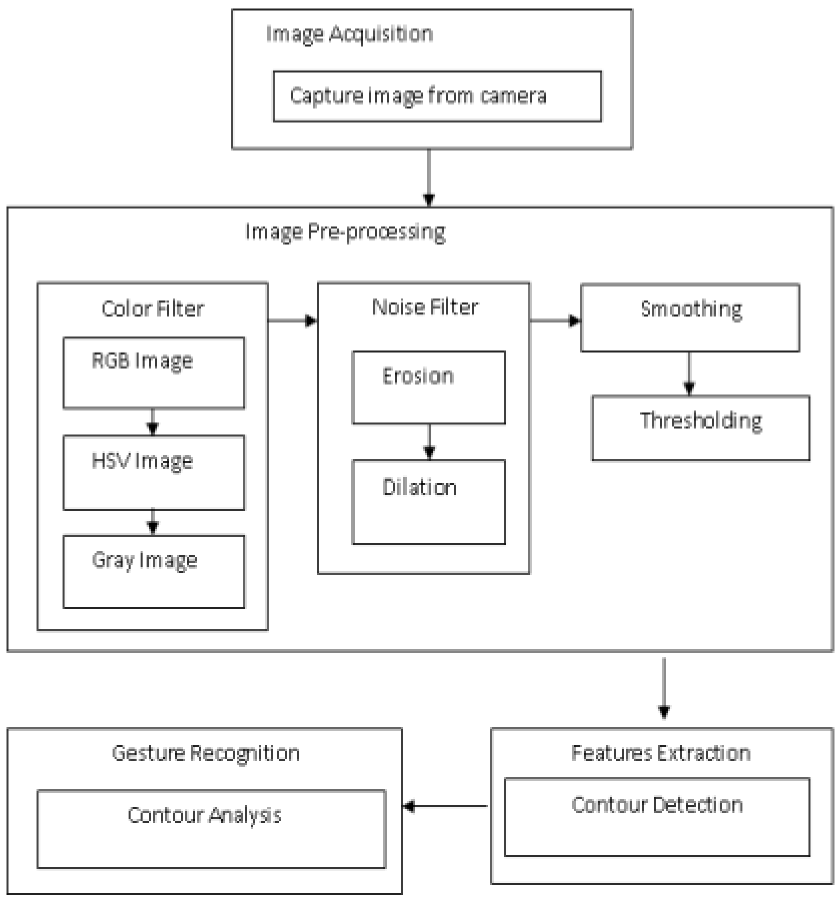

Figure 4.2. *Block Diagram of Image Process Techniques*

The diagram outlines a gesture recognition system that begins with image acquisition, where an image is captured from a camera. The captured image then undergoes pre-processing, which includes color filtering (converting to RGB, HSV, or grayscale), noise filtering through erosion and dilation to reduce noise, and smoothing to reduce sharp edges. After smoothing, thresholding is applied to convert the image into a binary format for easier object-background separation. The next stage involves feature extraction, specifically through contour detection, which identifies the object's edges or boundaries. Finally, gesture recognition is performed through contour analysis, allowing the system to recognize and classify different hand gestures based on the detected contours.

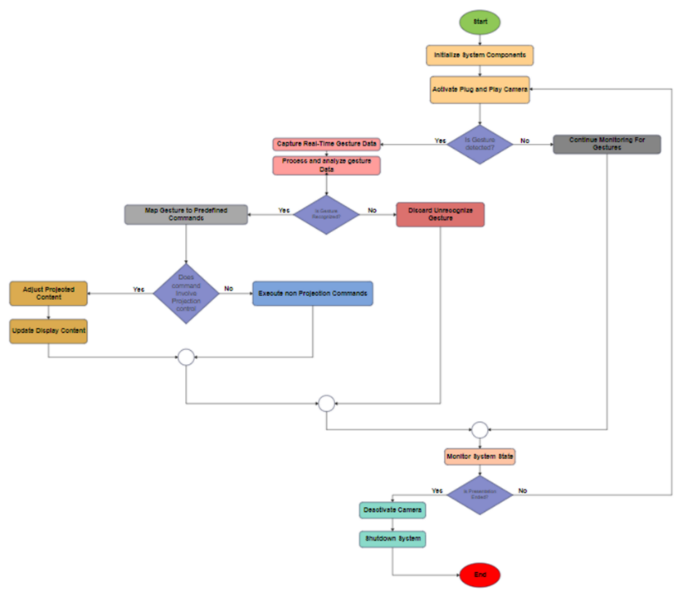

Figure 4.3. *Flow Chart*

Figure 4.3 presents the flowchart of the system, shows how different gestures used by the user on the surface of the touch screen and how the touch screen will respond to each of the gestures.The first step in the process is the activation of the system components and those that make use of the plug-and-play camera are activated ready to capture input from the user. It constantly scans for gestures and as mentioned earlier, the camera is used to always identify the gesture being done in real time. Once it recognizes a gesture it records and examines the information with the aim of identifying a match with an existing command. This is just in case the system identifies the meaning of the gesture and then links it with the useful command within the system. Depending on the command, the projected content is modified for instance in changing the slides, magnifying, or minimizing certain parts of the content or doing annotations or even pointer movement. The content which is displayed on the whiteboard is modified regarding the above descriptions. This state keeps the interactive system in the monitoring state, ready for the next gesture and stabilizes the execution. If the presentation is over, the camera is turned off and all the system components are stopped to indicate that the process is complete. The flowchart aims at the integration of the gesture recognition in managing the presentation and how inputs are processed to improve interaction of the user with the content on the projection screen.

Algorithm

Gesture-driven projection systems use cameras and sensors to transform traditional whiteboards into dynamic, interactive interfaces that respond to user gestures, enhancing presentations. Key components include a camera system for capturing gestures, a sensor array for detecting proximity and motion, a projection unit for displaying content, a processing unit for interpreting data, and software for gesture recognition and content management. The system's algorithm design involves pre-processing data, feature extraction, machine learning-based classification, and contextsensitive gesture mapping. Real-time processing ensures low latency and accuracy, with user interfaces providing feedback and customization options.

Implementation involves collecting diverse gesture data, training recognition models, integrating these models with hardware components, and calibrating the system for accuracy and responsiveness. User training is crucial to familiarize users with the system. The technology finds applications in education, corporate presentations, public speaking, and collaborative workspaces, offering enhanced interactivity and engagement. However, challenges include accommodating diverse gestures, maintaining performance across different lighting conditions, and balancing functionality with cost.

Future developments may include expanding gesture libraries, adaptive learning algorithms, multimodal inputs like voice commands, and cloud-based processing. These advancements aim to make the system more intuitive, versatile, and effective, potentially revolutionizing presentations by offering a more seamless and interactive experience.

Verification Plan

The Verification Plan provides a thorough strategy for ensuring the combined gesture-based presentation system's accuracy, dependability, and functionality. The first step is the verification of the camera system, which will be examined to see how well it can capture gestures at different angles and distances. The system will run through a test run session of 10 trials for each category. Along with thoroughly testing the gesture recognition algorithm to guarantee accurate and immediate gesture interpretation, the plan also entails a processing capacity assessment to verify the system's ability to process user inputs promptly. System integration will be verified to ensure smooth operation amongst all components. Usability testing, where input is obtained to assess satisfaction and identify areas for development, will prioritize the user experience. In order to evaluate the system's performance under various circumstances and high load scenarios, it will also go through environmental and stress testing. Throughout the process, thorough documentation will be kept up to date to document test findings and direct any necessary remedial measures, ensuring that the system satisfies all set performance and usability standards. The gesture-based presentation system will be fully validated and ready for efficient real-world use by putting this Verification Plan into practice.

