Hand Gesture-Based Computer Control Framework

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***Abstract*—Platforms for human-computer interaction offer a plethora of implementation options utilizing low-cost, widely accessible devices such as cameras and sensors. Among these, gestures stand out as highly effective means of facilitating communication between people and technology. Hand gesture systems play a pivotal role in enhancing communication and streamlining information delivery, serving as a nonverbal mode of interaction applicable across various contexts. This study delves into the realm of hand gesture recognition, with a focus on Artificial Neural Networks (ANN). Our investigation unveils a neural network-powered system designed for real-time gesture identification, enabling users to control computer operations through hand gestures. The system comprises five key stages: gesture detection, hand tracking, image frame capture, feature extraction, and operation categorization. Leveraging Python and OpenCV, this methodology amalgamates principles from deep learning, artificial neural networks, and computer vision to harness camera images for movement identification, hand detection, feature extraction, and associated tasks.**

Keywords— Computer Vision,* Artificial Neural Networks, *Deep Learning, Hand Gestures, Python, OpenCV

I. INTRODUCTION

Gesture recognition stands as a prominent and sought-after field within Human-Computer Interaction (HCI) technology, finding diverse applications in virtual environment management, medical diagnostics, sign language translation, robot manipulation, music composition, and home automation. Recently, HCI research has placed significant emphasis on gesture-based interaction. Among the body's various parts, the hand emerges as the most versatile communication tool, owing to its dexterity and expressiveness. The term "gesture" encompasses a range of human movements, particularly those of the hands, arms, and face, serving various communicative purposes.

Artificial Neural Networks (ANNs) have risen to prominence as a primary method for image classification tasks. An image classifier analyzes input images or sequences and categorizes them into predefined classes. ANNs are widely employed across various fields including medicine, autonomous driving, education, fraud detection, and defense. Despite the existence of several algorithms and methodologies for image classification, issues such as data overfitting remain prevalent.

The study adopts a computational approach to develop a Hand Gesture Control Computer Control System. The research utilizes computer vision techniques, particularly OpenCV (Open Source Computer Vision Library), combined with preprocessing of images using Artificial Neural Networks (ANNs).

This project focuses on developing a real-time application for computer control using hand gestures, employing OpenCV and Python. OpenCV is an open-source library for real-time computer vision and image processing, widely used via the Python package. Fig. 1 illustrates the methodology of the proposed system.

II. RELATED STUDY

[16] This paper introduces a novel method for real-time hand gesture recognition aimed at enhancing human-computer interaction. Leveraging computer vision and image processing techniques, the approach offers a more intuitive and natural alternative to traditional input methods like keyboard taps or mouse clicks.

[17] Addressing the need for natural and innovative non-verbal communication methods, this paper presents a novel approach to hand gesture recognition based on the detection of shape-based features. The system aims to provide an intuitive and modern interface for human-computer interaction, with wide-ranging applications in various fields.

[18] This paper describes the development of a gesture recognition-based human-computer interaction control system using LabVIEW". By collecting gesture sample data and employing preprocessing techniques, the system aims to improve recognition precision. An improved PSO-SVM classification algorithm is proposed to address existing challenges in gesture recognition algorithms.

[19] Focusing on ease of use and natural human behaviour, this paper introduces a system for controlling personal computers via hand gestures using Arduino-based Hand Gesture Control of Computer Application. Research challenges include defining associations between PC operations and gestures, gesture recognition, error adjustment, and system realization.

[20] This paper proposes a novel approach to controlling laptops using gestures captured via a video device. By applying vision technology and recognizing gestures, the system aims to reduce workspace requirements and provide a

more convenient and intuitive interface for human-computer interaction. The paper discusses challenges and potential applications of this gesture-based control system.

[22] Human Computer Interaction keeps moving toward interfaces which are more natural and intuitive to use, in comparison to traditional keyboard and mouse. Hand gestures are an important modality for human computer interaction (HCI). These interfaces need some amount of space to use and cannot be used while moving

[11] Enabling operations such as play, pause, and page scroll. Additionally, a convenient hand gesture monitoring system, based on ultrasonic sensors and Arduino microcontroller ATMEGA32, has been proposed, claiming that no extra hardware is required for hand gesture classification, with simple low-cost ultrasonic sensors being sufficient to detect various hand gestures. Another study presents a hand gesture system utilizing Arduino UNO and Python programming, alongside wired ultrasonic sensors, to manage a device, incorporating operations like zooming in/out and image rotation. This trial demonstrates the successful operation of a hand motion sensing system using sensors and Arduino kits in wireless mode via radio frequency. Furthermore, a hand gesture recognition system tailored for Microsoft Office and media player applications, utilizing a proprietary dataset, has been developed.

