Report on Final Phase of Project

"Portable Musical Instrument Device"

Submitted by

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August - December 2022

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FACULTY OF ENGINEERING
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CERTIFICATE

This is to certify that the Dissertation entitled

"Portable Musical Instrument Device"

Is a Bonafide work carried out by

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In partial fulfillment for the completion of 7th-semester course work in the Program of Study B.Tech in Electrical and Electronics Engineering under rules and regulations of PES University, Bengaluru during the period August 2022 – December 2022. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report. The dissertation has been approved as it satisfies the 7th-semester academic requirements regarding project work.

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1.
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DECLARATION

I Mayank Agrawal, hereby declare that the Capstone Project Phase - 2 entitled "***Portable Musical Instrument Device***" has been carried out by us under the guidance of Prof. Susmita Deb, Associate Professor, Dept. of EEE and submitted in partial fulfillment of the course requirements for the award of the degree of **Bachelor of Technology** in **Electrical And Electronics Engineering** of **PES University, Bengaluru** during the academic semester August – December 2022. The matter embodied in this report has not been submitted to any other university or institution for awarding any degree.

I Ishan Sinha, hereby declare that the Capstone Project Phase - 2 entitled "***Portable Musical Instrument Device***" has been carried out by us under the guidance of Prof. Susmita Deb, Associate Professor, Dept. of EEE, and submitted in partial fulfillment of the course requirements for the award of the degree of **Bachelor of Technology** in **Electrical And Electronics Engineering** of **PES University, Bengaluru** during the academic semester August – December 2022. The matter embodied in this report has not been submitted to any other university or institution for awarding any degree.

I K Sanjana Rao, hereby declare that the Capstone Project Phase - 2 entitled "***Portable Musical Instrument Device***" has been carried out by us under the guidance of Prof. Susmita Deb, Associate Professor, Dept. of EEE and submitted in partial fulfillment of the course requirements for the award of the degree of **Bachelor of Technology** in **Electrical And Electronics Engineering** of **PES University, Bengaluru** during the academic semester August – December 2022. The matter embodied in this report has not been submitted to any other university or institution for awarding any degree.

I Harshita M R, hereby declare that the Capstone Project Phase - 2 entitled "***Portable Musical Instrument Device***" has been carried out by us under the guidance of Prof. Susmita Deb, Associate Professor, Dept. of EEE and submitted in partial fulfillment of the course requirements for the award of the degree of **Bachelor of Technology** in **Electrical And Electronics Engineering** of **PES University, Bengaluru** during the academic semester August – December 2022. The matter embodied in this report has not been submitted to any other university or institution for awarding any degree.

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ABSTRACT

Music is a versatile art form that easily combines words, as in song, and with physical movement, as in dance. This style of art is becoming extinct in today's fast-paced society because it is difficult for musicians or artists who make music, to take their instruments about and seek inspiration. One thing successful musicians have to do is a lot of travel, and when you travel with an instrument, you increase its chances of getting damaged. The loss of an instrument, though, is about more than inconvenience or financial cost. It's about the loss of something that can feel like an integral part of a musician's being – it's their means of self-expression. Another option presented to them is to utilize a mobile application that would assist them in creating music on the go, but we all know that music is something that is felt by the soul. As a result, we present a solution to this difficulty for all artists by developing a gadget that allows them to play their keyboard as they usually would on any platform they want by simply putting our device on a stand.

We feel that by doing so, the art of good music composition will benefit. The device enables musicians to produce music at any time and in any location without having to carry their instrument and without losing the sensation of a real instrument. This product gives musicians the freedom to compose without worrying about transportation or loss of authenticity. It allows them to be as productive as possible while they're on the go.
This project was divided into two phases:

1. Device design and development involve assembling all of the necessary components in a logical order.
2. The device's logic was developed and uploaded to the microprocessor, which handled all of the components and determined the output.

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1. INTRODUCTION

1.1 BACKGROUND

India's recorded music industry is a little source note from an instrument. With the rise in tension and stress that we all face on a daily basis, the music industry will assist individuals in de-stressing and reducing stress. Although the industry is required in upcoming years, the artists are still stuck in old methods of music creation and there is a lack of innovation in the sector in order to increase the mobility of devices.

The Indian market capitalization of INR 1,068 crore for recorded music is only a fraction of what it was before the global financial crisis in 2008. However, this number is increasing year after year due to the rising demand for Indian music and its increasing popularity, showing an average growth of 40% year-on-year. With the increase in market size, there is a need for devices that can help them carry the experience of music creation with them wherever they go.

1.2 MOTIVATION / PROBLEM STATEMENT

Music is currently the only industry that has not been majorly affected by the Internet of Things. We all love the experience of listening to music. Our music experience has been enhanced with the help of technology. IoT is one such technology that is helping the music industry to make the user experience even more prolific. IoT is a modern technology that has grabbed the attention of geeks along with Artificial Intelligence and Machine Learning. We are living in an era where technology dominates. It is fascinating how humans have changed the traditional methods of doing things by taking the advantage of advancements in technology. The main goal of this project is to produce a gadget that allows artists to make music at any time and in any location. This may be performed by using microprocessors to display a keyboard's layout to aid our user with the keys. An image processing logic will be used to validate the key pressed. Once the pressed key is recognized by our image recognition logic, the respective keynote is played.