Component Verification. It involves a thorough assessment of individual system components, starting with the camera system. The objective is to ensure that the camera accurately captures gesture movements. Test cases will assess resolution and frame rate, evaluate gesture capture under various lighting conditions, and verify the camera’s field of view to cover the entire presentation area. Success is defined by the camera’s ability to capture clear and consistent gesture movements across all test conditions. Next, the sensor array will be tested to ensure accurate detection of proximity, motion, and specific gestures. This includes testing the camera’s responsiveness to different gesture speeds and directions, as well as verifying performance under varying environmental conditions such as temperature and humidity. Success criteria are based on accurate gesture detection and minimal error. The projection unit will be evaluated to confirm its ability to display content accurately and respond to gesture commands. Test cases will involve verifying image quality and alignment on the whiteboard, and assessing responsiveness to gestures like swiping and pinching. The projection unit must display clear, correctly aligned content and accurately respond to gesture commands to be deemed successful.

Software Verification. Ensuring the accuracy and dependability of the gesture recognition algorithm requires validation. The algorithm is trained using a variety of gesture datasets, and it is then tested using brand-new, untested gestures. At least 95% of gestures should be correctly recognized by the algorithm with the least amount of latency. It's also critical that the right actions are triggered by recognized gestures. Every gesture will be associated with a particular action and evaluated in a range of settings, including content editing and presentations. The software will undergo 10 trials to evaluate that the software will respond properly and to avoid the force close of the software while using it. Ideally, the system should react to gestures in less than 100 milliseconds, and it should do so consistently.

System Integration Verification. It will ensure the seamless integration of the camera, sensor array, projection unit, and software. End-to-end tests will be conducted to validate the system’s performance in a typical presentation setup. Success is defined by the effective coordination of all components, working together without interruptions or failures.

User Experience Verification. It will assess the system's ease of use and overall user satisfaction. User trials with participants of varying technical proficiency will be conducted to gather feedback on system responsiveness, accuracy, and user experience. High user satisfaction scores and positive feedback on usability will indicate success. Additionally, users' ability to quickly learn and adapt to the system will be evaluated through training sessions. The goal is for users to effectively use the system after a short training period and demonstrate continuous improvement.

Environmental and Stress Testing. It will verify the system's performance under various conditions, including different lighting, temperature, and humidity levels. The system must maintain performance and accuracy across all environmental conditions. Stress testing will evaluate system stability and performance under high load by simulating usage of user with the limit of 1 user using the system altogether and continuous gestures, and testing the system with complex, rapid gestures. The system must remain stable and responsive under high-stress conditions.

Documentation and Reporting. It will involve maintaining comprehensive records, including detailed test plans and procedures, logs of test executions and results, and reports on identified issues and corrective actions. Accurate and complete documentation will provide a clear record of the verification process, ensuring transparency and guiding future improvements.

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CHAPTER V

PRESENTATION AND ANALYSIS OF RESULT

This chapter presents the project setup, study results, implications of findings, and All other concepts involved in the development of the Gesture-Driven Cursor Control Interactive Projection System: Transforming Presentations with Camera and Interactive Whiteboard Technology.

Prototype

This section details the prototype developed for the project, as depicted in Figure 15. The prototype incorporates a computer system that processes real-time video feeds from a webcam. Because the camera is installed on motorized platforms, viewing angles can be changed by adjusting its stand. By using advanced computer vision algorithms to identify and interpret particular hand gestures, the system allows users to manipulate camera movements and initiate functions such as drawing on the presentations without having to physically interact with the device.

Figure 5.1 A Picture of Logitech C922 Webcam

Prototype Setup and Deployment

The implementation of the device involved strategically placing the camera depending on the user's decision. An interactive whiteboard was projected onto a large screen by a projector mounted on the ceiling. A high-definition camera is placed to record the presenter's hand and finger movements. The projector and camera were connected to the computer system that runs the software for the system. The system was started by turning on the computer and calibrating the projector and camera to guarantee precise image projection and gesture recognition. The system was prepared for use in presentations once it was up and running, enabling the presenter to manipulate the cursor and use hand gestures to interact with the projected content.

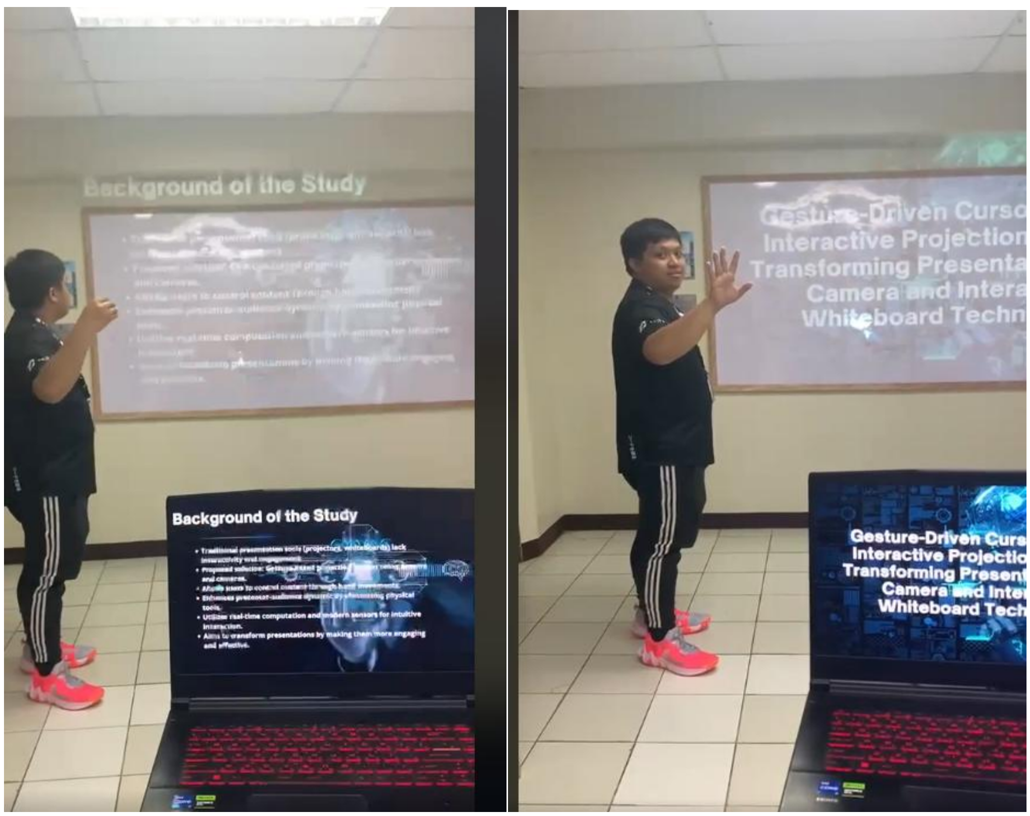

Figure 5.2 Project Prototype Setup

Testing plan

Our testing plan is designed to evaluate the effectiveness and usability of our "Gesture-Driven Cursor Control Interactive Projection System". This system aims to enhance presentation experiences by allowing presenters to control the cursor and interact with content using intuitive hand gestures.

