Gesture-Based Touchless Operations: Leveraging MediaPipe and OpenCV

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Abstract: Humans have only recently begun using hand gestures to interact with computers. The integration of the real and digital worlds is the aim of gesture recognition. It is considerably simpler to convey our intents and ideas to the computer via hand gestures. A simple and efficient touchless method of interacting with computer systems is through hand gestures. However, the limited end-user adoption of hand gesture-based systems is mostly caused by the significant technical challenges involved in successfully identifying in-air movements. Image recognition is one of the many ways that a computer may identify a hand gesture. The recognition of human movements is enabled through the implementation of a convolutional neural network (CNN). Within this study, we develop a simple hand tracking method for controlling a surveillance car operating on the Robot Operating System (ROS) by utilizing socket programming. Our model was trained on an extensive dataset consisting of over 3000 photographs, encompassing a wide range of letter configurations from A to Z and numbers 1 to 9. The developed algorithm demonstrates promising implications for individuals with disabilities, including those who are deaf or have speech impairments. Moreover, its versatility extends to public environments such as airports, train stations, and similar locations, offering potential for practical implementation. This approach leverages Google MediaPipe, a machine learning (ML) pipeline that incorporates Palm Detection and Hand Landmark Models. In the investigation, steering speed and direction of a ROS automobile are controlled. Vehicles for surveillance that can be operated using hand gestures may help to enhance security measures.

Keywords: Mediapipe, OpenCV, Tensorflow, scikit-learn 0.23.2, Matplotlib

1. INTRODUCTION

In the realm of digital art creation, the conventional methods of using a mouse or touchpad for painting and drawing have been known to be demanding and frenetic. While touch-screen laptops exist as an alternative, their high cost poses a barrier to widespread adoption. However, recent advancements in hand tracking technology have paved the way for a more immersive and intuitive approach to digital art, revolutionizing the way artists interact with computer systems. In this study, a sophisticated hand tracking technique, specifically focused on finger tracking, is employed as an external input device akin to a keyboard and mouse [4]. This methodology finds application across diverse industries, ranging from sign language recognition to virtual reality experiences. Notably, a hands-free digital drawing tool called Air Canvas has been developed, leveraging the power of camera technology, OpenCV (Open Source Computer Vision Library), and MediaPipe, a comprehensive framework for constructing machine learning pipelines. This tool accurately identifies objects and tracks hand motions, enabling users to seamlessly create art with their fingertips [8]. Air Canvas empowers users to utilize their finger as a brush or pen, granting them the ability to draw or annotate PDF files with ease. By leveraging computer vision techniques, the system allows for the manipulation of brush size and pen color through intuitive finger movements. Various shapes can be effortlessly drawn on a canvas or any available space, offering a versatile artistic experience. The system's code is implemented using the Python programming language, which facilitates efficient integration of the necessary computer vision functionalities. The core challenge of this endeavor lies in the application of machine learning algorithms to enable the precise tracking and interpretation of hand gestures. By leveraging camera data and the capabilities of MediaPipe, the system is able to accurately track the positions and movements of fingers, ensuring smooth and responsive interaction between the user and the digital drawing tool. This integration of machine learning techniques serves as a pivotal factor in enabling the application to function seamlessly. To evaluate the effectiveness of hand gesture-based interaction, two games were carefully selected for comparison—one utilizing a conventional controller and the other exclusively employing hand gestures. Through a thorough analysis of gameplay mechanics, enjoyable features, and replayability, a comprehensive assessment was conducted to highlight the advantages and potential of hand gesture-based interaction. Notably, despite the potential increase in difficulty, the utilization of hand gestures noticeably enhanced the overall gameplay experience, demonstrating the potential for more immersive and engaging gaming experiences. The structure of the remaining sections in this research paper is organized as follows: Section 3 provides an in-depth literature survey, presenting a comprehensive overview of the existing methodologies and approaches relevant to the study. Section 4 offers a detailed description of the methodologies and methods employed in this research, outlining the technical aspects of the hand tracking system and the underlying computer vision techniques. Section 5 focuses on the analysis of the obtained results and presents a comprehensive discussion of the findings. Finally, Section 6 concludes the paper, summarizing the key insights and implications of the study, as well as outlining potential avenues for future research and development in the field of hand gesture-based human-computer interaction.

