

Air Characters Writing Detection and Recognition using CNN

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Abstract— The integration of handwriting recognition (HWR) with existing human-computer interaction paradigms presents an intriguing avenue for advancing user input methodologies. While gesture recognition systems have seen substantial advancements, they predominantly focus on discerning predefined gestures rather than the intricate symbols and shapes inherent to handwriting. This research embarks on a comprehensive exploration of Air Handwriting Recognition (AHR) as a novel input modality, capturing and interpreting pen movements in a free space environment, akin to writing with an imaginary pen.

The distinction between traditional HWR and AHR is pivotal for understanding the unique capabilities and challenges of the latter. Air handwriting, a manifestation of hand movements devoid of tangible mediums such as paper or digital pads, emerges as an alternative input method in scenarios where conventional typing is cumbersome or impractical. This modality not only accommodates diverse user environments, including mobile and pen-based computing, but also offers a natural and intuitive means of data entry and interaction.

The study delves into a range of detection techniques tailored for AHR, each with its distinct advantages and challenges. Optical sensors offer high-resolution tracking but may be susceptible to ambient lighting conditions. Infrared sensors, operating based on heat signatures, excel in low-light environments but may require frequent calibration. Ultrasonic sensors leverage sound waves for precise tracking but can be affected by acoustic interferences. Capacitive sensors, sensitive to touch and proximity, offer versatility but may require direct contact or close proximity to the writing surface.

Despite the promising potential of AHR, several challenges necessitate innovative solutions. Noise interference, stemming from external factors or inherent sensor limitations, can compromise detection accuracy. Variability in handwriting styles across individuals introduces complexities in standardizing recognition algorithms. The demand for real-time recognition further amplifies computational requirements, necessitating efficient algorithms and processing techniques. Moreover, ensuring high accuracy and implementing robust error correction mechanisms are paramount to enhancing user trust and system reliability.

Beyond these challenges, the applications of AHR are manifold and transformative. It holds the potential to revolutionize gesture-based user interfaces, bridging the gap between natural human movements and digital interactions. In virtual and augmented reality environments, AHR can enrich user experiences by enabling intuitive interaction with virtual objects and interfaces. Additionally, AHR can facilitate real-time translation of sign language, empowering individuals with hearing impairments to communicate more effectively. Furthermore, the technology could be instrumental in forensic handwriting analysis, aiding investigators in

analyzing and authenticating handwritten documents.

In conclusion, while AHR is an emerging technology with inherent complexities and challenges, its potential to reshape human-computer interaction paradigms is undeniable. This paper serves as a comprehensive exploration into the realm of AHR, offering insights into its definition, detection techniques, challenges, and transformative applications. As this field is evolving, interdisciplinary research and collaboration will be critical in unlocking the full potential of AHR and paving the way for a future where handwriting and gesture-based inputs harmoniously coalesce in diverse computing environments.

***Index Terms*— Air writing, character recognition, human-computer interaction, convolutional neural network, gesture recognition, augmented and virtual reality.**

I. INTRODUCTION

Existing gesture recognition schemes are not particularly well-suited to achieving this kind of integration of handwriting data with the post-recognition processing of textual content. Most gesture recognition systems do not offer a means for flexible input of literal text. Rather, they operate by classifying the gesture into a small set of predefined command categories and then proceed by interpreting the gesture as a command. Although gesture recognition systems in general are getting much better at recognizing a richer array of primitive hand and arm movements, the recognition of symbols and shapes such as would be done in HWR is still not a primary focus of the field. Our preliminary investigations in applying known gesture recognition methods to the task of handwriting recognition have shown that this approach is less than ideal. Therefore, we would like to explore the feasibility of using HWR as an integrated input modality in a computer system with pen-based, gesture, and voice-based input. This provides us with the following research question [1, 2].

Air handwriting recognition (AHR) can be a vital input technique for online data entry for users working in mobile or other pen-based computing environments. In many of these situations, the computing environment is not particularly conducive to typing. For example, it may be difficult to set up a keyboard, difficult to use it because of space constraints, or difficult to use it because of the physical demands such as working while standing. In situations like these, input by a handheld writing implement is an attractive modality for data entry, but users will not always have the luxury of a pad of paper on which to write [3]. AHR would allow data to be entered in such contexts and then be reused as appropriate in subsequent computer processing or document-related tasks.

