International Journal of Technoinformatics Engineering
Vol: 01; **Issue**: 01; **pg**: 012-019

An Innovative Software Framework To Enhance Human-Computer Interaction

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Received: 2nd September 2024 / Accepted: 24th September 2024

Abstract: In the context of envisioning the future of computing, it is imperative to transcend the mere consideration of user-device interaction. A comprehensive understanding and collaborative development of technology necessitates the consideration of this perspective, as it highlights the interconnectedness between users and technology within a broader framework encompassing physical, digital, and social dimensions. The primary objective of this project is to investigate a novel software framework that augments the interaction between humans and computers. This research endeavor presents a highly efficient and advanced Multi Modal biometric recognition system, utilizing Human-Computer Interaction to investigate the mechanisms behind the interaction between humans and computer systems. In addition to the user interface, this encompasses the procedures that constitute these interactions. The system under consideration achieved an accuracy rate of 99.21%, a precision rate of 98.24%, a recall rate of 98.87%, and an F-Score of 98.55%. Based on the findings of this study, it can be concluded that the current biometric methodologies employed exhibit a higher degree of suitability and has the capability to mitigate the system's elasticity.
Keywords: *Software Framework; HCI; Software, Human Computer Interface, Interaction, Multimodal biometric Techniques.*

INTRODUCTION

The field of HCI has undergone substantial advancements in recent decades, emerging as a crucial domain of scholarly investigation and innovation due to the pervasive integration of technology into various facets of human existence [1]. HCI is a field that centers on the conceptualization and utilization of computer technology, with a particular emphasis on the interfaces that exist between users and computers. The exponential growth in the demand for intuitive, efficient, and user-centered interfaces can be attributed to the rapid improvements in computer power, artificial intelligence, and interactive technologies [2]. Conventional HCI frameworks, although fundamental, frequently encounter difficulties in adapting to the ever-changing and intricate requirements of contemporary users, particularly in domains such as virtual reality, augmented reality, and intelligent systems [3,4]. This phenomenon has resulted in an urgent demand for novel methodologies that can enhance user experience while simultaneously catering to the varied and rapidly changing needs of distinct user cohorts [5]. Figure 1 below depicts the Overview of Human-Computer Interaction. Human-Computer Interaction is a multidisciplinary domain that examines the nature of interactions between individuals and computers, as well as the extent to which computers are effectively designed for successful human engagement.

Fig. 1. Overview of Human Computer Interaction

The present study aims to tackle these difficulties through the creation and implementation of a novel software framework with the objective of improving HCI. This framework will be based on a thorough examination of current HCI designs, finding significant areas where current solutions are inadequate and suggesting novel techniques to address these shortcomings. The study aims to investigate multiple dimensions of HCI, encompassing usability, accessibility, user engagement, and adaptation, with the objective of developing a framework that possesses both resilience and versatility. Through the utilization of advanced technologies such as machine learning, natural language processing, and gesture recognition, the proposed framework endeavors to provide a user experience that is tailored and adaptable, to accommodate the unique requirements and preferences of individual users. Furthermore, the study will integrate perspectives from scholarly literature and industry methodologies, guaranteeing that the framework is not only theoretically robust but also practically relevant across diverse fields. The primary objective of this study is to provide a valuable contribution to the field of HCI by introducing an innovative framework that enhances the quality of interactions, increases user happiness, and lays the foundation for future advancements in this area.

LITERATURE REVIEW

The subsequent part provides a detailed analysis of previous research pertaining to the innovative software framework aimed at improving HCI.