2. LITERATURE REVIEW

Researchers have recently directed their focus towards vision-based hand gesture recognition. In a study by [1], the limitations associated with camera image acquisition, image segmentation and tracking, feature extraction, and gesture classification in vision-guided hand recognition were investigated across different camera orientations. Hand gesture recognition has gained prominence as an effective means of human-computer interaction due to its high flexibility and user-friendly nature. In [2], a real-time hand gesture recognition system was developed with a specific emphasis on achieving high recognition performance in the user interface. While various hand gesture recognition models based on deep learning have been proposed, [3] explores the relatively unexplored area of tuning hyperparameters in these models. In [4], the researcher introduced Handmate, a browser-based handheld gesture controller for Web Audio and MIDI, utilizing open-source position estimation technology from Google MediaPipe. Hands are a significant source of body language information, second only to the face. [5] achieved the best performance for each class among all the methods used in the research, with an accuracy of 86.26% and an F1 score of 82% using SVM with the polynomial kernel. [6] demonstrated the concept of multisensory artificial nerves and neuromorphic systems, presenting a nanowire intrinsically stretchable neuromorphic transistor (NISNT). A-mode ultrasound, like other biological signals, exhibits variations in signals obtained when performing the same gesture in different arm positions. To address this issue, [7] proposes a linear enhancement training (LET) procedure to compensate for deviations in gesture signals caused by forearm position changes. Considering the existing challenges in sEMG-based gesture recognition using deep learning, [8] introduces a deformable convolutional network (DCN) to optimize conventional convolutional kernels and achieve improved performance. Accurate gesture prediction is crucial for meaningful communication and enhanced human-computer interactions. [9] explores various techniques, classifiers, and methods available to improve gesture recognition. [10] proposes a portable CNN hybrid feature attention network (HyFiNet) for precise hand gesture recognition. Sign language recognition faces challenges such as accurate hand gesture tracking, hand occlusion, and high computational costs. To overcome these challenges, [11] presents a MediaPipe-optimized integrated recurrent unit (MOPGRU) specifically designed for Indian Sign Language recognition, while [16] utilizes the open-source MediaPipe framework and Support Vector Machine (SVM) algorithm for automating Sign Language Recognition. [18] employs Human-Computer Interaction (HCI) to enhance the hand gesture-based recognition system and define a sign language. In the context of yoga, [12] introduces an architecture for classifying different yoga postures to maximize their benefits. In [13], impairments in simple movement tasks involving the hands and fingers are evaluated as potential indicators of overall health deterioration. [14] employs a Python module to enable real human interaction with the system without the need for any character input device. To address the challenge of obtaining accurate depth information in 3D pose estimation, [17] proposes the use of a depth camera, achieving favorable results. [19] leverages state-of-the-art hand-tracking technology to construct an accurate and robust human-computer interaction (HCI) system. [20] presents a painting technique that allows real-time sketching or drawing on a canvas using hand motions. [21] utilizes the MediaPipe framework and OpenCV to identify key points of the hand and employs the Kalman filter algorithm to optimize the hand coordinates.

3. MATERIAL AND METHODS

MediaPipe, a highly versatile cross-platform framework, offers comprehensive support for constructing machine learning pipelines capable of adapting to diverse data types, including audio, video, and time-series data. This adaptable framework empowers developers to seamlessly integrate machine learning models and algorithms, enabling efficient processing and analysis of complex data streams across platforms such as Android, iOS, and the web. The significance of MediaPipe is reflected in its extensive adoption by various Google products and teams, encompassing critical services like Nest, Gmail, Lens, Maps, Android Auto, Photos, Google Home, and YouTube. The widespread utilization of MediaPipe within these domains underscores its reliability, performance, and applicability in real-world scenarios. By leveraging MediaPipe's rich features and functionalities, developers can harness its cross-platform capabilities to create robust and customized machine learning pipelines tailored to their specific data requirements. This includes leveraging advanced algorithms for tasks such as data preprocessing, feature extraction, and model training, while benefiting from MediaPipe's efficient data processing capabilities. Furthermore, MediaPipe's compatibility with multiple platforms facilitates the development of cross-platform machine learning applications, enabling consistent user experiences across diverse devices and operating systems. The framework provides a unified environment for developers to deploy their machine learning models seamlessly, regardless of the target platform. The adaptability and versatility of MediaPipe make it a powerful tool for building cutting-edge machine learning applications. Its comprehensive support for different data types and platforms empowers developers to overcome complex challenges and leverage state-of-the-art machine learning techniques for tasks like audio and video processing, gesture recognition, augmented reality, and more.