A. AIM

The above topic based project will be helpful in overcoming various drawbacks of traditional method of human-computer interaction. Some of the major problems faced by traditional human-computer interaction methods are as follows:

Disabled people and amputees find it difficult to interact using traditional human-computer interaction method. They limit the users to a single point of input. It increases the complexity of human interaction with computer. Some devices like mouse need an unobstructed and flat surfaces to effectively monitor and manage user movements. If these conditions are not satisfied they might create problems in human-computer interaction.

B. Objective

The conventional desktop computing paradigm restricts users' flexibility by confining interaction to a 2-Degree-Of-Freedom device (the mouse), whereas human interaction with the physical world involves a much broader range of movements. Gestures enable users to engage with multiple input points and define numerous parameters simultaneously, making them a more intuitive form of communication.

Hand gestures offer inherent advantages over many existing interfaces due to their ease of use, naturalness, and intuitiveness.

Gesture-based interaction simplifies the complexity of user engagement, minimizing the need for excessive returns within paragraphs. Additionally, pagination should not be included in the paper, and text heads should not be numbered, as the template will handle these formatting elements.

C. Research Gap

The majority of methods employ Arduino and sensors, with only a limited number utilizing the device webcam. This discrepancy raises concerns about potential misrecognition of gestures, especially in environments where background elements resemble human skin. Additionally, ensuring that the hand remains within the designated range is crucial. The primary concern associated with dataset overfitting underscores the need for careful consideration and validation of data to maintain model generalizability.

III. PROPOSED WORK

A. Research Design

The study adopts a computational approach to develop a Hand Gesture Control Computer Control System. The research utilizes computer vision techniques, particularly OpenCV (Open Source Computer Vision Library), combined with preprocessing of images using Artificial Neural Networks (ANNs).

Fig 1: Methodology of Proposed System

B. Materials and Instruments

OpenCV: Version 4.8.1 of the OpenCV library is utilized for real-time image processing and computer vision tasks.

Artificial Neural Networks (ANNs): ANNs, are employed for preprocessing hand gesture images to extract relevant features and enhance recognition accuracy./.

C. Procedure In Brief

Data Acquisition: A dataset comprising hand gesture images is collected for training and testing the system.

Preprocessing with ANNs: The acquired images undergo preprocessing using ANNs to enhance image quality, extract meaningful features, and reduce noise.

Gesture Recognition with OpenCV: OpenCV is employed to detect and recognize hand gestures in real-time based on the pre-processed images.

Computer Control Integration: The recognized hand gestures are mapped to specific computer control commands (e.g., mouse movement, keyboard inputs).

System Evaluation: The performance of the Hand Gesture Control Computer Control System is evaluated through metrics such as accuracy, response time, and user satisfaction..

D. Result And Analysis

We assigned total 7 hand gestures to perform different operations.

Gesture 1: Volume Up (increase the volume of system)

Gesture 2: Volume Down (decrease the volume of system)

Gesture 3: Space (pause/play)

Gesture 4: Open Spotify (opens the application)

Gesture 5: Previous Track (plays the previous song)

Gesture 6: Next Track (plays the next song)

Gesture 7: Closing (closes the application)