Handwriting recognition involves converting scanned handwritten text into encoded digital text. It can be in various forms: isolated characters/digits, cursive writing, or hand printing. Offline recognition analyzes static handwritten images, categorizing text into features or symbols. In contrast, online recognition records pen movements via a pointing device like a mouse or stylus, translating these movements into text [4].

Air handwriting is essentially online handwriting recognition without a physical pointing device. It involves recording pen tip movements in the air using an imaginary pen, making it a simulation of the text creation process without paper or a digital pad [5].

Air handwriting recognition is the process of interpreting and translating the recorded pen tip movements made in the air by an imaginary pen into digital text. It mimics online handwriting recognition but without the need for a physical pointing device, allowing users to write in the air and have their movements translated into usable text [6].

II. METHODOLOGY

Figure 1 depicts the fundamental steps of AIR- written character recognition.

A. Research Design

The study utilizes a mixed-modality research design, integrating both qualitative and quantitative research methods [2, 7]. This design facilitates a comprehensive exploration of Air Handwriting Recognition (AHR), allowing for the collection of both subjective user experiences and objective performance metrics.

Data Collection

Literature Review

A thorough literature critique was conducted to gather existing knowledge, techniques, and challenges related to handwriting recognition, gesture recognition, and AHR. This step provided a foundational conception of the research landscape and informed the development of the research objectives and hypotheses [8].

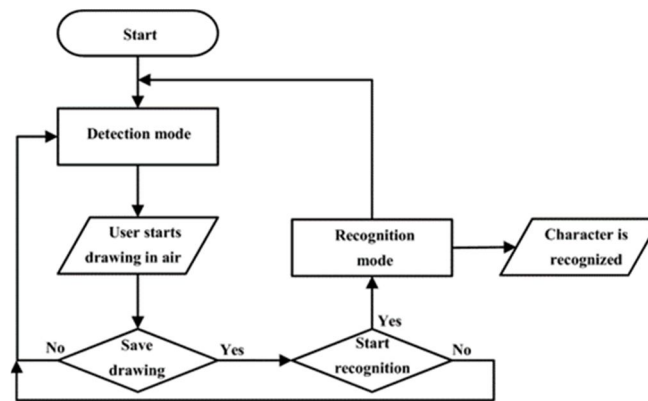


Figure 1. Fundamental steps of AIR- written character recognition

Experimental Setup

Participants: A diverse group of participants, including individuals with varying handwriting styles, was recruited for the study [9].

Equipment: Various sensors (optical, infrared, ultrasonic, and capacitive) were selected and calibrated for data collection. Additionally, pen-based computing devices and simulation software were utilized to simulate air handwriting scenarios [10].

Data Collection Protocol: Participants were instructed to perform specific writing tasks using both traditional pen-and-paper methods and air handwriting techniques. Data, including pen movements, stroke sequences, and handwriting samples, were recorded using the selected sensors and devices.

Data Analysis

Qualitative Analysis

User Experience Evaluation: Semi-structured interviews and questionnaires were employed to gather participants' perceptions, experiences, and preferences regarding AHR. Thematic analysis was conducted to identify common themes, patterns, and insights [11].

Handwriting Style Variation: Qualitative analysis of handwritten samples was performed to categorize and analyze variations in handwriting styles across participants.

Quantitative Analysis

Sensor Performance Evaluation: Performance metrics, including accuracy, precision, and latency, were quantitatively evaluated for each sensor type. Statistical analysis was conducted to contrast the performance of different sensors and identify the most suitable sensor(s) for AHR.

Recognition Algorithm Testing: Various handwriting recognition algorithms were tested using the collected data to evaluate their effectiveness in recognizing air handwriting strokes. Metrics such as recognition rate, false positives/negatives, and processing time were measured and analysed [12, 13].