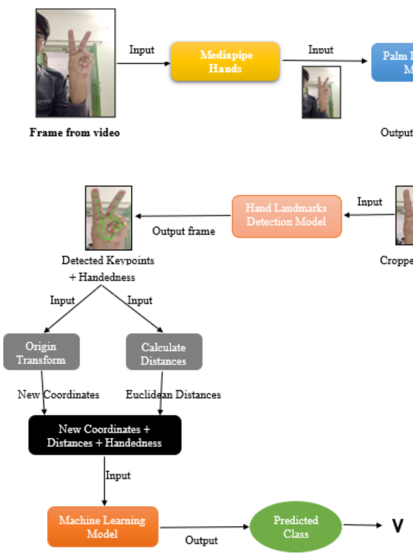

Figure 1 illustrates the flow diagram of the algorithm implemented in this research. The algorithm leverages landmarks and hand positions, employing the media pipe algorithm for video processing to detect the presence of palms in the initial frame. Subsequently, the model applies calculations to determine the origin and distance between the obtained coordinates. Finally, the predicted class is determined based on the outcomes of the algorithm. The field of human-computer interaction has undergone a significant revolution, driven by advancements in technology that have transitioned us from wired to wireless connectivity, traditional keyboards to touch screens, and offline to online experiences. This transformation has been fueled by remarkable breakthroughs in various technologies, including face recognition, speech recognition, touch screens, and other cutting-edge advancements, all of which owe their success to the application of artificial intelligence (AI) and machine learning (ML) techniques. In the present era, AI/ML technologies are extensively integrated into our daily routines, profoundly shaping the way we interact with and benefit from computer systems. In addition to these technologies, hand gestures have emerged as a prominent method of communication with computers, finding applications in diverse fields. Hand gesture recognition has proven to be immensely valuable in augmented reality, enabling intuitive interactions and enhancing user experiences. It plays a crucial role in assisting individuals with disabilities, providing alternative means of control and interaction. In the realm of gaming, platforms like PlayStation have embraced gesture-based interfaces to enhance gameplay experiences. Moreover, hand gestures are employed for controlling car dashboards and enabling gesture-based operations in smart TVs, facilitating more natural and seamless interactions. The integration of hand gestures into these contexts signifies the expanding range of applications where this technology is being deployed. Its utilization demonstrates its potential to enable intuitive and efficient human-computer interaction. By leveraging AI and ML techniques, researchers and developers are continuously advancing the field of hand gesture recognition, exploring new algorithms, models, and technologies to improve accuracy, robustness, and versatility. This ongoing progress holds promise for further advancements in gesture-based interfaces and the broader field of human-computer interaction.

