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Gesture Recognition for Interactive Presentation Control: A Deep Learning andEdge Computing Approach on Raspberry Pi

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Abstract

Gesture recognition is one of the important technologies for intuitive HCI applications, for example, in interactive presentations. This re- view focuses on recent work on gesture recog- nition systems, deep learning-based methods for presentation control by hand gestures, on edge devices like the Raspberry Pi. This work describes both static and dynamic frameworks for gesture recognition and human-machine interaction techniques based on deep learning.Recent studies show the usability of real-time hand gesture recognition using Python-based systems via Raspberry Pi, stressing portability and efficiency in solutions. The review discusses various deep learning frameworks such as TensorFlow, which can be used in image preprocessing and model training to enhance the accuracy of gesture detection. Techniques cover wear- able devices to computer vision and demon- strate the flexibility of gesture recognition in a variety of hardware platforms. Advances in edge computing enable complex gesture recog- nition on low-power devices, with reduced la- tency, and enables improved accessibility.The re- view addresses challenges such as gesture type distinction, responsiveness, and environmental variability in developing reliable gesture-based systems. In this regard, it emphasizes the Raspberry Pi as an edge computing solution for interactive presentation control in HCI.

Keywords

Gesture Recognition Human-Computer Interaction (HCI) Edge Computing Deep Learning Real-Time Gesture Detection

1 Introduction

As digital interaction develops, gesture recognition has increasingly come to be seen as a technology that allows for intuitive HCI. The main problem in this research area is therefore how to develop systems capable of real-time gesture recognition for interactive presentation control on low-cost, portable edge devices such as the Raspberry Pi. The system will accomplish a responsive, hands-free presentation system that can interpret static and dynamic hand gestures, thus being a potential substitute or complement to standard input devices. This is done in the context of availabilities in ML, edge computing, and computer vision research lines, aiming for technology concerning gesture recognition into the road towards greater accessibility, greater efficiency, and more exigent real-time applications.

It is a very demanding field of research in robotics, virtual reality, and smart technology for HCI. Deep models had achieved highly ac- curate classification for complex gestures. Most of the systems based on gestures are, however, rather very powerful computing usually cloud- based infrastructures that add latency and de-

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grade data privacy. It focuses on enabling gesture recognition in edge devices to allow real-time processing, minimize the number of network transmissions, and thereby deliver cost-effective practical solutions for classrooms and conference rooms.

A relevant literature review for this research collates existing knowledge on gestures recognition and identifies the latest advancements of deep learning and edge computing for low power devices. In this regard, such a review would encompass seminal methodologies as well as relevant frameworks that entail TensorFlow which can efficiently realize gesture detection in resource-constrained devices given the chal- lenges of differences in gesture types, variability in environments, and latency reduction.

This research is important because it adds interactive presentation control, allowing us to highlight our work as more engaging and accessible. Our findings could be significant in a broader HCI landscape, depicting the opportunity to combine the potential of deep learn- ing with edge computing in creating responsive gesture-based systems that can be deployed on affordable hardware, such as Raspberry Pi.

2 Background & Significance

Gesture recognition has become the transform- ing element of human-computer interaction, in as much as it allows intuitive control of the digital system even hands-free. This work ad- dresses one of those challenges: developing real- time gesture control systems specifically tailored for presentation control on a low-cost edge de- vice, the Raspberry Pi. It provides an optimally smooth and hands-free navigation using deep learning techniques on a fully portable, resource-constrained platform.

These advantages include, to be relatively specific, lower latency and better privacy. However, the integration of deep learning on such devices poses serious challenges in the form of computational constraints and real-time requirements.

This research is important because gesture- based control can redefine user engagement in presentations and make them more interactive and accessible. Using a low-cost edge device enables these applications to go beyond high-end systems into education, small businesses, and remote areas where affordability and portability become key.

Key research questions include:

1. Ways of improving deep-learning models to respond to static and dynamic gestures using a Raspberry Pi What pre-processing shall be performed to get reliable results with such varied lighting conditions?
2. How to minimize latency in order to enable real-time control without pause?

The literature review will touch on gesture recognition frameworks, especially deep learn- ing and image preprocessing, targeted for low- power devices. Development and analysis tools will comprise TensorFlow, OpenCV, and Medi- aPipe. Since the research is specifically focused on gesture-based control, voice commands and other modalities of HCI such as speech interac- tion have been omitted from the study for sim- plicity. This research will lead to an approach that can be practically applied to edge comput- ing to give gesture-based HCI access to perfor- mance and efficiency across a variety of environ- ments.

3 Literature Review

3.1 Python-based Raspberry Pi for Hand Gesture Recognition[1]

3.1.1 Methodologies

The paper describes a hand gesture recognition system for controlling a mobile robot through Raspberry Pi in which video frames are captured and processed using Python and OpenCV, ap- plying operations like Gaussian blur, threshold- ing, contour detection to differentiate the hand shapes and the positions of fingers. The ap- plied gestures are commands like forward and backward movements that will execute through GPIO pins of the Raspberry Pi.