Tab. 1. Related Works

Authors and Year	Methodology	Findings
Mohammed et al., (2021) [6]	Analysed 43 articles on HCI interface design methodologies for modern information systems to assess their usefulness.	The study concluded that current HCI design techniques rely on desktop paradigms, which do not offer location-based services for mobile users. A study found that current interface design standards employed by HCI specialists for user interfaces are ineffective and incompatible with new technology due to their flexibility.
Yun et al., (2021) [7]	This paper introduced a visual decision-making system for industrial data mining applications. The proposed visual decision-making system is optimised for data mining techniques to enhance performance.	A practical data mining case study is used to analyse the architecture of the decision support system. A thorough experiment demonstrated the effectiveness and robustness of the suggested strategy compared to others.
Eriksson et al., (2022) [8]	This is shown by a qualitative examination of 28 design issues and inspirational instructional activities to address them.	This overview of challenges and inspirational teaching activities on values in technology design can inspire teachers to sensitise their students and prepare them to become responsible designers by learning how to address and work with values in HCI.
Pushpakumar et al., (2023) [9]	Proposed a comprehensive framework for creating adaptive interaction	HCI researchers and designers can create interactive systems that enhance users' mental models and cognitive processes by studying human behaviour, cognition, and psychology.
He et al., (2024) [10]	To recognise and track gestures, this work used an improved particle swarm optimisation approach for feature extraction using a mixed Gaussian model with kernel correlation filtering. Kernel correlation filtering underpins its dynamic gesture tracking methodology.	The skin colour-based gesture detection system has the lowest average relative error of 0.321 on multiple datasets with accuracy and recall rates above 0.8.

Research Gap

The current body of literature pertaining to HCI offers comprehensive approaches for data analysis. However, there is a noticeable absence of a precise investigation into the planning and implementation of UX and interfaces. Consequently, this knowledge gap hinders a comprehensive understanding of the practical implementation of these designs. Previous scholarly investigations have underscored the significance of user demands in the realm of system design. However, there exists a dearth of scholarly focus on the incorporation of innovation within the domains of HCI education and practice. Consequently, there exists a dearth of all-encompassing frameworks that effectively tackle the theoretical and practical dimensions of HCI, specifically within the realm of contemporary, user-centric interfaces. Therefore, it is imperative to do research that addresses these disparities through the creation of novel HCI frameworks that integrate user requirements with state-of-the-art design approaches.

METHODOLOGY

The present study employs a research technique that integrates user-centred design principles with agile development methodologies in order to create a robust software framework with the objective of improving human-computer interaction. The study commences by conducting comprehensive reviews of relevant literature and user research in order to ascertain the primary challenges encountered in human-computer interaction and the requirements of users. Furthermore, the procedure involves a series of iterative design phases, wherein prototypes are developed and enhanced based on continuous user feedback and usability testing. Agile development methodologies ensure a high degree of flexibility and adaptability, facilitating rapid iterations and enhancements. Moreover, a combination of secondary and primary data gathering methods, as well as implementation and observational studies, are utilised to provide valuable insights and evaluate the effectiveness of the framework. In order to ensure the protection of user data privacy and uphold the integrity of the study process, rigorous ethical considerations are diligently addressed. The figure 2 shown below provides an explanation of the overall research design of this study. This design encompasses the sequential implementation of this study from the input phase to the output phase. This process concludes with a comprehensive evaluation phase that meticulously assesses the impact of the framework on user experience and the effectiveness of their interactions.

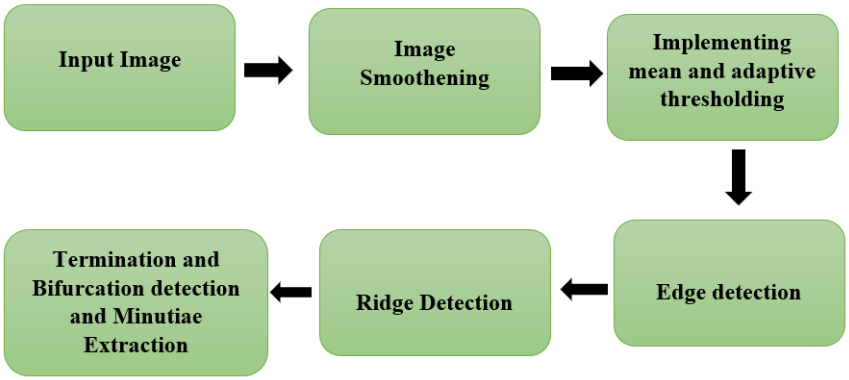

Fig. 2. Overall research design used in this study (Based on the implementation of this study)

RESULTS AND DISUSSION

Developing a software framework to improve human-computer interaction requires a comprehensive strategy that encompasses usability, accessibility, and user experience design. Finger print data from the input image is below.