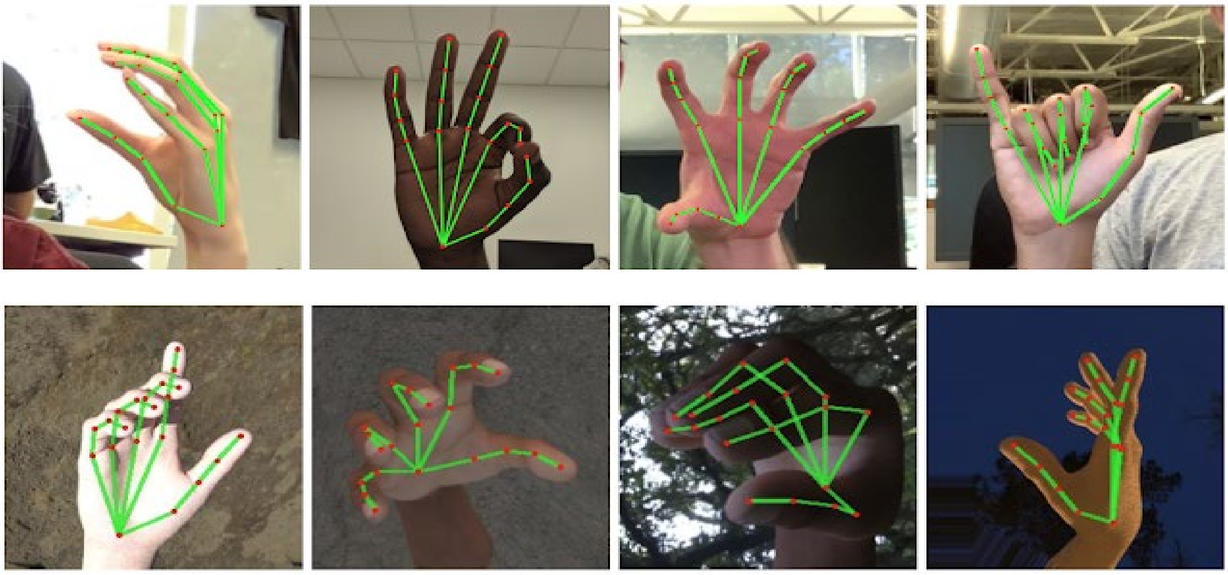

Figure 2: Results Prototype

Figure 2 [21] provides a visual representation of the results obtained from the implementation of the hand detection algorithm within the MediaPipe framework. The algorithm effectively identifies and delineates the contours of detected hands, enhancing their visibility by outlining them with a distinct green border. This visual emphasis facilitates a clearer understanding of the hand detection output. The MediaPipe framework, employed in this study, serves as a comprehensive and powerful tool for constructing machine learning pipelines. It offers a wide range of functionalities, including but not limited to, face detection, hand tracking, object detection, holistic mic integration, facial pose estimation, and more. By encompassing such diverse capabilities, MediaPipe enables researchers and developers to build sophisticated machine learning solutions that address various complex problems. In the context of hand detection, MediaPipe proves particularly valuable due to its robustness and versatility. The framework provides an efficient and reliable pipeline for processing hand-related data, facilitating accurate detection and tracking of hand contours. This capability opens up numerous possibilities for practical applications, such as gesture recognition, human-computer interaction, augmented reality, and virtual reality systems. By leveraging the MediaPipe framework, researchers and developers can harness its extensive functionalities and integrate them seamlessly into their machine learning workflows. This empowers them to explore novel solutions, advance the state-of-the-art in hand detection, and contribute to the wider field of computer vision. The adaptability and flexibility offered by MediaPipe make it a valuable asset for creating diverse machine learning solutions in various domains.

3.1. DATASET DESCRIPTION

MediaPipe Hand represents a cutting-edge machine learning solution that revolutionizes hand and finger tracking with unparalleled precision. This sophisticated technology exhibits exceptional proficiency in detecting and capturing 21 landmark points on a hand within a single frame, enabling a comprehensive understanding of its intricate movements and positions. The foundation of MediaPipe Hand's proficiency lies in its utilization of multiple models that operate concurrently and synergistically. These models collaborate harmoniously to optimize the accuracy and reliability of hand tracking. Through their concerted efforts, MediaPipe Hand ensures that even subtle variations and complex motions of the hand are faithfully recorded and interpreted. The output generated by MediaPipe Hand provides detailed and granular information about the hand's landmarks, delivering invaluable insights into its configuration and motion. This wealth of data opens up a multitude of applications across diverse domains. From augmented reality experiences that seamlessly integrate virtual objects with real-world hand gestures, to interactive gaming platforms that translate hand movements into game controls, MediaPipe Hand empowers developers and users alike with an immersive and intuitive interface. Moreover, MediaPipe Hand's robust tracking capabilities find utility in various fields, including sign language recognition, hand gesture-based control systems, and human-computer interaction in smart devices. By accurately and reliably capturing the intricacies of hand movements, this advanced technology offers endless possibilities for enhancing communication, accessibility, and user experiences.