3.1.2 Limitations

The system has limitations in that it reads only basic finger-count gestures, limiting its applications. It performs well in consistent lighting and simple backgrounds and is less adequate under varied environments. Classical image processing techniques applied to this system limit the accu- racy for complex gestures, which deep learning may be more effective at resolving. The absence of feedback, coupled with the slow processing of the Raspberry Pi, also leads to latency in real- time response.

3.1.3 Learnings

This study's methods can be used for a gesture-controlled presentation system with a Raspberry Pi camera. Pre-processing steps are better done with Gaussian blur and contour detection, and with the upgrade of hardware or incorporation of a USB accelerator, latency will be minimized, aiming for better real-time gesture recognition in presentations.

3.2 A Deep Learning Framework for Recognizing Both Static and Dynamic Gestures[2]

3.2.1 Methodologies

taDNet uses pose-driven spatial attention with the use of OpenPose for extracting pose and depth estimation. The former is captured by a CNN where LSTMs are utilized for modeling the temporal aspects of dynamic gestures. Furthermore, cropping RGB frames around hand regions fosters gesture detection in a sensor-less scenario while normalizing joint velocities and accelerations improve accuracy.

3.2.2 Limitations

Since the system uses RGB images, it is light sensitive and best suited for indoor use. It does not support continuous gesture recognition but instead works only on single/isolated gestures.

3.2.3 Learnings

The approach of StaDNet can thus adapt for the presentation control system with pose-driven spatial attention and architecture CNN-LSTM with TensorFlow Lite running on the Raspberry Pi. In this way, gesture recognition may be enabled in real time, with a reliability improvement of variable lighting conditions using intuitive gestures to support the control of slides in a presentation.

3.3 Exploring The Techniques and Applications of Hand Ges- ture Recognition for Human- Computer Interaction [3]

3.3.1 Methodologies

The paper utilizes OpenCV and Mediapipe for real-time video capture and hand tracking. Mediapipe's solutions.hands module detects hand landmarks, while Euclidean distance calcula- tions identify specific gestures. Machine learning models, such as TensorFlow models trained on custom datasets, support applications like sign language recognition, with gestures mapped to specific functions through a Tkinter interface.

Limitations

The system encounters challenges in maintain- ing accuracy under non-ideal lighting and is con- strained by a reliance on predefined gestures. Mediapipe's performance varies under certain conditions, which can impact gesture recognition accuracy and usability in diverse environments.

3.3.2 Learnings

This paper provides useful methods for gesture detection, particularly through Mediapipe and OpenCV, which you can use for real-time hand tracking in your presentation system. Implementing similar gesture-mapping techniques al- lows you to customize commands for slides and multimedia control. Leveraging TensorFlow Lite models on Raspberry Pi can enhance gesture recognition speed, while data augmentation can address lighting variability for more robust performance

3.4 Human-machine interactions based on hand gesture recog- nition using deep learning methods[4]

3.4.1 Methodologies

The paper uses CNNs for extracting key ges- ture features and LSTMs to capture temporal patterns, improving gesture accuracy. Medi- aPipe detects hand landmarks (e.g., fingertips) in real-time video, enabling gesture-based con- trol. Data on hand movements is mapped to specific actions, and these mappings train CNN and LSTM models for tasks like cursor control.

3.4.2 Limitations

Challenges exist in achieving big labeled datasets for training while, at the same time, there are real-time processing challenges on de- vices like the Raspberry Pi. Gesture recognition performance may also be sensitive to environ- mental factors, such as lighting and background, which can impact the accuracy.

3.4.3 Learnings

The CNN-LSTM framework and MediaPipe-based tracking can be utilized for enhanced gesture accuracy of slide control on a Raspberry Pi. Obvious guidelines gained in this paper form guidelines for how to adapt to lighting variability, and how the system might operate reliably: a good foundation on which to build a successful presentation control.

3.5 Carry Out Computer Tasks with Gesture using Image Pre- Processing and TensorFlow Framework [5]

3.5.1 Methodologies

The paper uses Image Segmentation and it is able to separate the hand against the back- ground using techniques such as background subtraction and binary thresholding, will be suitable for the accurate detection of the hand in dynamic scenarios. Besides that, the paper proposes Gesture Dataset Creation by labeling images to train it on presentation control ges- tures. Furthermore, the CNN Model Training method utilizing TensorFlow can be adapted for gesture classification, and thus real-time Gesture Prediction toward controlling presentations.

3.5.2 Limitations

Some of the key restrictions are as follows: it must be stable in the background condition, and also sensitive to the illumination conditions affecting proper recognition of gestures. It is challenging on hardware like the Raspberry Pi to require a GPU for smooth operation. Also on the list are false positives during highly dynamic environments.