The testing process occurred in a room, where we set up and tested different hand gestures that can be executed by the system. During this phase, we considered those delays and errors to add more effort to deal with them, ensuring that the system can execute more accurately in recognizing gestures.

Figure 5.3. *The hand and fingers are recognized by the system.*

In this section, we first introduced a system for hand and finger recognition as shown by the following figure. The first step of our system development is by installing libraries such as OpenCV and MediaPipe, which will be crucial in hand tracking in real time. With these tools, we started the hand tracking module of MediaPipe, which allows the detection and tracking of hand landmarks. The system can effectively distinguish the position and organization of the hand and fingers through marking important points and linking them with lines. This makes it easier to validate the recognition as it is presented in the format of a figure. This perspective makes sure that the hand movement can be well detected and analyzed, thus can be used in gesture-based interfaces, interactive projections, as well as other interactive systems.

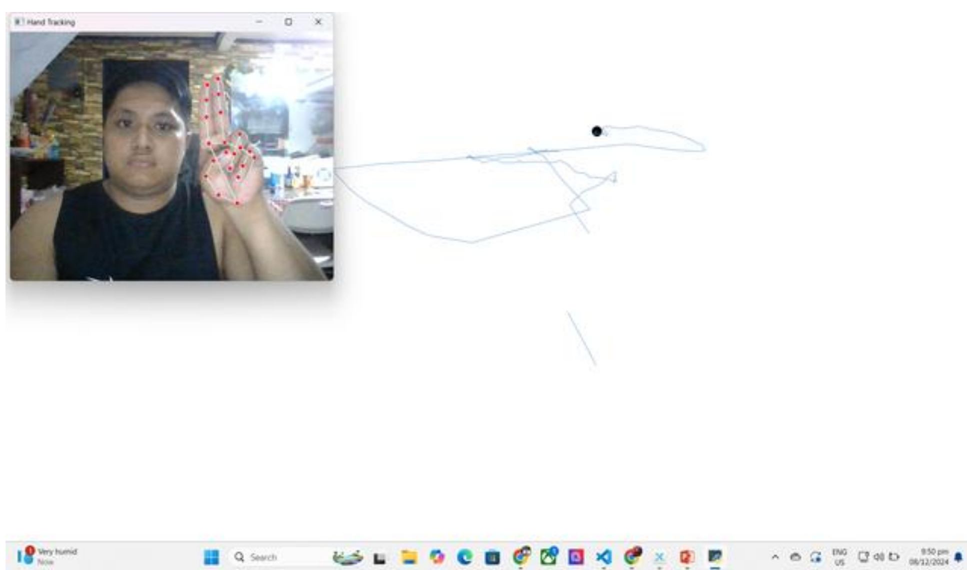

Figure 5.4. *The hand gestures recognized by the system for drawing on the board.*

In this part of our project, we added a writing function to our system that allows users to write on PowerPoint. As it has been shown, the system identifies certain hand movements and can manipulate the cursor and draw simultaneously. By following the movement of the user's hand, the system converts the gestures into the drawing commands, which use the hand as a digital pen. This functionality is rather important for applications where users expect to have a simple and intuitive experience interacting with the product, like educational or creative applications.

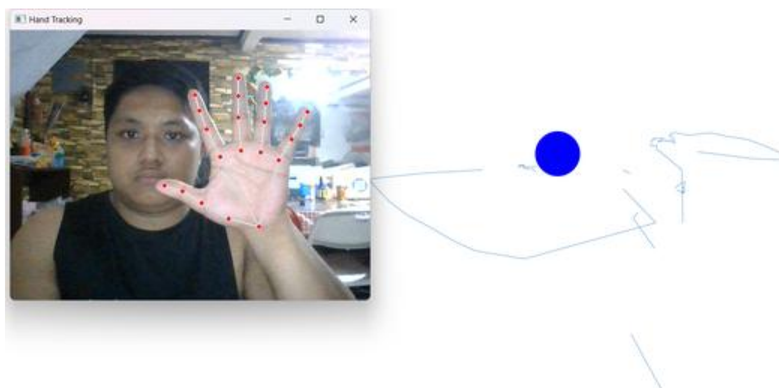

Figure 5.5 *The hand gesture is recognized by the system as the drawing gesture stops.*

In this part of our project, we further enhanced the system by incorporating an eraser tool that allows users to erase their drawings on the PowerPoint. The system can recognize specific hand gestures to switch between drawing and erasing modes. When the system identifies the gesture for stopping the drawing function, it activates the eraser tool, indicated by a different visual cue. This functionality adds versatility to the system, making it more interactive and user-friendly, especially for applications like presentations where users may need to modify their drawings or notes dynamically.

Figure 5.6.*Hand Gesture Recognition for Pointing Gesture*

The system effectively identifies a pointing hand gesture. The system uses an algorithm that receives various points in the hand, finds that the first extended finger code corresponds to a 'pointing' gesture when the other fingers are contracted. This detection is just followed by a visible connection of red nodes and white lines drawn all over hand suggesting how the palm ‘structure’ looks like. The detected gesture can be used for controlling the cursor on the screen. This functionality underlines interactivity and offers usability, which allows users to have the natural interaction with the systems using hands.