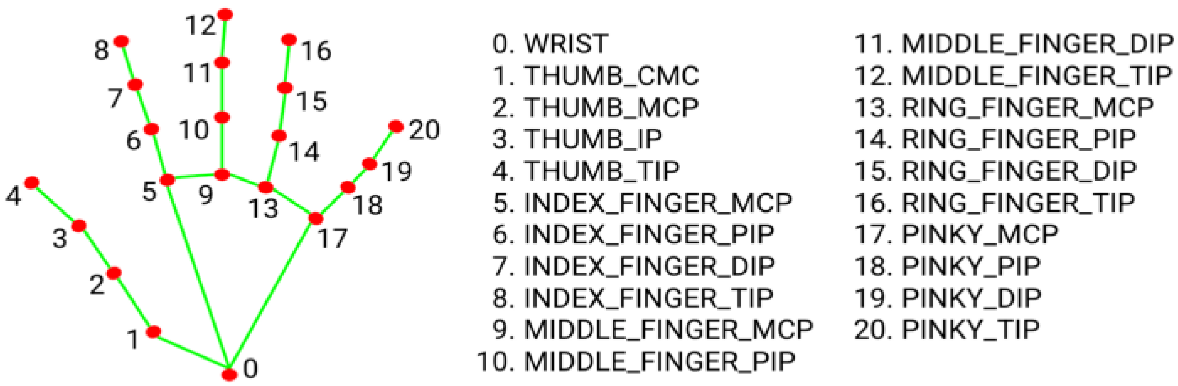

Figure 3: Mediapipe Algorithm hand coordinates

To accurately identify and track the hand within an image, our system employs a two-step process, integrating the Palm Detection Model and the Hand Landmark Model. Initially, the Palm Detection Model is utilized to detect the presence of a hand within the entire image and enclose it within a bounding box. This step effectively localizes the hand region of interest. Following the successful identification of the hand by the Palm Detection Model, the Hand Landmark Model operates specifically on the cropped image defined by the bounding box. By leveraging this refined input, the Hand Landmark Model precisely computes the 2D coordinates of key points that correspond to distinct hand landmarks. These keypoints represent crucial landmarks such as fingertips, knuckles, and palm center. The output generated by this two-step approach is presented in Figure 3 [22], illustrating the effectiveness of our methodology in accurately localizing and capturing intricate details of the hand. The resulting output serves as a testament to the high-fidelity tracking of hand keypoints, enabling precise analysis and interpretation of hand gestures. By combining the Palm Detection Model and the Hand Landmark

Model, our system achieves robust hand localization and accurate keypoint tracking. This methodology forms the foundation of our hand gesture recognition system, enabling reliable and effective interactions between humans and computers.

4. RESULTS

The findings of our study provide compelling evidence of the remarkable ability of our model to accurately anticipate human hand movements. This achievement is made possible through the synergistic combination of our algorithm, MediaPipe, and OpenCV. The training of our model involved an extensive dataset consisting of over 3000 images encompassing diverse configurations of letters from A to Z and numbers from 1 to 9. The significance of our algorithm extends to individuals with various disabilities, including those who are deaf, mute, or face other challenges. By leveraging hand gesture recognition, our algorithm offers a valuable solution for enhancing communication and interaction for individuals with special needs. Furthermore, the versatility of our algorithm allows for its application in public settings such as airports, train stations, and other public venues, where it can contribute to a more inclusive and accessible environment. The potential for improving the lifestyle of the deaf and mute community is vast through further expansion and development of this technology. For instance, our algorithm enables the visualization of mathematical operations through animated hand gestures, as depicted in the outcome images presented in Figure 4. This feature holds particular relevance in public settings like banks, airports, and other locations where individuals with special needs may encounter challenges in carrying out their daily tasks effectively. The animated hand gestures not only facilitate comprehension and engagement but also provide a practical solution for individuals who may struggle with traditional modes of communication. The integration of such technology in public environments can empower individuals with special needs to navigate and interact more effectively, enhancing their overall experience and independence. As we move forward, there is a growing potential for further advancements and wider adoption of hand gesture recognition technology. Continued research and development efforts in this field will enable us to refine and expand the capabilities of our algorithm, making it even more accessible and beneficial for individuals with disabilities and transforming the way they engage with their surroundings.