1.3 OBJECTIVES / DELIVERABLES

The objective of this project is to create a device that contains a handmade projector - made using a magnifying glass and a portable light source, a raspberry pi 2 B plus, a raspberry pi-camera module, and a power source to power all the devices. The projector will be emitting a keyboard-like structure on a surface, which will be used by the user to play the notes, the entire process will be in constant monitoring with help of a camera module to recognize the key being pressed and a sound will be played. A live demonstration or a video recording of the entire functionality will be presented.

1.4 MUSIC AND ITS IMPORTANT ATTRIBUTES

Music is an art form that combines rhythm and sound to form a functional melodic line. The music itself transcends time, space, and culture. Music can carry a mood without speaking any specific words. It can also be captured and recorded in a written universal language unique to any other art form. While creating music, numerous considerations must be made, including note sync, rhythm, and, most importantly, feel. Since our device helps in music creation using multiple electronic components, we have to make sure that all the components are in the proper rhythm for proper music generation.

The reaction time of a physical instrument to make a sound once a note is pressed is the most significant and least obvious component. Because of the mechanical connection between the many components within a keyboard, the reaction time is small, and we can't tell whether there was any delay in the output. When dealing with computers and other electrical components, we must ensure that our microprocessor's calculation time is nearly non-existent for seamless music composition.

Secondly, on a physical instrument, the note fades away in a specific manner, as indicated in figure 1. Due to the energy loss that resulted in the generation of sound, this may be simply performed in the case of mechanically coupled components.

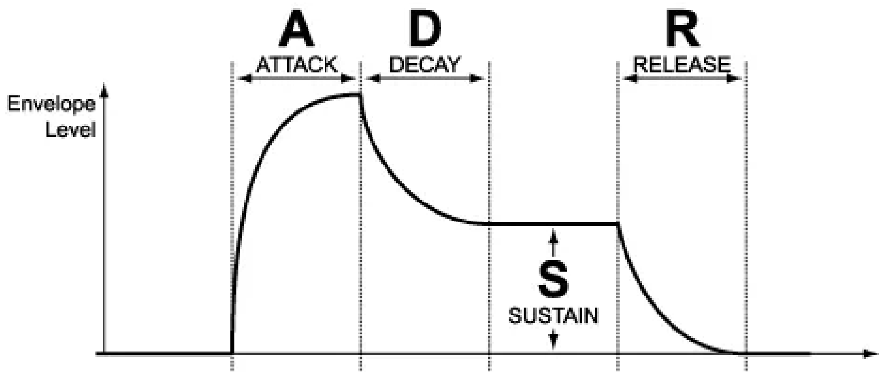


Figure 1: Decay of note

When the key is pressed, a sound is produced, which decays after a certain amount of time, as shown in the figure above. To make our project sound like a genuine instrument, we'll need to take a few steps to follow the following pattern.

2. LITERATURE SURVEY & EVALUATION OF VARIOUS METHODS

2.1 Paper [1]: Convolutional Neural Network (CNN) for Image Detection and Recognition *by Rahul Chauhan, Kamal Kumar Ghanshala, R.C Joshi*. Convolutional neural network models are used in this paper for image recognition and object detection on the MNIST and CIFAR-10 datasets, respectively. The implementation of models is addressed, and their accuracy is evaluated. In the realm of computer vision, deep learning algorithms have made significant progress. Deep Learning is a method of simulating the activities of the human cerebral cortex by using artificial neural networks with several hidden layers. Deep neural networks have layers that extract many features and hence provide multiple degrees of abstraction, it can't extract or work on numerous features as shallow networks can. By inputting a 2D image and convolving it with filters and producing output volumes, convolutional neural networks are a sophisticated deep learning algorithm capable of coping with millions of parameters and saving computing costs.

2.2 Paper[2]: Study and comparison of various image edge detection techniques by *Maini, R. and Aggarwal, H. A comparison* of several Image Edge Detection algorithms is offered in this research. MATLAB 7.0 was used to create the program. The Canny's edge detection technique has been found to outperform all of these operators in practically every circumstance. The photos indicate that under noisy situations, Canny, LoG (Laplacian of Gaussian), Robert, Prewitt, and Sobel perform better, respectively. The method of detecting and pinpointing sharp discontinuities in a picture is known as edge detection. Discontinuities are sharp shifts in pixel intensity that define the edges of objects in a picture. Edge detection using traditional approaches entails convolving the picture with an operator (a 2-D filter) that is designed to be sensitive to big gradients in the image while returning zero values in uniform regions.

Figure 2: Outputs of different edge detection models

2.3 Paper [3]: Mini-YOLOv3: Real-Time Object Detector for Embedded Applications *by Qi-Chao Mao, Hong-Mei Sun, Yan-Bo Liu, Rui-Sheng Jia*. Mini-YOLOv3 is a lightweight object detection approach intended to increase the performance of multi-scale object detection. In comparison to the original YOLOv3, it has a lower model size, fewer trainable parameters, and fewer floating-point calculations. Mini-YOLOv3 has a parameter size that is only 23% of that of YOLOv3 and achieves comparable detection accuracy while only taking 1/2 the time to detect. Mini-YOLOv3 obtains mAP-50 of 52.1 and AP: 0.5: 0.95 of 29.8 at 67 frames per second on the MS-COCO benchmark. This type of performance is quite competitive in embedded applications. Mini YOLOv3 is not recommended for use with niche models where large datasets are difficult to come by, so this version of Yolo was not chosen.

2.4 Paper [4]: Overview on Edge Detection Methods *by Waghule, D.R. and Ochawar, R.S.* this study examines a variety of edge detection approaches for picture segmentation. Various edge detection algorithms can be tested depending on the need for picture segmentation and application requirements. Methods based on wavelets are more accurate than others. Following a review of the literature on edge detectors, they have been divided into four categories: wavelet-based approaches, classical methods, FPGA-based methods, and other methods.