System Development and Implementation

Based on the findings from the data analysis, a model AHR system was developed and implemented. The system incorporated the most effective sensors, algorithms, and user interface designs identified during the research. Iterative testing and refinement were conducted to optimize system performance and user experience.

Validation and Evaluation

The developed AHR system was validated through rigorous testing involving real-world scenarios and tasks [14]. Participants were engaged in hands-on sessions using the system, and their interactions, feedback, and performance were meticulously evaluated. Comparative analysis was conducted to assess the system's performance against existing handwriting and gesture recognition systems.

Ethical Considerations

All participants were informed about the research goals, procedures, and data handling protocols. Informed consent was obtained from each participant before data collection. Confidentiality and anonymity of participants

were ensured throughout the research process, and data were securely stored and handled in compliance with relevant data protection regulations [3].

III. FUTURE PROSPECTS AND ADVANCEMENTS IN AIR HANDWRITING DETECTION

A. Integration with Augmented Reality Technology

Combining air handwriting detection with augmented reality (AR) technology enables innovative user interactions and experiences [15, 16]. Users can write notes, annotate virtual objects, and create 3D drawings within augmented environments, enhancing creativity, collaboration, and immersive storytelling in AR applications.

B. Enhanced Accuracy through Deep Learning Algorithms

Continued advancements in deep learning algorithms, including convolutional neural networks (CNNs), recurrent neural networks (RNNs), and transformer architectures, promise to revolutionize air handwriting detection [17–20]. These algorithms can learn complex hierarchical features, temporal dependencies, and contextual information from handwriting data, achieving unprecedented levels of accuracy, robustness, and adaptability across diverse writing styles and environments.

IV. RESULTS

Figures 2 and 3 show the output of trained model along with output predictions made during the validation phase. Figure 4 shows the sample of images used for training and validation of CNN model used for the experiment.