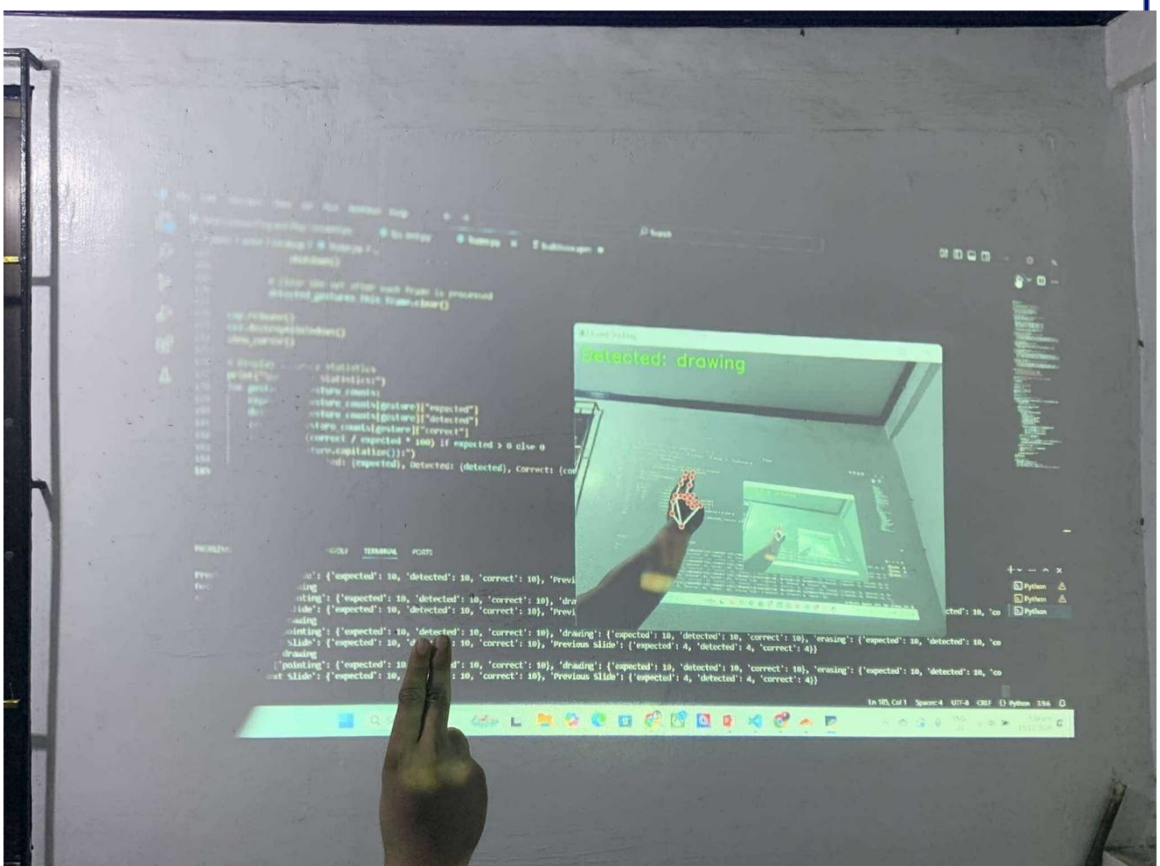

Figure 5.7 *Hand Gesture Recognition for Drawing Gesture*

In this part of our Project, the system can recognize a “drawing” hand gesture through the implementation of an improved hand tracking mechanism. The detection is realized by marking the main points of the hand with red nodes and connecting them with white lines to define the general shape of the hand. The recognized gesture is created by two raised fingers – the index and middle fingers – and the others, either clenched or bent. This formation looks like a typical motion that is typical to signaling graphics or building something in the virtual world.

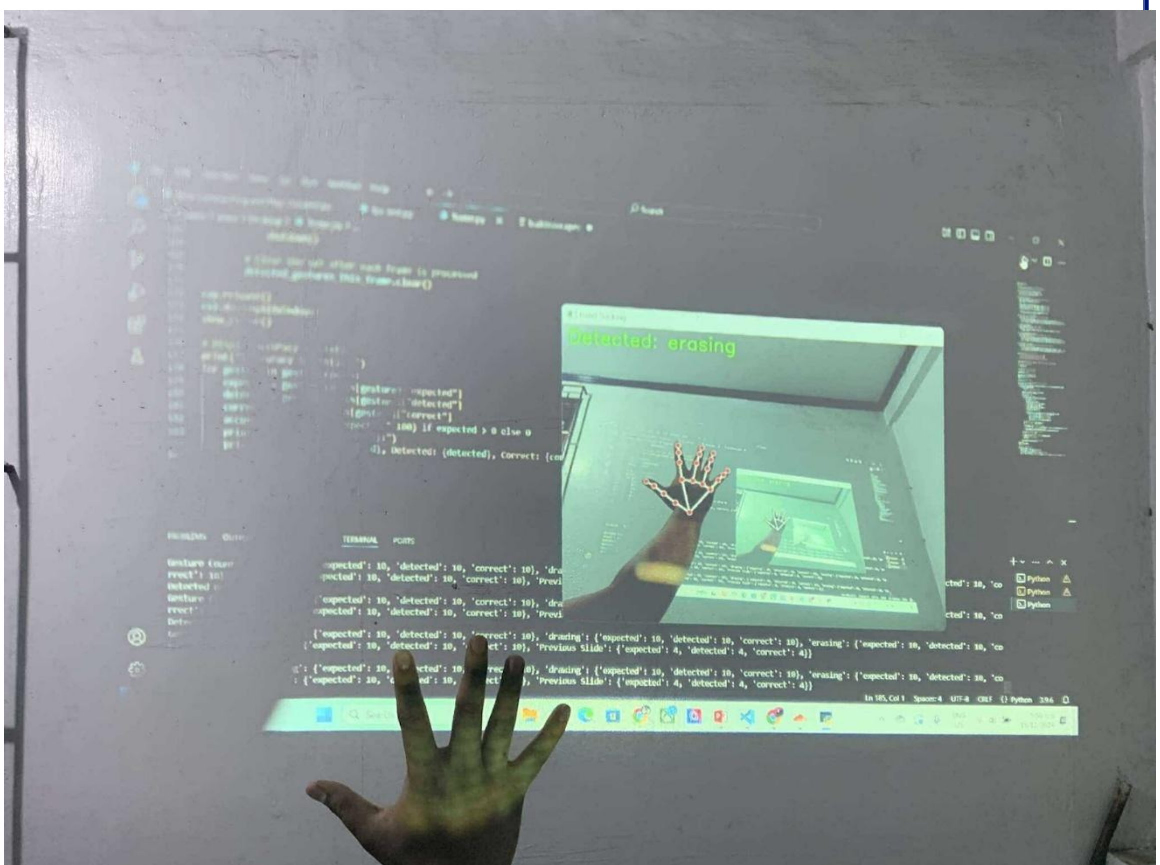

Figure 5.8 *Hand Gesture Recognition for Erasing Gesture*

In this part of our project, the system successfully performs hand detection and recognition of an “erasing” hand gesture. The system uses red nodes for representation of key points on the hand and the connectivity is established by graph formation using white lines to have a visible structure that represents the hand. The identified gesture means an 'empty' hand with palm up and fingers out straight, resembling a natural wiping or erasing movement.

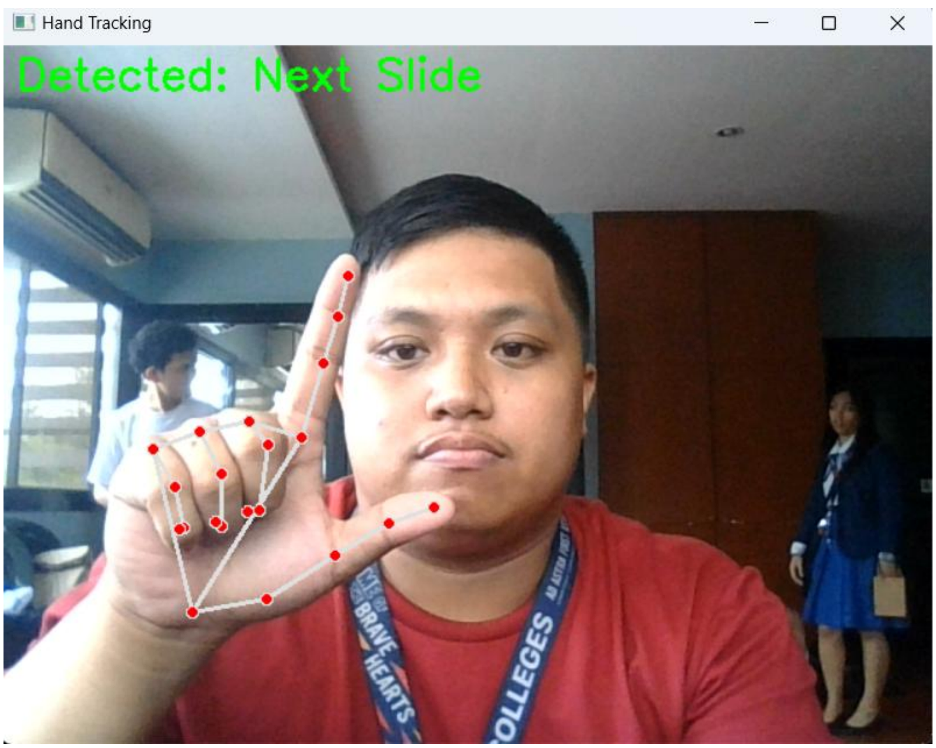

Figure 5.9 *Hand Gesture Recognition for next slide Gesture*

In this part of our project, the system is able to identify the "Next Slide" hand gesture. When the user is still or if there is no movement detected for a while, the system displays the points corresponding to the key parts of the hand as red nodes connected by white lines to show the structure of the hand. This gesture is performed by extending the thumb and pointer finger, while the remaining fingers are bent.