2.5 Paper [5]: Different Edge Detection Techniques *by Sun, X., Wei, Y., Liang, S., Tang, X. and Sun, J.* describes a new cascaded pose regression technique for 3D articulated objects in this work. It introduces a new feature parameterization for improved 3D invariance, as well as a hierarchical approach that maximizes the use of the articulated structure. For hand position estimation, it delivers state-of-the-art performance in terms of both accuracy and efficiency. There were two types of accuracy metrics utilized. The first is an average of per-joint error across all photos (in millimeters). The second component is the success rate or the percentage of good frames. The greatest joint error of a frame is judged good if it is less than a specified requirement (such as 20 mm). Before being applied to the hand, this strict criterion was first employed to evaluate the human location.

2.6 Paper [6]: Real-Time Object Detection and Tracking Using Deep Learning and OpenCV *by Chandan G, Ayush Jain, Harsh Jain, and Mohana*, in this paper, detection, and tracking using SSD and MobileNets-based algorithms are performed in a Python environment. Object detection includes identifying an object's region of interest within a class of images. Frame differencing, optical flow, and background removal are the methods. This is a technique that uses a camera to find and locate an object that is moving. Extraction of the characteristics from images and videos for security applications is used to define detection and tracking techniques. With the use of CNN and deep learning, features are retrieved. Classifiers are employed in the counting and categorization of images. Using the principles of deep learning, a YOLO-based method with a GMM model will provide good feature extraction and classification accuracy.

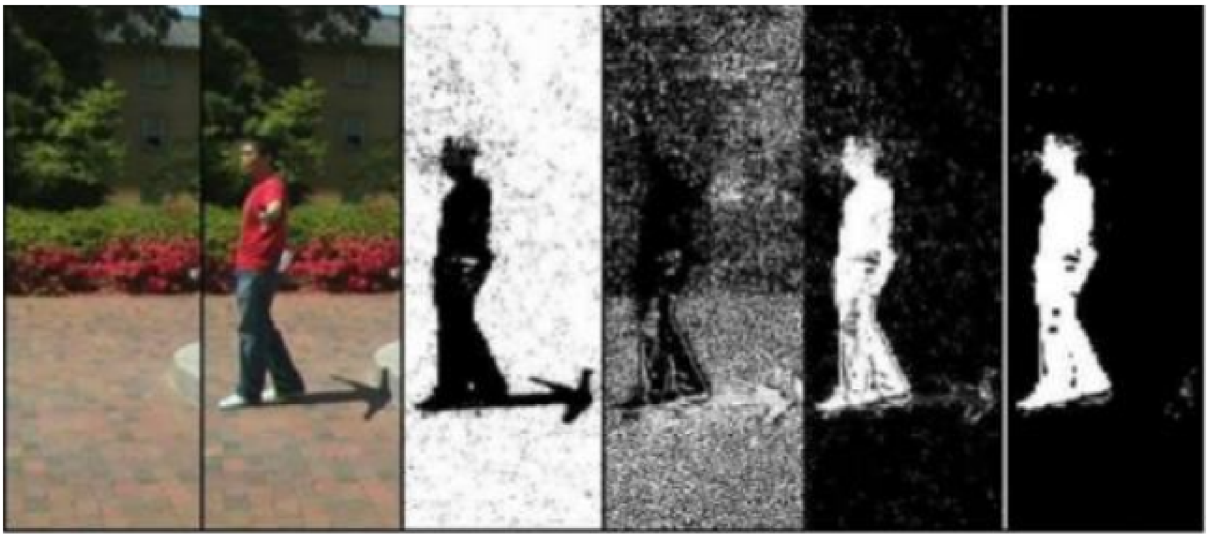


Figure 3: Detection of humans from background subtraction

2.7 Paper [7]: Multiple Object Detection using OpenCV on an Embedded Platform *by Souhail Guennouni, Anass Mansouri*. The variety of applications that use object detection has led to a lot of interest in this field. The development of object detection technologies has been fueled by the expansion of hardware and software processing capacity. This paper presents a created application for multiple object detection that uses OpenCV libraries. In order to detect objects using a cascade classifier, complexity-related factors were taken into account. Additionally, the profiling, porting, and comparison of the application to an embedded platform with the standard platform are shown. The proposed application implements real-time systems, and the findings show where object detection applications might be more complicated and where they might be easier.

2.8 Paper [8]: Tracking the Object Features in Video Based on OpenCV *by M. Michalko, J. Onuška, A. Lavrín, D. Cymbalák, O. Kainz*. The purpose of this work is to build and put into practice a method for tracking an object's characteristics, in this case, a human hand in a video. Current solutions need specialized gear, like a depth sensor, to operate. The technique proposed in this study seeks to acquire the attributes of the object only with the assistance of commercially accessible camera equipment. The intended system handles input data in real-time, reading it from a local file or a linked camera device. The solution itself acts as an interface between a person and a computer and enables control of other programs through analysis and processing of the image of a human hand. The answer is to deliver the results.