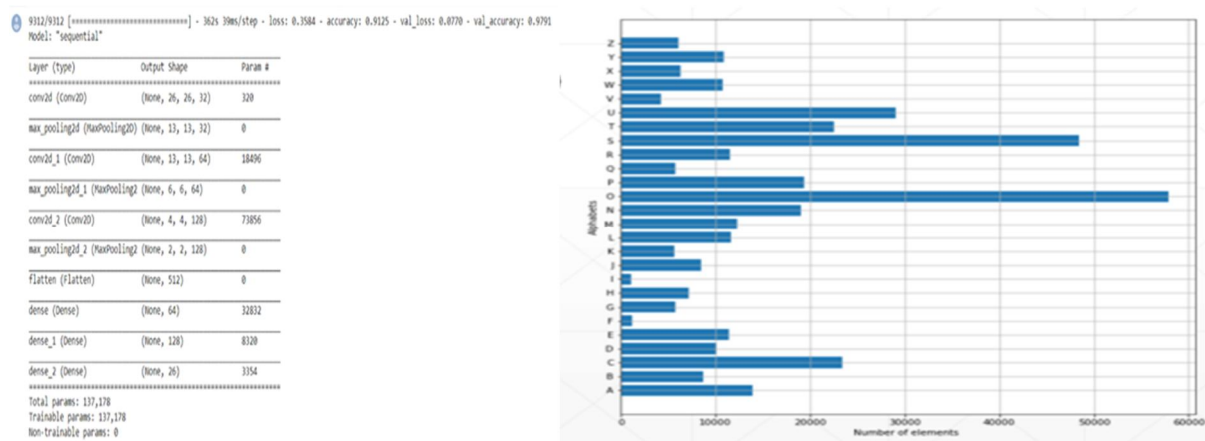


Figure 2. Output of trained model



Figure 3. Output predictions of trained model

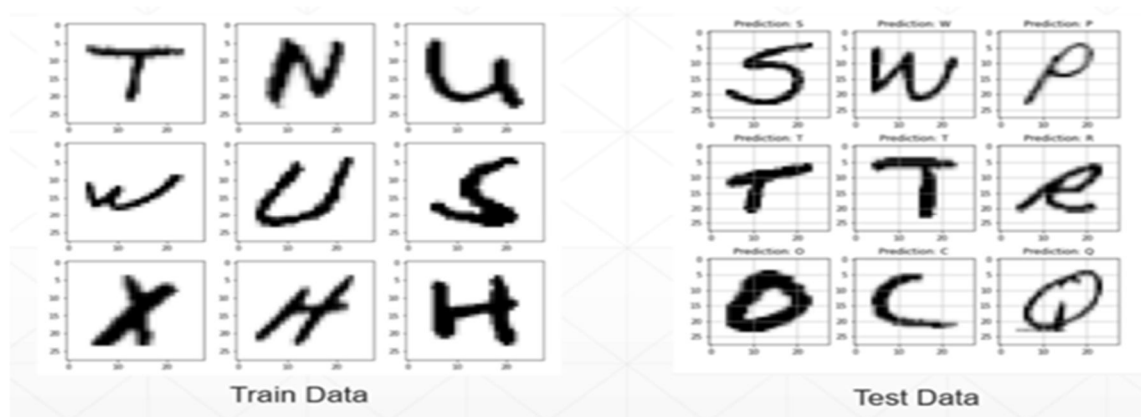


Figure 4. Sample for AIR written-character recognition. (a) training data sample (b) test data sample

- Dataset- <https://www.kaggle.com/sachinpatel21/az-handwritten-alphabets-in-csv-format>
- Total no. of characters- 26 folders (size - 28 x 28)
- Gray scale image
- Split into- 20-80%
- Train data shape: (297960, 28, 28)
- Test data shape: (74490, 28, 28)

The validation precision is : [0.9791381359100342]

The training precision is : [0.9573432803153992]

The validation loss is : [0.07700876146554947]

The training loss is : [0.15533433854579926]

REFERENCES

- [1] K. Venugopalan, M. Pullat, T.P. Safa, K. Shinsha and S. Reshmi, "Survey on Air Writing Recognition," <https://ijream.org/papers/IJREAMV05I0250141.pdf>
- [2] M. Jabde, C. Patil, S. Mal and A. Vibhute, "Comparative Study of Machine Learning and Deep Learning Classifiers on Handwritten Numeral Recognition," In: S.M. Thampi, J. Mukhopadhyay, M. Paprzycki, K.C. Li, (eds.) International Symposium on Intelligent Informatics. ISI 2022. *Smart Innov. Syst. Technol.*, vol. 333, 2023. Springer, Singapore. https://doi.org/10.1007/978-981-19-8094-7_10
- [3] G. Bastas, K. Kritsis and V. Katsouros, "Air-Writing Recognition using Deep Convolutional and Recurrent Neural Network Architectures," *2020 17th International Conference on Frontiers in Handwriting Recognition (ICFHR), Dortmund, Germany, 2020*, pp. 7-12, doi: 10.1109/ICFHR2020.2020.00013.
- [4] M.S. Alam, K.-C. Kwon, M.A. Alam, M.Y. Abbass, S.M. Imtiaz and N. Kim, "Trajectory-Based Air-Writing Recognition Using Deep Neural Network and Depth Sensor," *Sensors* vol. 20, p. 376, 2020. <https://doi.org/10.3390/s20020376>
- [5] S.H. Ali and M.B. Abdulrazzaq, "A Comprehensive Overview of Handwritten Recognition Techniques: A Survey," <https://thescipub.com/pdf/jcssp.2023.569.587.pdf>
- [6] M. Bashir, G. Scharfenberg and J. Kempf, "Person Authentication by Handwriting in air using a Biometric Smart Pen Device," <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=4044165e3f27db3295aaa9b32a52831093aa42d1>
- [7] M. Jabde, C. Patil, A. Vibhute and S. Mali, "A Comprehensive Literature Review on Air-written Online Handwritten Recognition," *Int. J. Comput. Digital Syst.* vol. 15, 2024. <http://dx.doi.org/10.12785/ijcds/150124>
- [8] R. Meghana, K.J. Pallavi, S. Aditi and A.S. Manek, "Air Canvas – Air-Writing Recognition Model for Environmental and Socioeconomic Issues," <https://www.taylorfrancis.com/chapters/edit/10.1201/9781003282990-16/air-canvas-air-writing-recognition-model-environmental-socioeconomic-issues-meghana-pallavi-aditi-asha-manek>
- [9] K.R. Amith, R. Nikhil Holla, and J. Prashanth, "Air Writing Detection and Recognition," *Int. J. Adv. Res. Sci. Commun. Technol. (IJARSCT)* vol. 4, 2024. DOI: 10.48175/IJARSCT-15381
- [10] K. Niu, F. Zhang, X. Fu and B. Jin, "In-Air Handwriting Recognition Using Acoustic Impulse Signals. In: Aloulou, H., Abdulrazak, B., de Marassé-Enouf A., Mokhtari, M. (eds) *Participative Urban Health and Healthy Aging in the Age of AI. ICOST 2022. Lecture Notes in Computer Science*, vol. 13287. Springer, Cham. https://doi.org/10.1007/978-3-031-09593-1_25
- [11] B. Saez-Mingorance, J. Mendez-Gomez, G. Mauro, E. Castillo-Morales, M. Pegalajar-Cuellar, "Air-Writing Character Recognition with Ultrasonic Transceivers,"