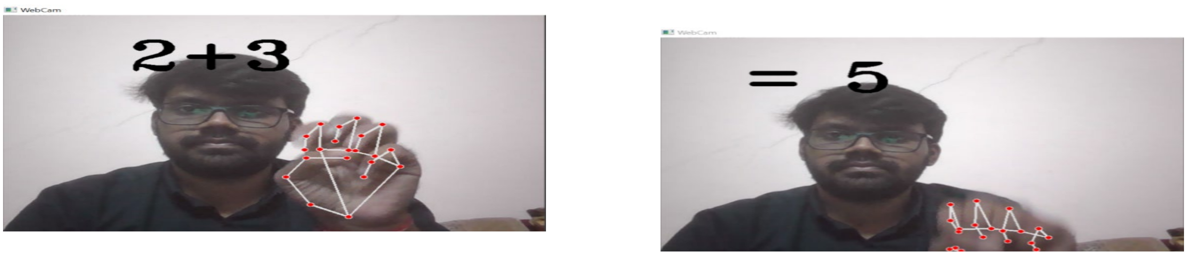

Figure 4: Hand Gesture result

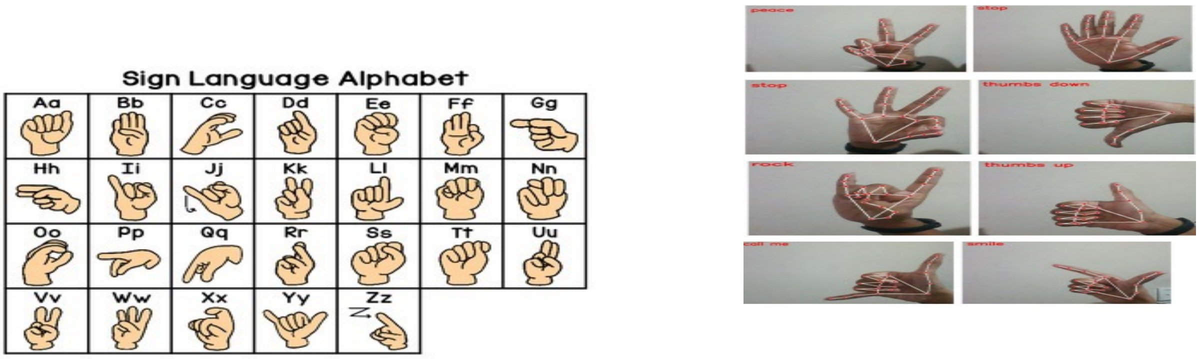

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Figure 5: Hand Gesture result prototype

5. CONCLUSION

The results obtained from our algorithm, leveraging the capabilities of MediaPipe and OpenCV, demonstrate the ease and accuracy with which our model predicts hand gestures. The model has been trained using a dataset comprising over 3000 images encompassing various configurations of alphabets from A to Z and numbers from 1 to 9. The significance of this algorithm lies in its potential to benefit individuals with disabilities, particularly those who are deaf and mute. Additionally, it holds promise for deployment in public places such as airports and railway stations, where it can enhance accessibility and facilitate smoother interactions for individuals with different abilities. Furthermore, this technology has the potential to contribute to the overall improvement in the quality of life for the deaf and mute community. While applications utilizing hand gestures are currently uncommon, there is a growing opportunity for their widespread adoption and increased benefits. Instead of relying on traditional input devices like keyboards and mice, this application capitalizes on the natural movements of hand gestures. The successful implementation of this application heavily relies on the utilization of machine learning techniques. To evaluate the effectiveness and user experience of our application, we conducted a comparison between two games. One game utilized a conventional controller, while the other leveraged hand gestures as the input method. The comparison was based on factors such as gameplay, enjoyable features, and replayability. Notably, as the difficulty level increased, the use of hand gestures in the game resulted in noticeable improvements in these three aspects. These findings highlight the potential and advantages of incorporating hand gesture recognition through machine learning in interactive applications. As technology advances and further research is conducted in this field, the widespread adoption of such applications is anticipated, bringing significant benefits to users and paving the way for more intuitive and engaging human-computer interactions.

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