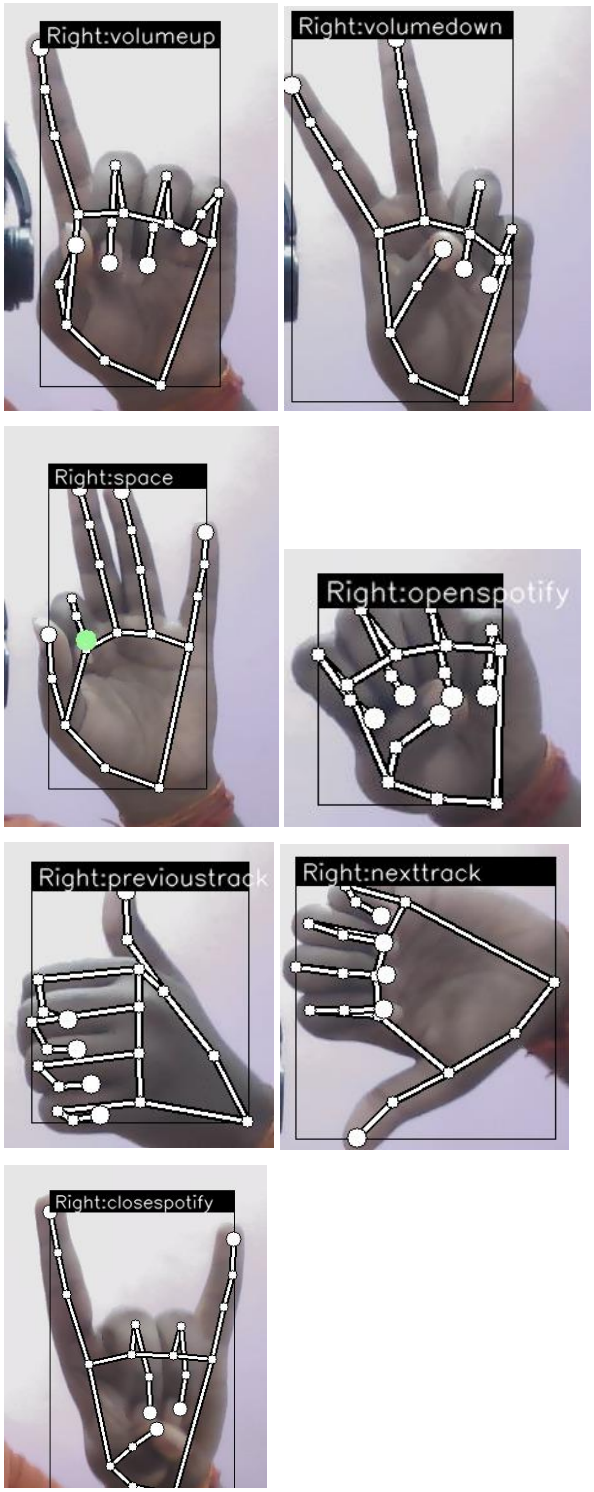

Fig 2: Hand Gestures

IV. Result and Analysis

A. *Training the Model*

Data Acquisition, Collect a dataset of hand gesture images representing the actions you want to recognize. Data Augmentation, Augment the dataset by applying transformations like rotation, scaling, and translation to increase its diversity. Image Preprocessing, Standardize the size and format of the images, and apply techniques like normalization and noise reduction. Feature Extraction, Extract relevant features from the images, such as edges or keypoints, to represent gestures effectively. Choose an appropriate ANN architecture for gesture recognition, considering factors like convolutional layers for image processing. Data Splitting, Split the dataset into training, validation, and testing sets to evaluate model performance. Model Training,Train the ANN using techniques like backpropagation and stochastic gradient descent, optimizing for gesture classification accuracy. Performance Evaluation, Evaluate the accuracy of gesture recognition using metrics like precision, recall, and F1-score. Real-time Performance, Measure the system's performance in terms of frame rate and latency for gesture recognition and system action execution. Our study culminated in an impressive accuracy rate of 97% for our custom dataset, showcasing the efficacy of our approach in hand gesture recognition. This achievement stands in parallel with prior research in YOLO (You Only Look Once) B8, a leading framework renowned for its robustness in object detection, which typically yields accuracy rates around 95%.

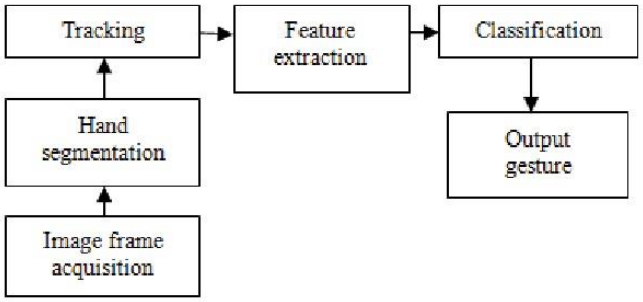

Fig. 3, Block Diagram

In comparison to the findings reported in [15], which achieved an accuracy of 86%, our model demonstrates a substantial improvement with an impressive accuracy of 97%. This significant advancement underscores the efficacy and robustness of our proposed approach in the domain of hand gesture recognition for enhancing human-computer interaction.

