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Gesture-Based Air Writing System Utilizing Computer Vision

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Abstract
The Gesture-Based Air Writing System Utilizing MediaPipe and Computer Vision presents an innovative solution for air-writing recognition, leveraging artificial intelligence (AI) techniques to provide an efficient and user-friendly experience. This project integrates MediaPipe, a real-time hand tracking library, to accurately capture air-writing gestures from users using a single web camera. The system eliminates the need for physical constraints such as delimiters or imaginary boundaries, allowing unrestricted hand movements. A custom preprocessing pipeline is employed to convert the captured hand trajectory data into suitable formats, which are then processed by deep learning models, particularly convolutional neural networks (CNNs), for precise character recognition. MediaPipe's hand tracking algorithm enhances the robustness and accuracy of the system by detecting and following finger movements in real time. The use of CNNs ensures that the system can effectively recognize air-written characters while maintaining high accuracy.
Keywords: *Gesture recognition, Air writing, Computer vision, MediaPipe, Hand tracking, AWS Textract, Real-time text conversion.*

1. Introduction
Traditional text input methods, such as keyboards and touchscreens, often present challenges in accessibility and usability for certain individuals and contexts. This includes people with disabilities, environments where touch-based input is impractical, and virtual reality settings lacking physical input devices. There is a need for an alternative and intuitive text input method that can effectively address these limitations. The Air Writing and Recognition System using MediaPipe and AWS Textract aims to resolve this problem by enabling users to write in the [1-3] air using hand gestures. This system combines real-time tracking and precise recognition of finger movements with advanced machine learning techniques to translate and convert the air-written text into digital form accurately. By providing a hands-free and adaptive input method, this solution seeks to enhance accessibility and usability in diverse scenarios. The "Gesture-Based Air Writing System Utilizing Computer Vision" leverages advanced computer vision techniques to enable users to write in the air using natural hand gestures. This innovative system relies on the MediaPipe module to detect and track hand movements in real-time, accurately identifying hand landmarks to [4] interpret finger positions and movements. As users move their fingers in specific patterns, the system captures the gesture path and analyzes the coordinates of the hand joints, translating these motions into structured writing. By focusing on gesture-based input, this approach provides an intuitive way of interaction that does not require physical touch or traditional input devices. [5]

2. Literature Survey
Chaur-Hsieh,You-ShenLo,Jen-Yang Chen And Sheng-Kai Tang(2022) Air-Writing Recognition Based on Deep Convolutional Neural Networks Chaur-Heh Hsieh, You-Shen Lo, Jen-Yang Chen, And Sheng-Kai Tang : Air-writing recognition has received wide attention due to its potential

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application in intelligent systems. To date, some of the fundamental problems in isolated writing have not been addressed effectively. This paper presents a simple yet effective air-writing recognition approach based on deep convolutional neural networks (CNNs). R.Vasavi, Nenavath Rahul, A Snigdha, K. Jeffery Moses Painting with Hand Gestures using MediaPipe R.Vasavi, Nenavath Rahul, A Snigdha, K. Jeffery Moses, S.Vishal Simha The main objective of this project is that the hand gesture recognition can also be utilised in applications including industrial automation control, sign language interpretation, and rehabilitation equipment for individuals with physical disabilities of the upper extremities Seong Kyu Leem , Graduate, Faheem Khan. Detecting Mid-Air Gestures for Digit Writing With Radio Sensors and a CNN Seong Kyu Leem , Graduate, Faheem Khan, and Sung Ho Cho,In this paper, we classify digits written in mid-air using hand gestures. Impulse radio ultrawideband (IRUWB) radar sensors are used for data acquisition, with three radar sensors placed in a triangular geometry. Yujie Wu,Hong Zhang,Yawei Li. In this article " In this article, we propose an end-toend blur-aid feature aggregation network (BFAN) for video object detection. The proposed BFAN focuses on the aggregation process influenced by the blur including motion blur and defocus with high accuracy and little increased computation. [7]

3. Problem Statement

In the age of touchless technology, traditional input devices such as keyboards and touchscreens present limitations in scenarios where contact-free interaction is necessary—such as in sterile environments, public spaces, or for individuals with mobility impairments. There is a growing demand for intuitive, hands-free interaction systems that can recognize and interpret human gestures for text input. This project aims to develop a gesture-based air writing system utilizing computer vision, where users can write characters in the air using hand gestures, and the system will recognize and digitize the text in real-time. The system must be able to accurately detect hand movements using a standard camera, extract meaningful gestures, track the motion trajectory, and classify the written characters using machine learning techniques. Key challenges include background noise, variable lighting, diverse writing styles, and real-time processing requirements [6]

4. Propose System

The Gesture-Based Air Writing System Utilizing Computer Vision operates by leveraging the MediaPipe module to detect and track hand movements in realtime. The system uses computer vision techniques to identify and analyze hand landmarks, such as joint positions and finger placements, allowing it to interpret the user's hand movements in the air. As users gesture, the system records the path of their fingers, capturing detailed data about their movement trajectory. This data is continuously analyzed to identify patterns, providing the foundation for converting these gestures into text. Unlike machine learning models, this system employs a rule-based approach that focuses on predefined gesture patterns to interpret hand movements. It directly maps the movement of the user's fingers to specific characters or words by analyzing the coordinates of hand joints and recognizing gesture sequences. This method allows for quick and accurate identification of letters as the user writes in the air. (Figure 1) [8]