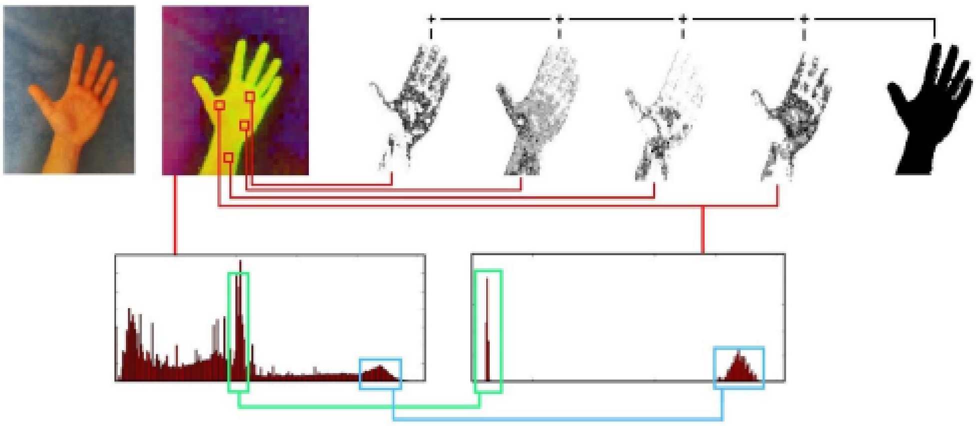


Figure 4: Mask creation process visualized

2.9 Paper [9]: Canny edge detection based on Open CV *by Zhao Xu, Xu Baojie, Wu Guoxin.* The most fundamental aspect of an image is its edge, which is the collection of pixels that abruptly ends. The grayscale has changed. Edge detection is a fundamental technique for identifying and segmenting images' edges based on grey discontinuous points. The Canny operator is a multiply-scale edge detection technique that John F. Canny invented in 1986 with the aim of discovering the best edge detection algorithm. These algorithms are widely utilized in the field of image processing and are continuously being refined and innovated. The Canny operator uses a threshold approach to select the edge locations, therefore the threshold value has a significant impact on the outcomes of picture edge detection. A major issue is how to achieve an accurate threshold and identify the best threshold. However, the impact of various thresholds on the outcomes of detection cannot be represented numerically. The excellent functionality of OpenCV makes it a fantastic tool for image processing, and its computer vision library is large enough to handle most graphic issues. Programming with the OpenCV algorithm library allows for the display of various results under various thresholds, making it simple to select the best threshold and advantageous for image edge recognition.

2.10 Paper [10]: Novel Image Processing Technique for Feature Detection of Wheat Crops using Python OpenCV *by Mamoon Rashid, Balwant Ram, Ranbir Singh Batth, Nazir Ahmad, Hatim M. Elhassan Ibrahim Dafallaa, Mohammed Burhanur Rehman.* The objective of this study is to remove sick leaf tissue from leaf images. For the purpose of distinguishing the sick portion of the leaf from the image of the leaf, the authors devised and implemented an image processing technique utilizing OpenCV. Images of wheat are processed using Foreground Extraction, Edge Detection, Color Filtering, and a combination of Edge Detection with Color Filtering. This cutting-edge method can make it easier to find infections in wheat plants. The device enables users to capture plant photos in a certain manner so that risks can be swiftly assessed. This research can automate the detection process without the need for human resources for feeding the dataset to the model, which is a much more reliable method, in addition to aiding humans in the detection of diseases in plants. In the end, this research will help automate agricultural processes more quickly and enable farmers to cultivate more land in a shorter length of time.

3. HARDWARE & SOFTWARE ARCHITECTURE

3.1 SCHEMATIC

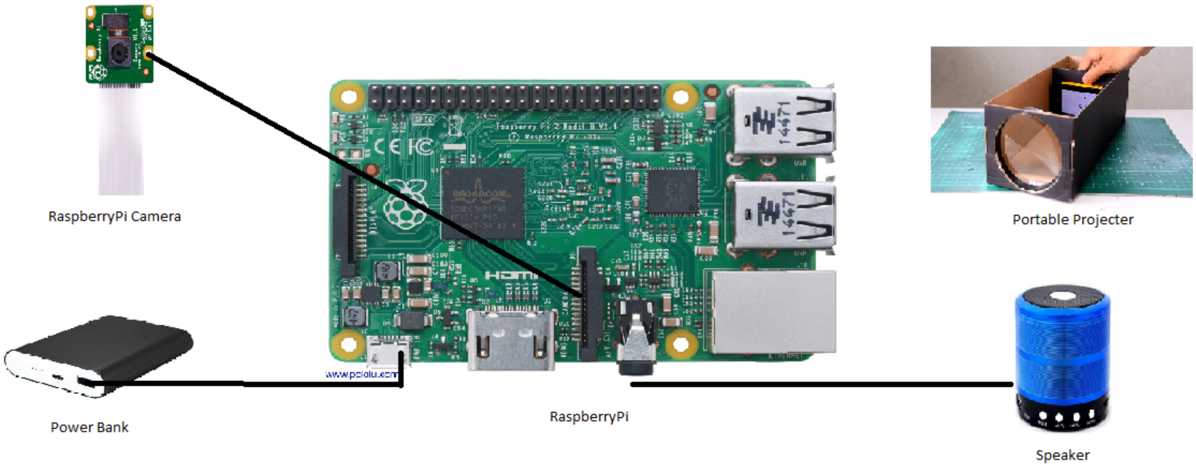


Figure 5: Hardware Schematic

Hardware used	Software used
RaspberryPi	OpenCV
RaspberryPi Camera Module	RaspberryPi OS
Bluetooth Speaker with audio jack	PuTTY
Power Bank	VNC Viewer
Portable Homemade Projector	

3.2 REQUIREMENTS OF PROJECT AND USE CASES

Edge detection is a fundamental technique for identifying and segmenting images' edges based on gray discontinuous points. Hence we require a good knowledge of working with python and its libraries like openCV and mediapipe and hence a knowledge of image processing and its implementation to get the desired output is needed. For the hardware, we need portable devices for the device to be more compact and handy, therefore avoiding the usage of bulky equipment. We have dealt with a few image extraction and image processing algorithms like the canny algorithm, ultrametric contour map, and minEnclosingCircle.