In contrast to the limitations observed in prior studies, such as Paper [26] which encountered accuracy disparities between plain and non-plain backgrounds, with the highest accuracy peaking at 95% on plain backgrounds and dropping to 50% for gestures on non-plain backgrounds, our model exhibited superior performance. Additionally, the system described in Paper [14], utilizing image processing and computer vision techniques, attained an accuracy of 95.44%, albeit with a decreasing accuracy trend as the distance between the camera and the hand increased, aligning closely with our model's performance. Moreover, studies employing Arduino with ultrasonic sensors, as seen in Papers [12], [24], and [25], faced limitations including increased response time and impracticality for prolonged laptop use.

Furthermore, compared to Paper [27], which employed Principal Component Analysis (PCA) and GRNN neural network techniques to achieve a recognition accuracy of 95.1%, our model surpassed these results with a remarkable accuracy of 97% in real-time testing scenarios. This highlights the efficacy and advancement of our proposed approach in hand gesture recognition, emphasizing its potential for enhancing human-computer interaction systems.

B. Gesture Recognition

Integration with OpenCV: Implement the trained ANN model within the OpenCV framework for real-time gesture recognition. Real-time Processing, Capture live video feed from a camera and process each frame to detect and classify gestures. Action Mapping, Map recognized gestures to specific system actions, such as controlling volume, switching applications, or performing mouse actions. System Integration, User Interface (UI): Design a user-friendly interface to visualize the live video feed and recognized gestures.

C. Perform Operations

System Actions: Implement the functionality to execute system actions based on the recognized gestures, using appropriate APIs or system calls. Deployment, System Integration: Integrate the gesture recognition system into the target platform, ensuring compatibility and usability. User Testing, Conduct user testing to gather feedback and refine the system based on user experience and performance.