- <https://www.proquest.com/openview/35021b96a9bb76f36a82152e2c6b3dc5/1?pq-origsite=gscholar&cbl=2032333>
- [12] D. Deepa and R. Dharmalingam, "Feature and Processing of Recognition of Characters, Words & Connecting Motions," <https://www.ijariit.com/manuscripts/v3i2/V3I2-1455.pdf>
 - [13] M.L. Tiny, "Air Writing Recognition with Nicla Sense ME," 2022. <https://maker.pro/arduino/projects/tiny-ml-air-writing-recognition-with-nicla-sense-me>
 - [14] S. Aqab and M.U. Tariq, "Handwriting Recognition using Artificial Intelligence Neural Network and Image Processing," *Int. J. Adv. Comp. Sci. Appl.* vol. 11, 2020. <http://dx.doi.org/10.14569/IJACSA.2020.0110719>
 - [15] P. Bojja, N.S.S.T. Velpuri, G.K. Pandala, S.D.L.R. Sharma Polavarapu and P.R. Kumari, "Handwritten Text Recognition using Machine Learning Techniques in Application of NLP," <https://www.ijitee.org/wp-content/uploads/papers/v9i2/A4748119119.pdf>
 - [16] A. Choudhury and K.K. Sarma, "A CNN-LSTM based ensemble framework for in-air handwritten Assamese character recognition," <https://openurl.ebsco.com/EPDB%3Agcd%3A2%3A20397282/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A153872231&crl=c>
 - [17] F.A. Abir, M.A. Siam, A. Sayeed, M.A.M. Hasan and J. Shin, "Deep Learning Based Air-Writing Recognition with the Choice of Proper Interpolation Technique," *Sensors* vol. 21, pp. 8407, 2021. <https://doi.org/10.3390/s21248407>
 - [18] C.-H. Hsieh, Y.-S. Lo, J.-Y. Chen and S.-K. Tang, "Air-Writing Recognition Based on Deep Convolutional Neural Networks," *IEEE Access*, vol. 9, pp. 142827–142836, 2021, doi: 10.1109/ACCESS.2021.3121093.
 - [19] M.S. Alam, K.-C. Kwon, and N. Kim, "Trajectory-Based Air-Writing Character Recognition Using Convolutional Neural Network," *2019 4th International Conference on Control, Robotics and Cybernetics (CRC)*, Tokyo, Japan, 2019, pp. 86–90, doi: 10.1109/CRC.2019.00026.
 - [20] S. Md. Alam, K.-C. Kwon, I. Md. Shariar, H. Md. Biddut, B.-G. Kang, N. Kim, "TARNet: An Efficient and Lightweight Trajectory-Based Air-Writing Recognition Model Using a CNN and LSTM Network," *Human Behav Emerg Technol*, 6063779, 13 pages, 2022. <https://doi.org/10.1155/2022/6063779>.