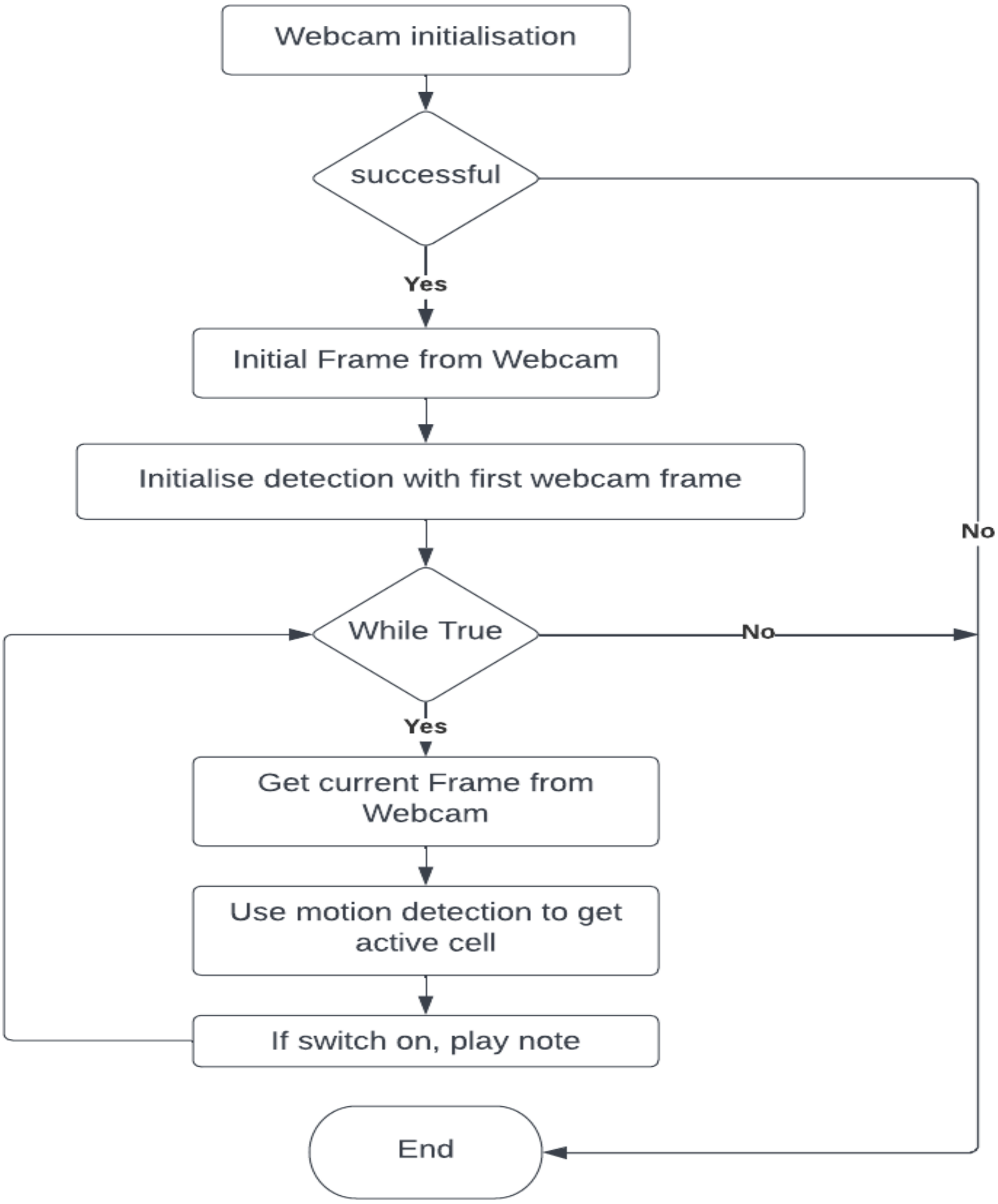
3.3 HARDWARE ARCHITECTURE

Firstly, we have used a power bank/regular power supply to provide a power source to the Raspberry Pi. We have made a portable homemade projector which has been designed according to our use case. The projector has been made using a convex lens, a cardboard box that has been black coated inside and a light source has been fitted. We have used a Raspberry Pi camera module which is connected to our Raspberry Pi. The Raspberry Pi Camera Board is a custom-designed add-on module for Raspberry Pi hardware. It attaches to Raspberry Pi hardware through a custom CSI interface. The sensor has a 5-megapixel native resolution in still capture mode. In video mode, it supports capture resolutions up to 1080p at 30 frames per second. The camera module detects the image of the hand and the piano tiles image which is then passed to the Raspberry Pi which is taken as an input and the image processing technique is applied to it and we obtain the sound of the key that is being pressed as the output through the speaker.