Figure 5.9. *Hand Gesture Recognition for previous slide Gesture*

In this part of our project, the system correctly identifies a “previous slide” gesture. Several key points of the hand are highlighted, where red nodes are displayed, and these points are connected with white lines to form the structure of the hand. When only the thumb is extended while all other fingers are curled, the system recognizes that the user is performing the designated hand gesture.

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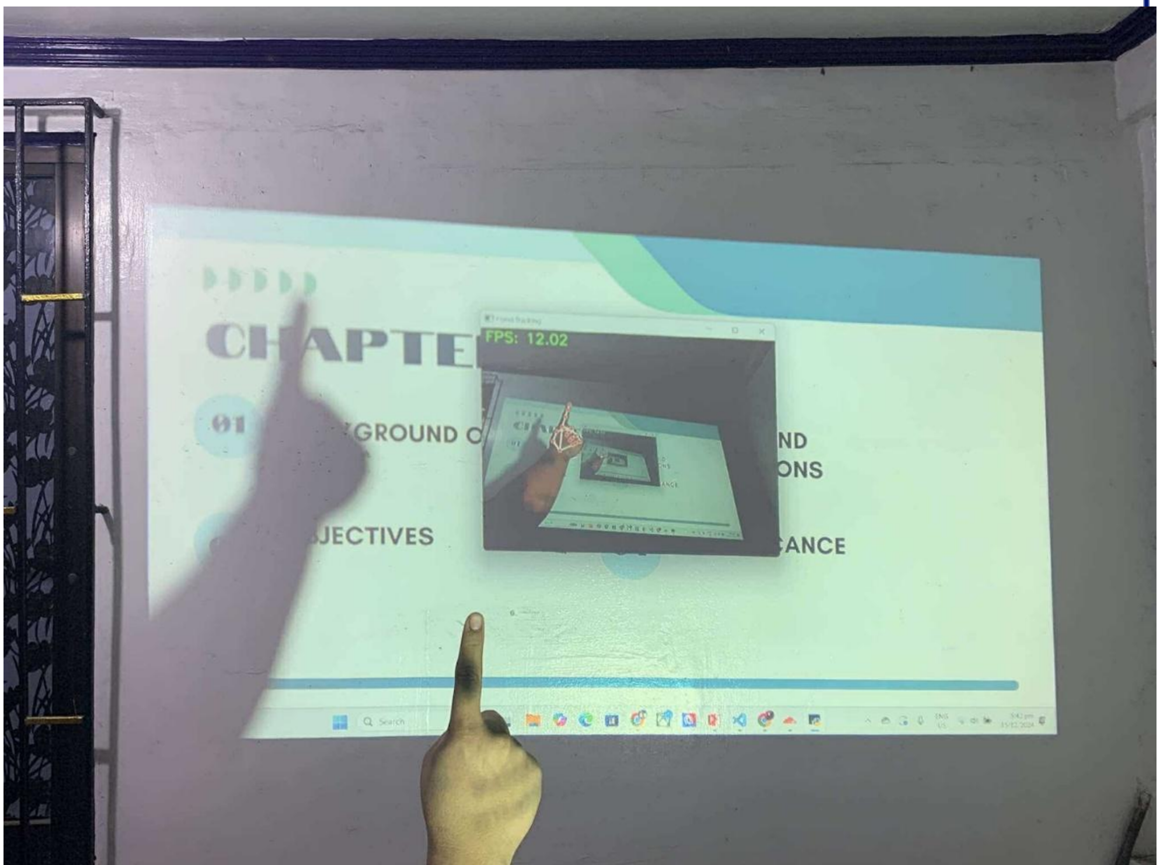

Figure 5.10. *Cursor FPS tracking*

The gesture recognition and tracking performance of the system is shown as frame rate (FPS) of 12.02 in the interface. This real time cursor control also allows simple and direct manipulation of data with no input devices, in presentations, information displays and interfaces, or any kind of human-computer interface. The dark pointing hand well derives an impression for the projection-based setup and depicts the integration of gesture to the visuals and vice versa. This functionality illustrates how the system must make user interactivity more effective and convenient as compared to typical manual operations.

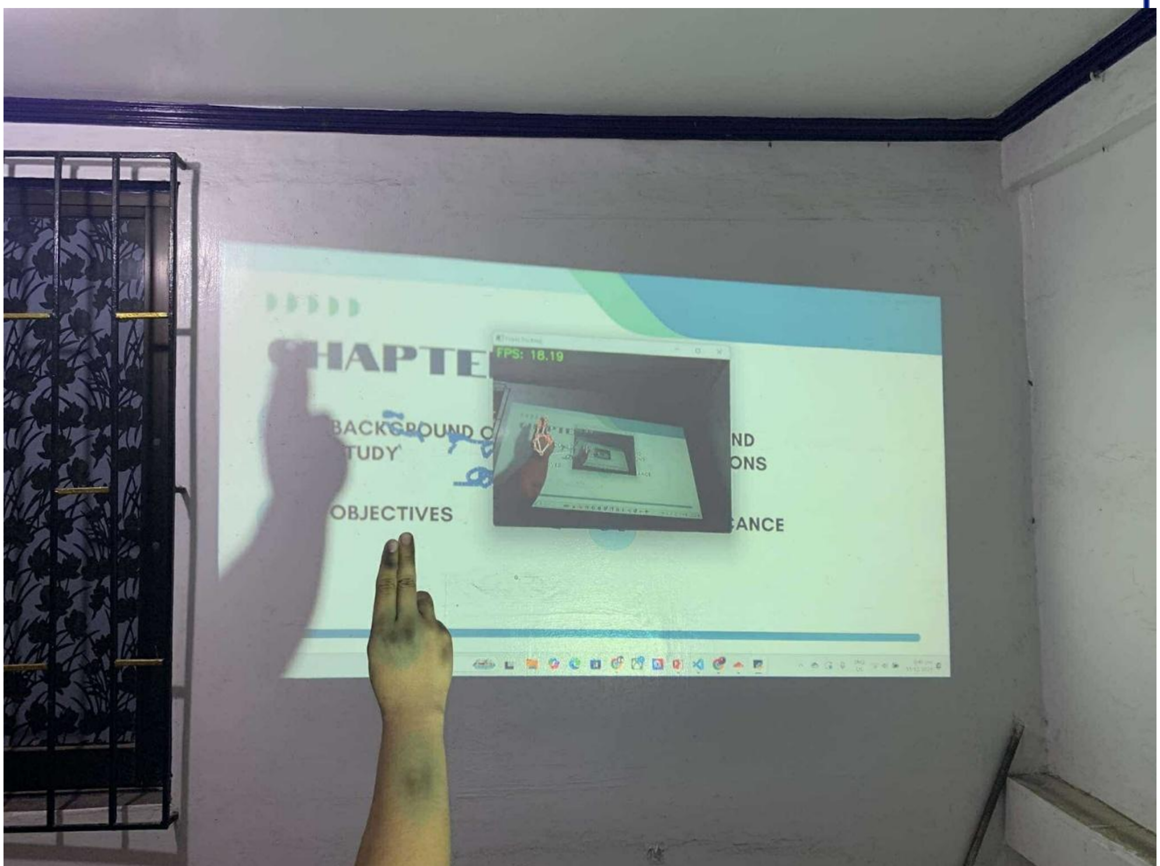

Figure 5.11. *Drawing tool FPS tracking*

The frame rate (FPS) of 18.19, shown in the interface during tracking, reflects a swift and efficient functioning of the system during real-time tracking. This example illustrates how multitouch includes free form gestures recognized by the system to support drawing, or writing gestures on digital tables. The coupling of gesture recognition with display feedback improves usability, adds flexibility to touchless interaction in artistic and communicative context.