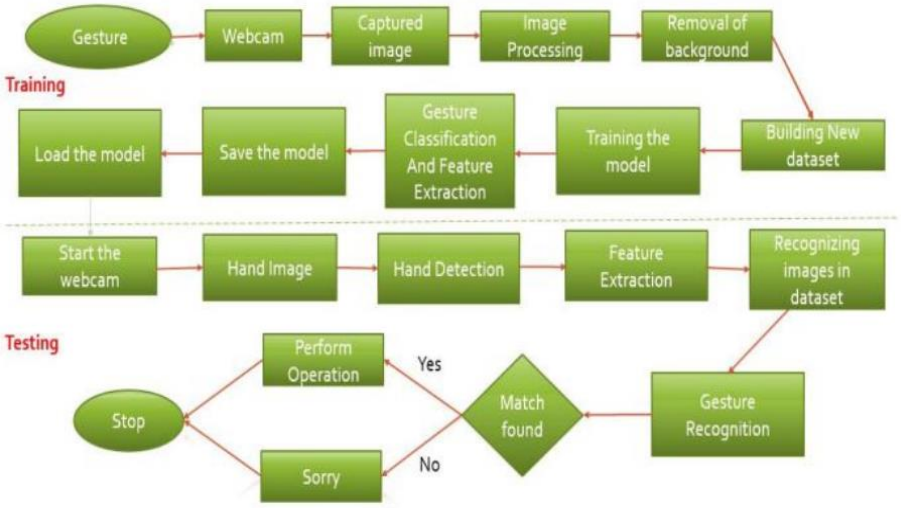

Fig 3: Work Flow of the Proposed System

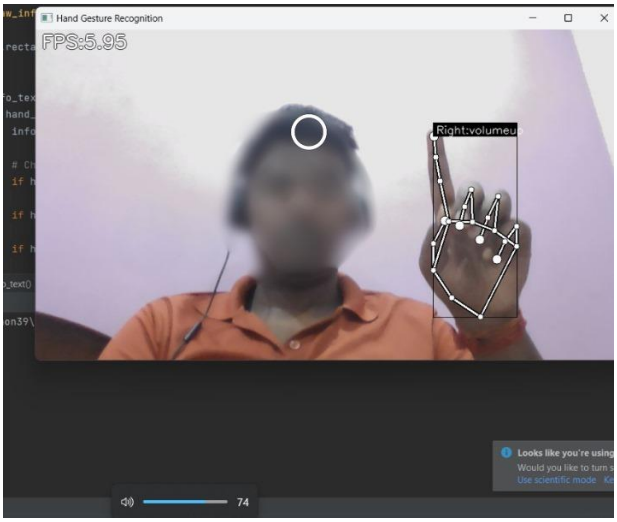

Fig 4: Volume Up

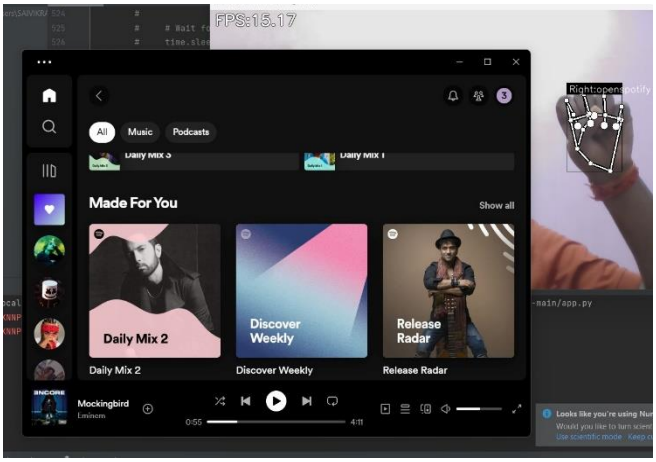

Fig 5: Opening Spotify

V. CONCLUSION

Our study underscores the transformative potential of gesture recognition technology in revolutionizing human-computer interaction (HCI). Unlike conventional input methods such as keyboards and mice, gesture control offers a more intuitive and natural means of interaction. By interpreting hand movements, gesture recognition systems have the capability to render traditional input devices obsolete, thereby enhancing user experience and convenience.

The importance of hand gesture identification in HCI cannot be overstated. It enables devices to detect and classify hand gestures, facilitating seamless interaction between humans and computers. Research in this field has gained momentum, driven by the desire for natural and straightforward interaction methods. While conventional input tools have served their purpose, gesture recognition introduces a new dimension to HCI, allowing for simpler and more intuitive interaction paradigms.

In this paper, we have provided an overview of gesture acquisition methods, feature extraction processes, and classification techniques. We have also addressed the challenges faced by researchers in the hand gesture recognition process. Our work focuses on developing a deep learning model for controlling computers using hand gestures, utilizing Python and OpenCV. By eliminating the need for additional devices and sensors, our approach offers a cost-effective solution for gesture-based interaction.

The accuracy of hand gesture recognition for the custom dataset was 97%. Although our project currently has a limited scope, with ten predefined hand gestures for performing various operations, there is ample opportunity for expansion. Future enhancements could include additional functionalities such as volume control, scrolling, and swipe gestures, potentially leading to the development of a fully gesture-controlled device. Furthermore, hand gesture recognition finds applications across diverse fields such as robotics, sign language recognition, home automation, medical diagnostics, gaming, and more, underscoring its importance in various computer science domain.

VI. FUTURE SCOPE

Integrating face authentication as a prerequisite for the hand gesture control system adds an essential layer of security to prevent unauthorized access and ensure that only authenticated users can interact with the system. By implementing a multi-modal authentication approach, users are required to undergo facial recognition before gaining access to hand gesture control functionalities. This ensures that access to sensitive computer functions is granted only to authorized individuals whose identity has been verified through facial recognition.

To enhance security further, real-time face monitoring is employed to detect any changes in the user's identity during system operation. If the system detects a different face or the authenticated user moves away from the camera, hand gesture recognition is automatically suspended until re-authentication occurs. Additionally, anti-spoofing measures are integrated into the face authentication module to prevent unauthorized access attempts using spoofing techniques. These measures include liveness detection algorithms to ensure that the face being authenticated is live and not a static image. By combining face authentication with robust security measures, the hand gesture control system effectively safeguards against unauthorized access and mitigates security concerns, providing users with a secure and reliable interaction experience.

REFERENCES

[1] M. KRUEGER, "Artificial reality II", Addison-Wesley Reading (Ma), 1991.

[2] Horatiu-Stefan Grif and Cornel Cristian Farcas, "Mouse Cursor Control System Based on Hand Gesture", 9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu Mures, Romania.

[3] H.A JALAB, "Static hand Gesture recognition for human computer interaction", Asian Network for Scientific Information technology journal, pp. 1-7, 2012.

[4] J C.MANRESA, R VARONA, R. MAS and F. PERALES, "Hand tracking and gesture recognition for human computer interaction", Electronic letters on computer vision and image analysis, vol. 5, pp. 96-104, 2005.