3.4 SOFTWARE ARCHITECTURE

Initially, the frame is captured to find out the coordinates of the keyboard projected, this initialization is made in order to fix a frame in consideration so that in upcoming frames only the area of interest can be looked upon for faster implementation. Parameters like the position, center, and width of the keyboard are stored. The keyboard is divided into 7 equal partitions each representing a note. The centers of each note and position are also recorded during the initialization phase. In all the subsequent frames recorded by the camera module, the area of the keyboard - recognized during the initial frame, is only taken into consideration. The image processing logic determines the difference in the initial frame and the subsequent or the current frame, the area of interest is then taken into consideration to find the note that was pressed using the position of the finger that is detected.

3.4.1 SOFTWARE FLOW CHART



3.5 DESIGN OF THE PORTABLE PROJECTOR

In order to make the project more portable, a portable projector has been designed. This is a basic Do-It-Yourself Projector that uses the concept of simple physics and operates on the basis of refraction using convex lenses. Initially, a screen was placed behind the lens which contained the image of a keyboard to be projected. The drawback that was faced with this method was that the image obtained on the screen was not sharp enough for the Pi camera to detect it. Therefore, an alternative was proposed in which a beam of light is projected onto the convex lens of the projector and the image that we obtain on the screen is the image of the keyboard. This image is obtained as a set of fringes that was attached to the convex lens. These fringes were made using strips of paper that covered the surface of the convex lens in a fringed pattern. The drawback was successfully overcome and the image of the keyboard was enhanced and sharpened and therefore, easily detectable to the Pi camera. Additionally, we added a battery-operated bulb using a switch that can be accessed using a basic ON/OFF switch which makes the projector more advanced and portable.

Construction:

We made the body of the projector using a cardboard box. The convex lens used is a basic magnifying glass which is attached to the cardboard box in order to project the beam of light on the screen. We also added strips of paper on the surface of the magnifying glasses to provide a fringing effect on the screen to replicate a keyboard surface. Now, to produce a beam of light, we are using a battery operated bulb which operates using ON/OFF switch.

Figure 6: Homemade projector

4. RESULTS AND DISCUSSIONS

4.1 INITIAL PHASE

The literature survey has been completed and the required knowledge has been obtained to move ahead with the implementation part. The submission included the software implementation, written in Python. The implementation can be considered as a proof of concept and the idea is feasible in the given time frame. We were able to generate the sound of a key pressed using a simple image processing code. That takes input from a webcam and checks for the key that was pressed, and we can hear the sound corresponding to that note.

For now, the implementation does not take into consideration the noise that is present in the frame except the keyboard area, the duration of the key pressed, considers each frame as a different image, and decides if the key has been pressed or not.

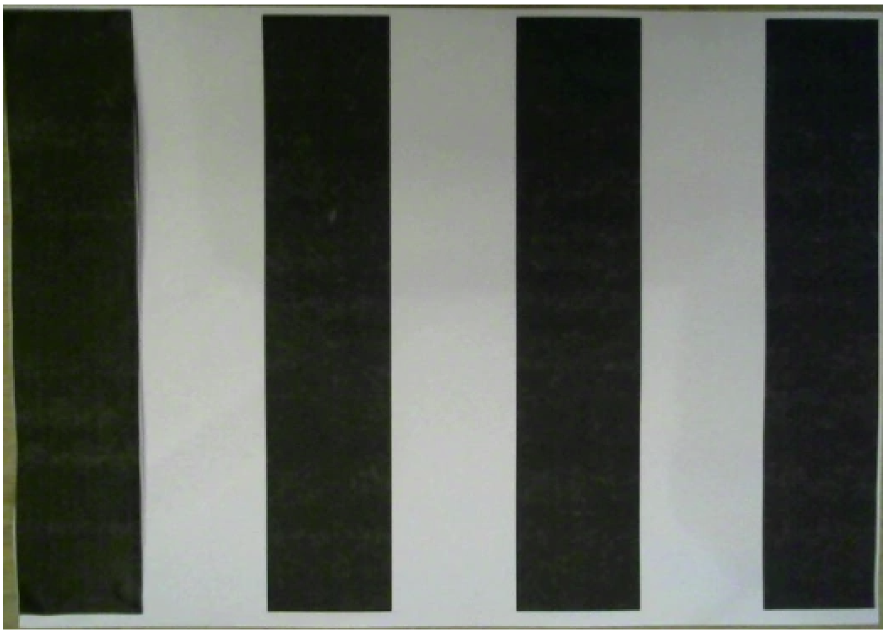


Figure 7: The input key layout

The above image was used as the base input for the keyboard layout, it has 7 keys of the same width. For now, we used a hand-drawn keyboard layout due to the unavailability of a projector. For pressing any key we need to place a finger on top of it, after performing image processing we get an output of just the finger as shown in Figure 5.

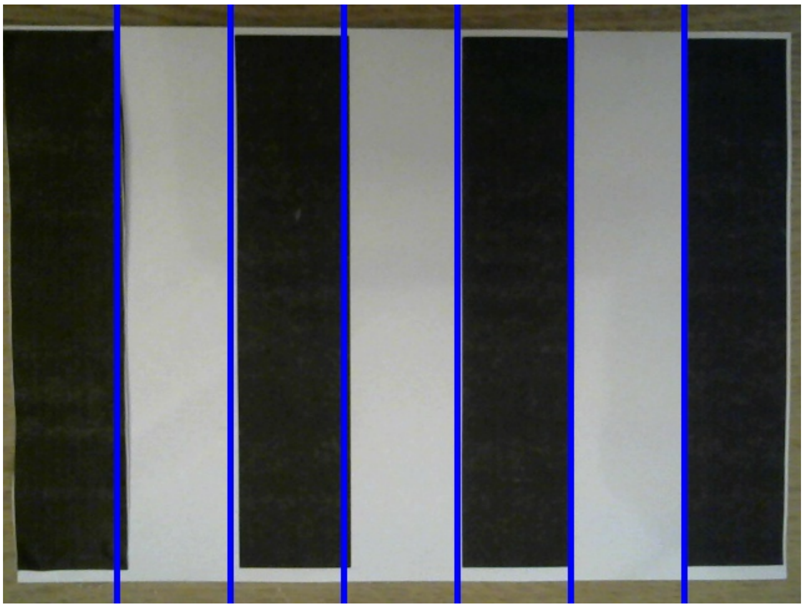


Figure 8: Segmented input key layout

By pointing the webcam at the input keyboard layout, we split the resultant image into seven cells.