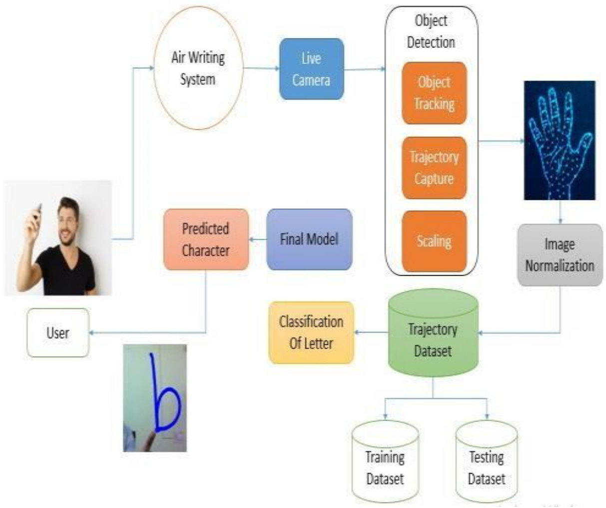

Figure 1 Proposed System Architecture

AWS Textract is then utilized to convert the recognized gestures into digital text by interpreting the structured motion of the hand. As the gestures are captured and analyzed, Textract translates these physical movements into text that can be displayed on a screen or integrated into digital platforms. The

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combination of MediaPipe's real-time tracking capabilities and AWS Textract's text recognition ensures that the air writing process is intuitive and user-friendly. Hand Detection and Tracking Using MediaPipe: The system begins by utilizing the MediaPipe module to detect and track the user's hand in realtime.MediaPipe's pretrained computer vision algorithms identify the position of the hand and recognize hand landmarks (key points like fingertips and knuckles). Identification of Finger Movements: Once the hand is detected, the system focuses on tracking finger movements to interpret gestures in the air. Using the precise location of hand joints and fingertip positions, the system continuously monitors finger paths to determine the gesture patterns.This step helps differentiate between writing gestures and nonwriting movements by analyzing the specific finger joint movements.Gesture Path Analysis and Trajectory Mapping:The detected gestures are mapped into a trajectory representing the movement path of the user's finger in the air. The system analyzes the continuous flow of finger motion and translates it into coordinates that represent the shapes of letters or symbols. Trajectory mapping helps in start,end,and direction stroke made by the user. RuleBased Gesture Interpretation: Instead of relying on machine learning, the system uses rulebased algorithms to interpret these hand gestures into meaningful symbols or text. Predefined gesture patterns for alphabets, numbers, and special characters are used to match the trajectory maps to known shapes.Integration with AWS Textract for Text Conversion: AWS Textract is employed to accurately convert the detected gesture patterns into structured digital text. Textract processes the captured gesture trajectory and extracts text information by recognizing the structure and order of the writing.This ensures high accuracy in converting airwritten gestures into readable text that matches the intended input. Data Processing Without Machine Learning Techniques: The system focuses on processing the gesture data using computer vision and rulebased logic rather than complex machine learning models. This approach reduces the computational load and increases the speed of text conversion, making it more accessible and faster to deploy. The absence of a training phase makes the system easily adaptable to different environments without requiring extensive setup (Figure 2,3,4) [9]

Figure 2 Snapshots

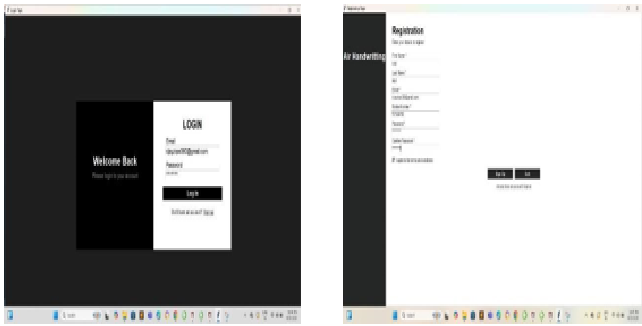

Figure 3 Snapshots

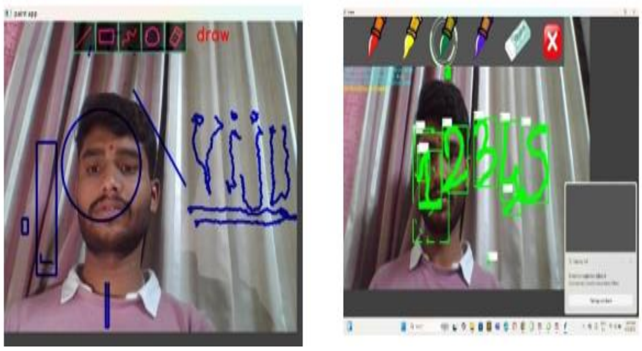

Figure 4 Snapshots

Conclusion

The gesture-based air writing system utilizing computer vision presents a novel and intuitive approach to human-computer interaction, enabling users to write in the air using natural hand movements without the need for physical input devices. By leveraging computer vision techniques such as hand detection, gesture tracking, and character recognition, the system effectively translates spatial movements into digital text. This technology has promising applications in education, virtual reality, accessibility for individuals with physical disabilities, and touchless user interfaces. Despite current limitations in accuracy and environmental sensitivity, continued advancements in machine learning and real-time processing can significantly enhance the reliability and usability of such systems in the near future [10]

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