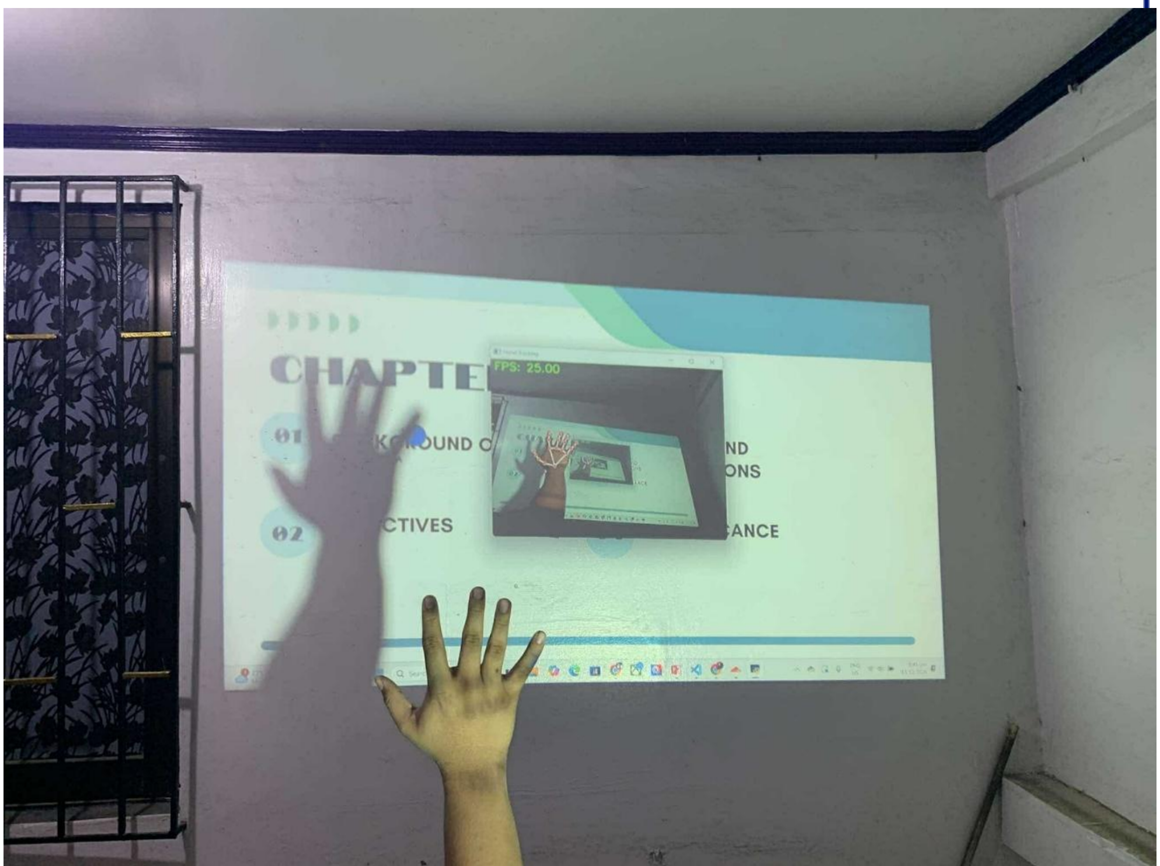

Figure 5.12 *Erasing tool FPS tracking*

Real-time capturing of a user's hand gesture takes place with an output frame rate of 25 FPS to guarantee the best tracking experience. The system is able to capture and interpret gestures with fairly good precision as ideal for methods like cursor moving by hand gestures or manipulating interfaces. This configuration offers easy and effortless control of the system, revealing its ability to offer fast, accurate control.

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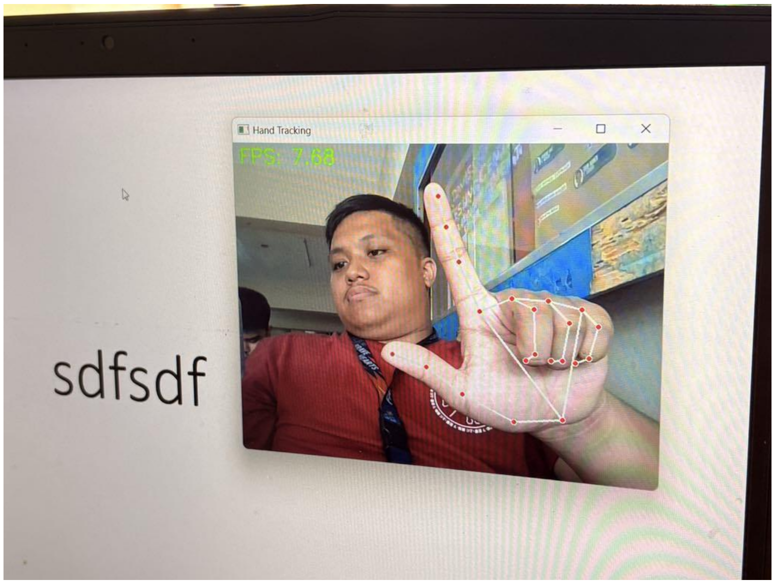

Figure 5.13 *Next slide FPS tracking*

The user hand gesture is then recorded real time with a high frame rate of 30.06 FPS ensuring the tracking is smooth. Such a gesture recognition makes it possible for the user to easily move to the next slide, as it shows the main idea of the system and its applicability for the further presenting control. This arrangement makes navigation easier, more efficient and also does not require the hands of the user making it suitable for live and interactive demonstrations.

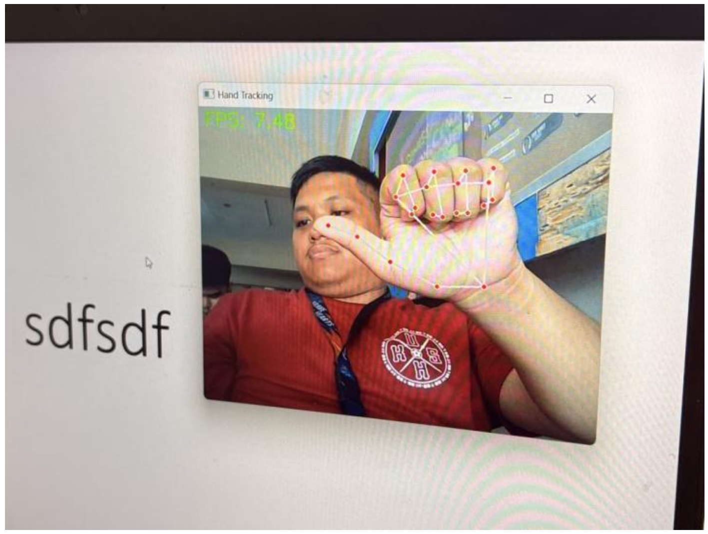

Figure 5.14 *Previous slide FPS tracking*

Real-time hand gesture is recorded based on user interaction with the system to have a higher frame rate of 17.78 FPS. This gesture recognition makes it possible that the user can easily go back to a certain previous slide and is an example of the kind of interactivity that the system has on handling presentations. This setup improves on the user interface since it simplifies presentation interactions to be more natural and easier to control as will be seen in this work.