Figure 9: The difference obtained after image processing

This image helps us know what section of the image the finger was placed on and we then map it to the note that corresponds to the key which is pressed. The note is then played using the Bluetooth speaker connected to the laptop.

4.2 Final Phase

After testing and trying different algorithmic approaches, we have finally developed our own procedure. We start by lighting up our projector which projects the image of the piano tiles on a screen in a dark environment. We start our Raspberry Pi camera which has been positioned to focus on the piano tiles image and thus the input image without any fingers is taken. Now we start pressing a keynote and corresponding to the key, the respective note sound is being played.

4.2.1 Initialization Procedure

Coming to the working procedural part, when we switch on the Raspberry Pi camera, the image of the piano tiles is taken and fed to the main.py file. The initial frame is converted to greyscale and Canny edge detection is applied to find the edges of the keynotes being projected.

The list of edges is then iterated in order to find all contours, which are stored. These contours are then used to find a circle that can fit all the keynotes inside it and the center being the center of the keyboard. Taking the diameter of this circle as the total width of the keyboard, 7 equal vertical partitions are made and the center of all the partitions is marked.

By doing the above-mentioned process the area of interest is defined and all the subsequent processing takes place only in the area of interest, therefore, reducing the computation required in the upcoming frames.

Figure 10: Piano Image from the projector

Figure 11: Segmented input key layout and finger detection

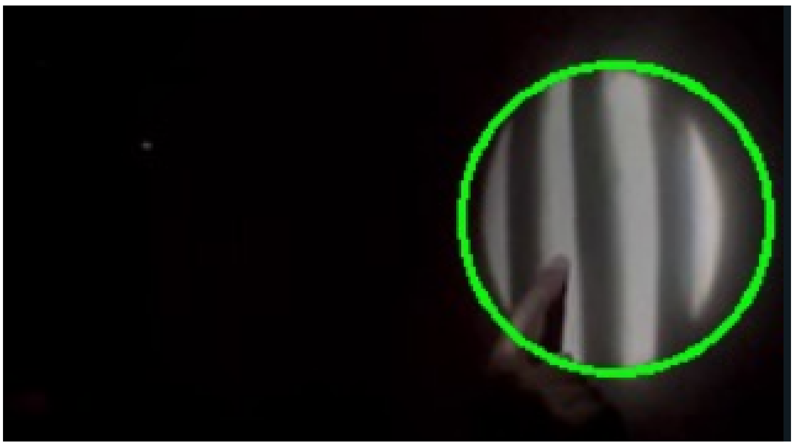


Figure 12: Area of interest recognition

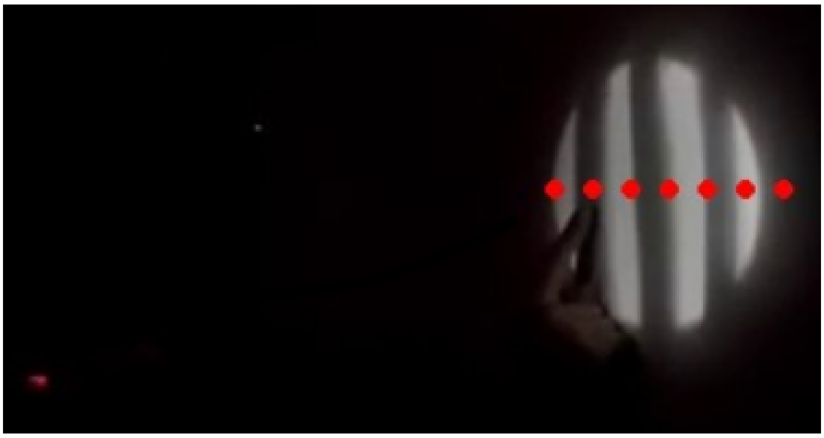


Figure 13: Identifying each node

4.2.2 Subsequent Process

Once the initialization process is complete, the subsequent frames are taken from the pi-camera module. These images are now converted to grayscale and canny edge detection is again implemented on the grayscale image. The edges received are then checked for overlap with the area of interest, the circle containing the keyboard, and the key pressed is determined by finding the distance of new edges with the center of keys that was determined during the initial phase. Once the key is recognized, a .wav extension file audio file corresponding to the note is played. The program does not wait for the audio file to complete playing, the audio output happens parallelly to key recognition

5. CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

Our project aims to create a device that can replicate a physical musical instrument, focused on a keyboard, on any surface with the use of a camera, projector, speaker, and image processing algorithm. The current implementation that has been discussed in this report has a very fundamental solution to this problem, and more features and smoothness needs to be added to the audio output. The project is implemented in Python3 and is tested on a Raspberry pi 2 B plus model by connecting all the components, like the raspberry pi-camera, speaker, etc logically. The audio outputs have been smoothened and follow the pattern as shown in figure 1.