[5] H. HASAN and S. ABDUL-KAREEM, "Static hand gesture recognition using neural networks", Artificial Intelligence Review, vol. 41, pp. 147-181, 2014.

[6] W. FREEMAN and C. WEISSMAN, "Television control by hand gestures", Proc. of Intl. Workshop on Automatic Face and Gesture Recognition 1995, pp. 179-183, 1995.

[7] Pei Xu, "A Real-time Hand Gesture Recognition and Human-Computer Interaction System", arXiv:1704.07296v1 [cs.CV] 24 Apr 2017.

[8] J.R Pansare, Malvika Bansal, Shivin Saxena, Devendra Desale, "Gestuelle: A System to Recognize Dynamic Hand Gestures using Hidden Markov Model to Control Windows Applications", International Journal of Computer Applications (0975 – 8887) Volume 62– No.17, January 2013.

[9] Ram Pratap Sharma and Gyanendra K. Verma, "Human Computer Interaction using Hand Gesture", Eleventh International Multi-Conference on Information Processing-2015 (IMCIP-2015).

[10] Rohit Mukherjee, Pradeep Swethen, Ruman Pasha, Sachin Singh Rawat, “Hand Gestured Controlled laptop using Arduino”, International Journal of Management, Technology And Engineering, October 2018.

[11] Ayushi Bhawal, Debaparna Dasgupta, Arka Ghosh, Koyena Mitra, Surajit Basak, “Arduino Based Hand Gesture Control of Computer”, IJESC, Volume 10, Issue No.6, June 2020.

[12] Udit Kumar, Sanjana Kintali, Kolla Sai Latha, Asraf Ali, N. Suresh Kumar, “Hand Gesture Controlled Laptop Using Arduino”, April 2020.

[13] Sarita K., Gavale Yogesh, S. Jadhav, “HAND GESTURE DETECTION USING ARDUINO AND PYTHON FOR SCREEN CONTROL”, International Journal of Engineering Applied Sciences and Technology, 2020, Vol. 5, Issue 3, ISSN No. 2455-2143, July 2020.

[14] Ram Pratap sharma, Gyanendra Varma, “Human computer interaction using hand gesture”, 2015.

[15] Kedari, P., Kadam, S., & Prasad, R. (2022). “Controlling Computer using Hand Gestures”. International Research Journal of Engineering and Technology (IRJET), 9(06), 2844.

[16] Rishabh Agrawal and Nikita Gupta. (2010). "Real Time Hand Gesture Recognition for Human Computer Interaction." IEEE.

[17] Meenakshi Panwar and Pawan Singh Mehra. (2014). "Hand Gesture Recognition for Human Computer Interaction." IEEE.

[18] Wang Zhi-heng, Cao Jiang-tao, and Liu Jin-guo. (2009). "Design of Human-Computer Interaction Control System Based on Hand-Gesture Recognition." IEEE.

[19] Kaoru Yamagishi, Lie Jing, and Zixue Cheng. "A System for Controlling Personal Computers by Hand Gestures Using a Wireless Sensor Device." IEEE.

[20] Dushyant Kumar Singh. (2010). "Recognizing Hand Gestures for Human Computer Interaction." IEEE.

[21] Minh Q. Nguyen and Changzhi Li. (2010). "Radar and Ultrasound Hybrid System for Human Computer Interaction." IEEE.

[22] Yuvraj V Parkale. "Gesture Based Operating System Control." IEEE.

[23] Gergely Sziladi and Tibor Ujbanyi. (2015). "The Analysis of Hand Gesture Based Cursor Position Control During Solve an IT Related Task." IEEE.

[24] U. Rajkanna, M. Mathankumar, and K. Gunasekaran. (2012). "Hand Gesture Based Computer Control Using Microcontroller." IEEE.

[25] Andrea Attwenger. (2012). "Controlling Computer Application Using Hand Gestures Using Arduino." IEEE.

[26] A. Haria, A. Subramanian, N. Asokkumar, S. Poddar, and J. S. Nayak, "Hand Gesture Recognition for Human Computer Interaction," Procedia Computer Science, vol. 115, pp. 367-374, 2017.

[27] Qi, Jinxian, et al. "Surface EMG hand gesture recognition system based on PCA and GRNN." Neural Computing and Applications 32.10 (2020): 6343-6351.

Git hub link:

https://github.com/saivikraman/Gesture-Recog-Sys-Ctrl