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Gesture	Expected	Detected	Correct	Accuracy	FPS Average
Pointing	10	10	10	100.00%	12.02
Drawing	10	10	10	100.00%	18.19
Erasing	10	10	10	100.00%	25.00
Next Slide	10	10	10	100.00%	7.68
Previous Slide	10	10	10	100.00%	7.48

Table 5.1 *Performance Evaluation of Gesture Recognition functions of the system*

To evaluate the effectiveness of the gesture Recognition functions and how other functions can be detected and recognized by the system. The functions tested were pointing functions, drawing functions, erasing functions, next slide functions, and previous functions. For every function, the supposed 10 gestures were given to the system where all functions were recognized and then classified with a hundred percent accuracy. The steadiness attained in these points proves the durability and accuracy with which the system can identify hand movements. The exact conceptual understanding of the commands demonstrated through this display makes it a highly reliable tool for interaction like presentations or virtual reality. This evaluation shows the effectiveness of the system in providing a focused experience so that users can be easily accommodated and the interactive experience improved.

For the pointing function, 10 gestures were detected and recognized correctly with an accuracy of 100%, achieving an FPS of 12.02. The drawing function also had 10 out of 10 gestures recognized correctly, with an FPS of 18.19. Similarly, the erasing function showed 100% accuracy for 10 gestures, with an FPS of 25.00. The next slide function demonstrated flawless recognition of all 10 gestures, with an FPS of 7.68. Lastly, the previous slide function maintained the same accuracy, recognizing all 10 gestures correctly, with an FPS of 7.48. These results indicate the system's effectiveness in providing a focused and efficient interactive experience, enhancing user accommodation and interaction.

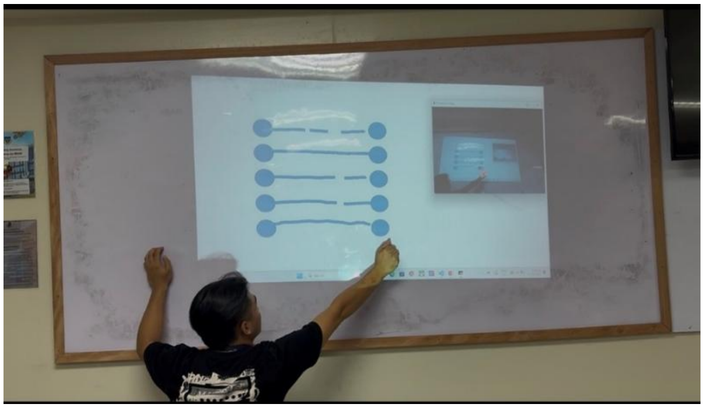

Figure 5.15. First Part Trial of Writing in a 15 cm apart

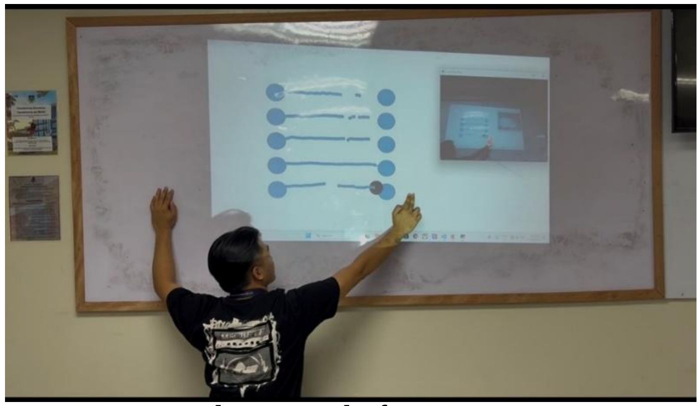

Figure 5.16. Second Part Trial of Writing in a 15 cm apart

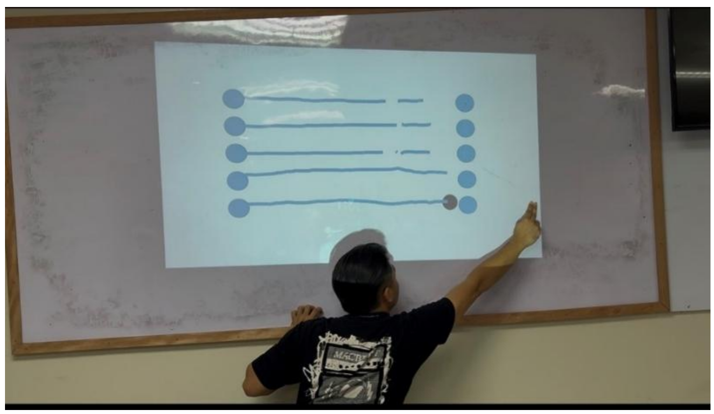

Figure 5.17. First Part Trial of Writing in a 30 cm apart

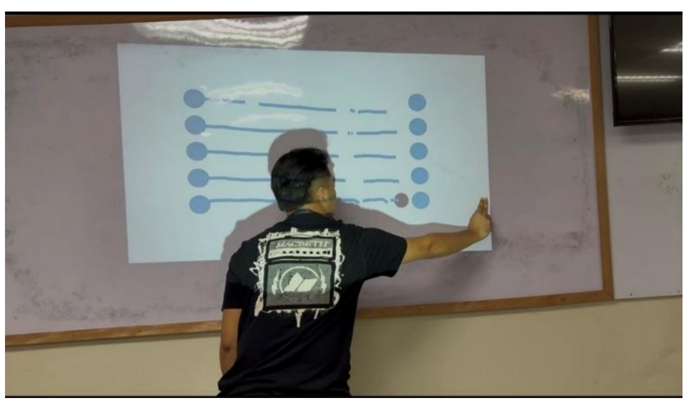

Figure 5.18. Second Part Trial of Writing in a 30 cm apart

A participant conducts writing tests through projections showing 15 cm-spaced markings in Figures 5.15 and 5.16. Two writing trials during this session showed evidence of regular spacing as well as correct alignment. The differences in-between trials indicate space maintenance issues that might stem from ergonomic factors along with system responsivity issues. Precise control requires proper body posture and hand positioning according to the images and any physical strains observed during the trials could suggest adaptation when reaching intended points. Digital tracking system data can indicate calibration issues together with system responsiveness problems when it shows inconsistencies. The participant's performance in the second trial demonstrates better outcomes because they become experienced with the interface system. The obtained results deliver information about digital writing setup usability while all detected discrepancies signal needed interface design or user guidance changes for optimization.

Writing test results using points set 30 cm apart can be seen in Figures 5.17 and 5.18. The participant conducted the first trial segment by working on the projected interface to accurately link points during this interval as demonstrated in Figure 5.17. The writing trajectory indicates a stage where the participant adopted a strategy to preserve accuracy in their movements. The participant continues to use the interface with 30 cm spacing intervals during the ongoing portion of the trial as displayed in Figure 5.18. The second stage reported better results for both accuracy and movement consistency in writing tasks. The graphical representations of participant performance data serve to show the participant's actions while writing tasks that enable experts to evaluate both movement precision and all encountered difficulties.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATION

Summary

The Gesture-Driven Cursor Control Interactive Projection System can be said to follow the similar approach to the Immersive Media System that was proposed in Lee et al.’s (2020*) Design and Implementation of Immersive Media System Based on Dynamic Projection Mapping and Gesture Recognition*. Both systems rely on gesture recognition to ensure that users have an elaborated, responsive and natural manner of controlling digital content, as a demonstration that technology can process enough mechanisms to do away with contacting gadgets.