We have worked on the delay and accuracy of our model and have learned a lot from testing and running it in our initial phase. We discovered that the Canny edge detection algorithm was working in a better way in our use case for accuracy concerns. We have worked and calibrated the delay to match it as close as possible to a real keyboard instrument.

We have also compared the working of the code on two versions of Raspberry Pi, (model 2 B plus and Model 3 B plus) and concluded that the latest version of Raspberry Pi gives a smoother and better working, and is more convenient to operate. We have the task manager snippets of our code running on both RaspberryPi 2 and RaspberryPi 3 to compare the computational potential of our code on both of these devices. We observed that on RaspberryPi 3 model B plus the CPU usage when we ran the code was around 70% generally but the CPU usage on RaspberryPi 2 model B plus was around 90 to 95% on average.

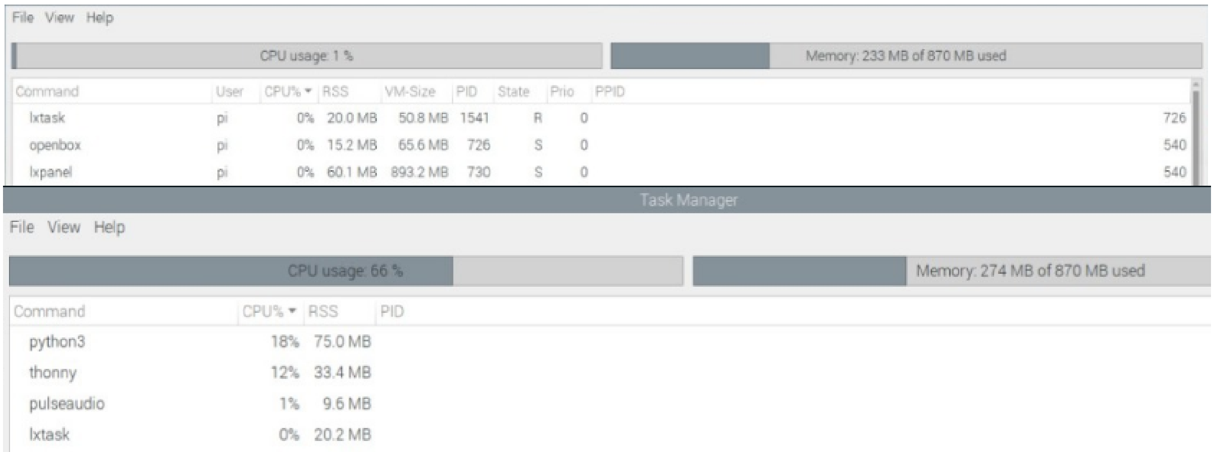


Figure 14: The CPU usage when the code is not implemented v/s when it is implemented respectively on RaspberryPi 3

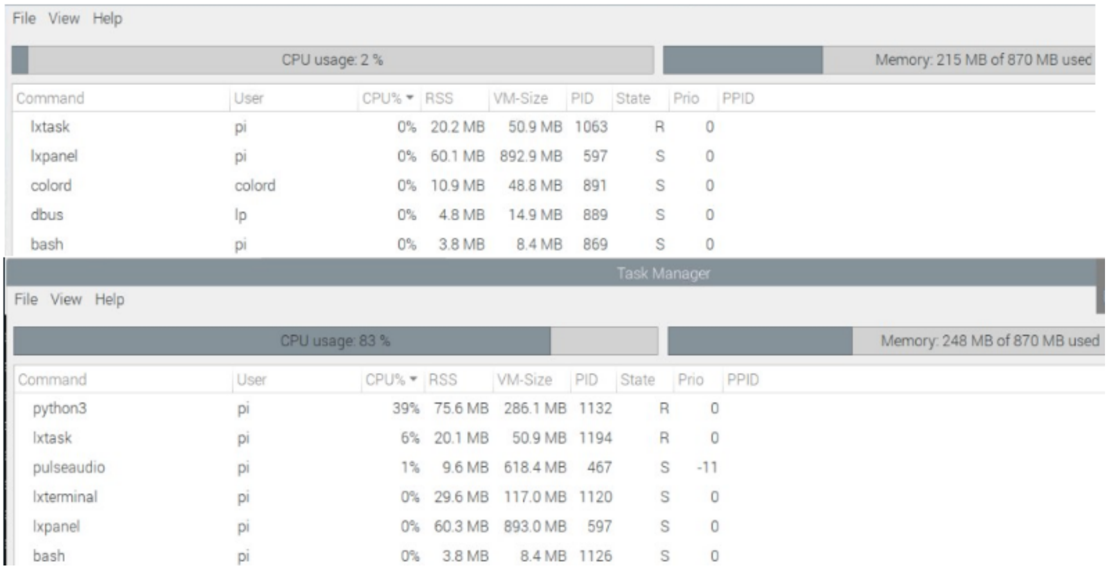


Figure 15: The CPU usage when the code is not implemented v/s when it is implemented respectively on RaspberryPi 2

5.2 Future Scope

Current project focuses on implementing a basic keyboard instrument for music generation with a homemade projector that can only emit keyboard patterns. More instruments can be added to functionality so that the user can change and play the instrument of choice by using only this one device.

The current implementation takes only 7 keynotes into consideration which can be further extended to accommodate various other pitches to the instrument; an interactive smart projector would help in order to make this possible.

As music is often analyzed by listening to the tune after it is composed, a self-record feature and integration with the mobile app would help creators to go back and listen to the tune and even share it with others.

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