3.5.3 Learnings

Image segmentation-based hand detection builds a presentation control-specific gesture dataset, and it can also deploy CNNs with TensorFlow Lite to the edge for final inference. Thus, increasing reliability under varying con- ditions can be achieved using techniques such as the use of HSV color space to handle lighting as well as background instability.

3.6 Gesture-based Human-Computer Interaction using Wearable Devices [6]

3.6.1 Methodologies

The paper discusses methods for collecting and processing gesture data with wearable de- vices, including feature extraction using Prin- cipal Component Analysis and Fourier Trans- forms. It explores machine learning models like CNNs, RNNs, and Hidden Markov Models for gesture recognition, along with real-time pro- cessing techniques such as parallel processing and sensor data fusion to enhance accuracy and reduce latency on low-power devices.

Limitations

One of the main disadvantages is that wear- ables differ significantly from one another in terms of effectiveness and dependency on hard- ware; more than likely the environment- light- ing, impediments- impacts the accuracy of ges- ture detection although low processing could possibly cause latency.

3.6.2 Learnings

It is possible to control presentations using ges-ture recognition models such as CNNs or RNNs for Raspberry Pi. Using real-time processing techniques capable of improving responsiveness, such as parallel processing

4 Methadology

The literature review methodology involved identifying and synthesizing research articles, technical reports, and case studies on gesture recognition for interactive presentation control, deep learning models, and edge computing with Raspberry Pi. Sources were selected from Google Scholar, IEEE Xplore, and ScienceDi- rect, focusing on studies from 2017 to 2024 us- ing key search terms like "gesture recognition," "Raspberry Pi," and "deep learning for hand gestures." A thematic analysis grouped studies into core areas such as gesture recognition frameworks, CNNs and RNNs, real-time edge computing, and applications in interactive presentations. The review aimed to assess advancements, challenges, and potential for future research in improving system efficiency and accessibility.

5 Implications and Consider- ations for Future Work

- **Challenging Theoretical Frameworks and Assumptions**: The findings may cast doubt on the viability of utilising edge com- puting and deep learning for real-time ges- ture detection on devices with limited re- sources, such as Raspberry Pi.

- **Suggestions for Subsequent Research**: Future research could concentrate on inves- tigating hybrid models (such as CNNs and RNNs) for improved dynamic gesture recog- nition and optimising models to lower la- tency and computational load.

- **Implications for Practitioners**: Practi- tioners could use these findings to create more efficient and accessible gesture-based control systems, particularly for hands-free environments.

- **Influence on Programs, Methods, and Interventions**: This study could lead to more inclusive and user-friendly technolo- gies for individuals with disabilities or for applications in interactive settings.

- **Contribution to Solving Problems**: It may help solve accessibility issues by devel- oping technology that doesn't rely on tradi- tional input devices, improving inclusivity.

- **Improvements or Changes Needed**: Improvements should focus on enhancing gesture recognition robustness, addressing environmental challenges, and optimizing real-time processing on devices like Rasp- berry Pi.

6 Conclusions

This work applies deep learning and edge com- puting on a Raspberry Pi to exhibit the signif- icance of gesture detection in interactive pre- sentation control. Currently, the study focuses on the requirement of hands-free control sys- tems applied in many areas, including assistive technology and public speaking. This disser- tation aims to look into the implementation of deep learning models, namely CNNs and RNNs, on edge devices so as to provide real-time ges- ture recognition facilities for interactive presen- tations.
The chosen approach employs deep learning frameworks and picture pre-processing utilizing Raspberry Pi to achieve real-time performance with a cost-effective tool. The work has very important implications that can be exploited to transform technology which is more widely ac- cessible to all sorts of users, therefore improv- ing systems in human-computer interaction sys- tems.

References

[1] Ali A, Abed SA, Rahman O. Python-based Raspberry Pi for Hand Gesture Recognition. International Journal of Computer Applica- tions. 2017;173(4):18–24.

[2] Osama M, Sofiane R, Andrea C. A Deep Learning Framework for Recognizing Both Static and Dynamic Gestures. Sensors. 2021;21(6):2227.

[3] Anonymous. Exploring The Techniques and Applications of Hand Gesture Recognition for Human-Computer Interaction. Indian Scientific Journal Of Research In Engineer- ing And Management. 2023;07(05).

[4] Zholshiyeva L, Manbetova Z, Kaibassova D, Kassymova A, Tashenova Z, Baizhumanov S, et al. Human-machine interactions based on hand gesture recognition using deep learning methods. International Journal of Electrical and Computer Engineering. 2024.

[5] Magar P, Singh S, Mishra S, Gaikwad P. Carry Out Computer Tasks with Gesture us- ing Image Pre-Processing and TensorFlow Framework. International Journal of Engi- neering Research and. 2020;9(09).

[6] Bansal JL. Gesture-based Human-Computer Interaction using Wearable Devices. Interna- tional Journal for Research Publication and Seminar. 2023.