In their system, Lee et al. introduced the use of dynamic projection mapping and gesture recognition since a user is able to draw and manipulate projected media such as designing unique t-shirts for pattern projection. Likewise, the Gesture-Driven Cursor Control allows a user to control cursors and draw, as well as interaction with projected presentation with the help of hand gestures. Each system employs real time hand and finger tracking relying on OpenCV and/or MediaPipe to decode gestures into action commands.

However, the Gesture-Driven Cursor Control system particularly provides added confidence to presentations by augmenting the web applications especially interactive presentation. It has features such as drawing and erasers for enhancement during live presentations since one is able to make changes. This targeted application seamlessly fills in the gap between fully interactive media and business-oriented presentation applications making it easy to use for learning and business environments. These projects emphasize on the capability of the gesture-based interfaces in creating engaging, immersive and even interactive user experience.

Conclusions

Upon finalizing the Gesture-Driven Cursor Control Interactive Projection System, which resulted in the development of an advanced interactive presentation tool, the following conclusions were drawn:

1. The researcher was able to design and implement a system that supports gesture control and cursor movement, content interaction and gesture drawing tools. Components like high-definition cameras, interactive presentations with ceiling projector are integrated into this system.

2. Programmable real-time hand & finger tracking is accomplished using computer vision libraries such as OpenCV and MediaPipe. These algorithms make possible cursor control, drawing on the screen using PowerPoint, and toggling cursor mode, drawing mode, erasing mode next and previous slide.

3. The system was subjected to validation testing in order to verify its accuracy and therefore the reliability. The hand tracking and gesture recognition modules provided good results where errors and delay were corrected during the trial process. The writing function and eraser tool were tested with a view of ascertaining compatibility interoperability and ease to use.

4. In testing the system, it did not show any errors; it had high accuracy and fast response time across several iterations.

5. The system was successfully implemented using the Virtual Studio Code as the main IDE used in development of the system and integrating several computer vision libraries and a laptop, high definition camera, projector.

6. To evaluate the usage of the system for gesture recognition, a controlled environment was created and the system was found to be successful for real-time hand tracking for gesture interaction for presentation software.

7. Overall, the proposed system shows that the system was very responsive, user friendly, and novel to facilitate presentations through gesture control.

Recommendations

The following recommendations have been developed based on the outcomes of the Gesture-Driven Cursor Control Interactive Projection System:

1. Additional hardware of higher processing power of the used computer is required to make the system response time shorter and gestures are recognized faster to enhance the overall presentation process for the audience.

2. As it has been noticed, using the proposed system can increase the performance of the given mail clients for the sample users Thus, extending the usage scenarios with a large and multiple set of users may reveal additional opportunities of the system effectiveness.

3. More advancement may refer to adding other learned/augmentation modules for assistive learning or presentation to enable the structure more flexibility between academic or workplace situations.

4. Increasing the number of hand gestures will enable better recognition of hand movements while improving the gesture set. This could extend the interactivity range of the system and offer the users more states of control.

5. Comparing with other computer vision and gesture recognition libraries may allow finding better solutions for increasing the system's precision that can become a

problem in different lighting or when used by individuals with different hand sizes and movements.

6. Additional adjustments to the system could also be based on various experiments applied to the training process, for example, instead of using more commonly utilized data augmentation techniques or modifying such factors of the chosen model as number of layers, learning rate, etc.
7. Realizing an individual user's profile for monitoring one's development level and evolving interests would significantly enhance adaptability of the overall user interaction experience, especially in learning situations.

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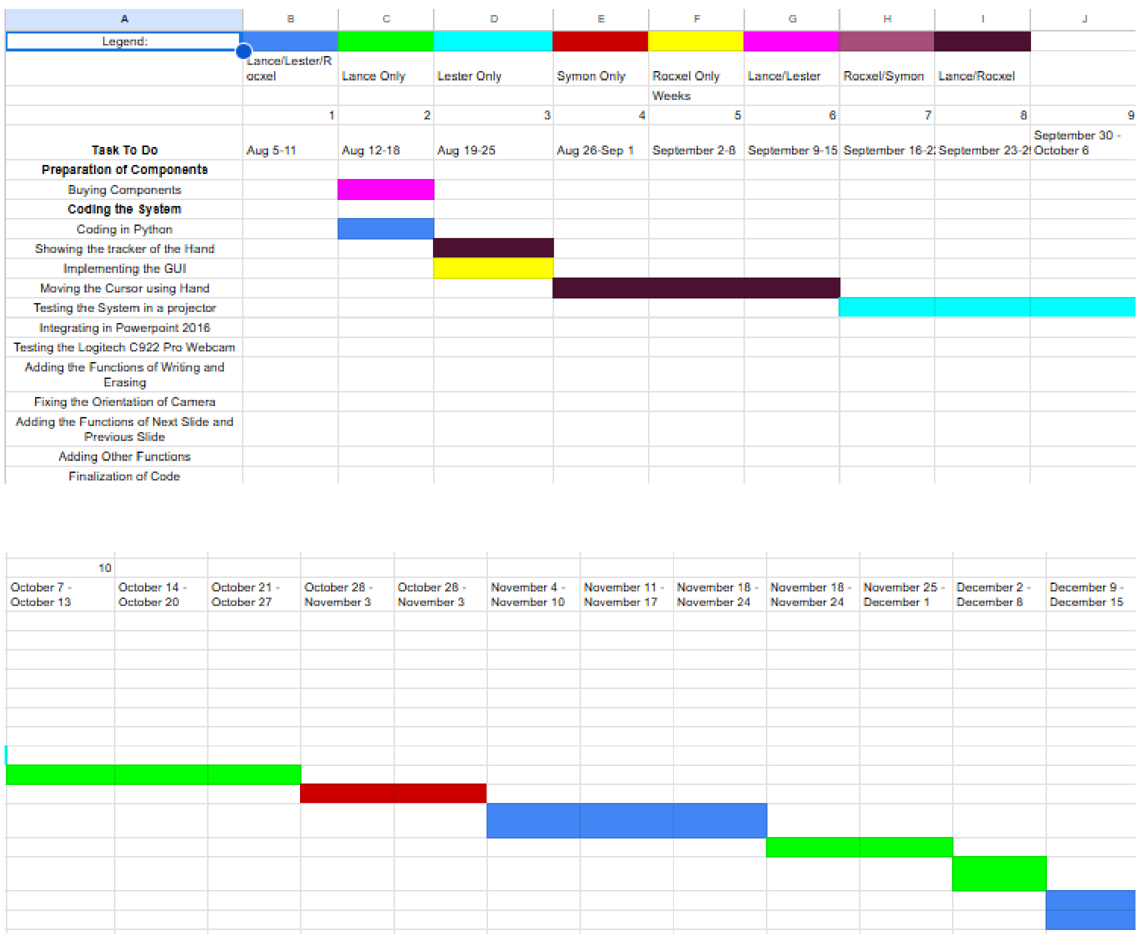
APPENDICES

GANTT CHART



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