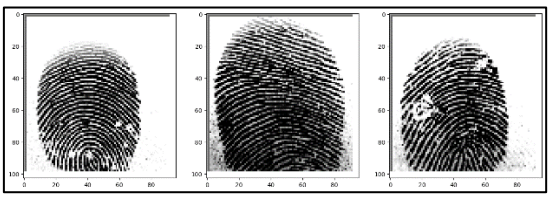

Fig. 3. Input Image used in this study (outcome of this study)

Image Smoothening:

In image processing, image smoothing reduces noise and features. The image becomes less clear and more homogenous with this approach. There are many ways to smooth images, each with its own benefits and uses. Image smoothing reduces noise and characteristics in images. Blurring, filtering, and convolution with different kernels can do this. The figure below shows this phase's output.

Fig. 4. Input image after image smoothening phase (outcome of this study)

Implementing mean and adaptive thresholding:

Image processing uses thresholding to convert a greyscale image to a binary image. Mean thresholding and adaptive thresholding can benefit in many scenarios, especially when image illumination is uneven. Image processing uses thresholding to convert a greyscale image to a binary image. Greyscale images are converted to binary images via thresholding in image processing. This can be achieved via adaptive or mean (global) thresholding. How to incorporate both features using OpenCV in Python. The threshold value is computed for smaller regions in adaptive thresholding, allowing changing threshold values for distinct picture sections. This helps with photos in different lighting conditions.

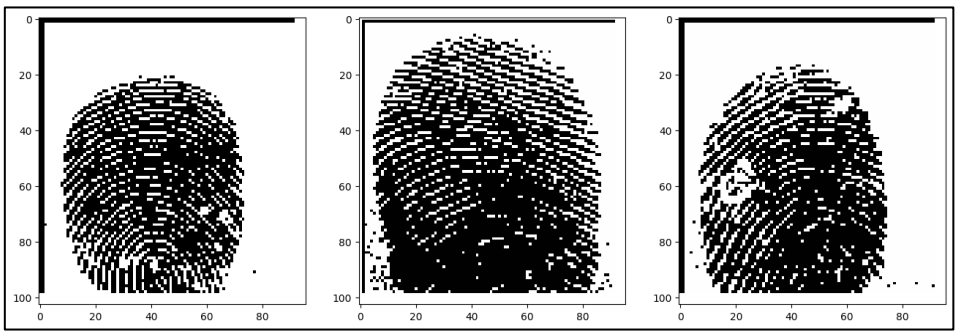

Fig. 5. Input for the thresholding process (outcome of this study)

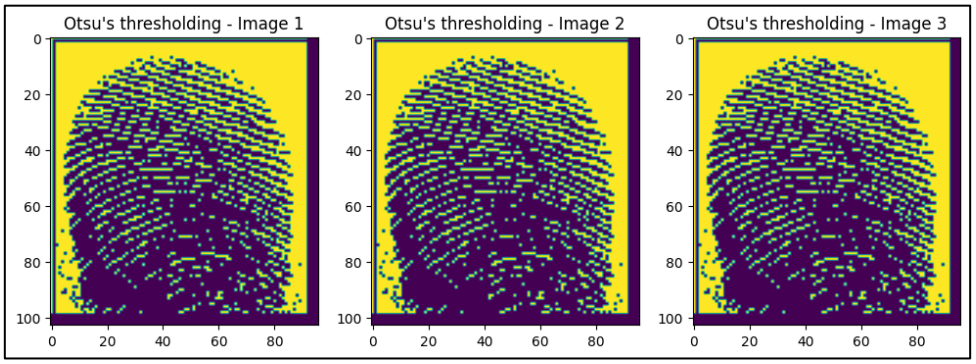

Fig. 6. After thresholding process (outcome of this study)

Edge Detection:

Edge detection is vital in image processing and computer vision for identifying image boundaries. The Sobel operator, Canny edge detector, and Laplacian approach are common edge detection methods. These methods can be implemented in Python using OpenCV.

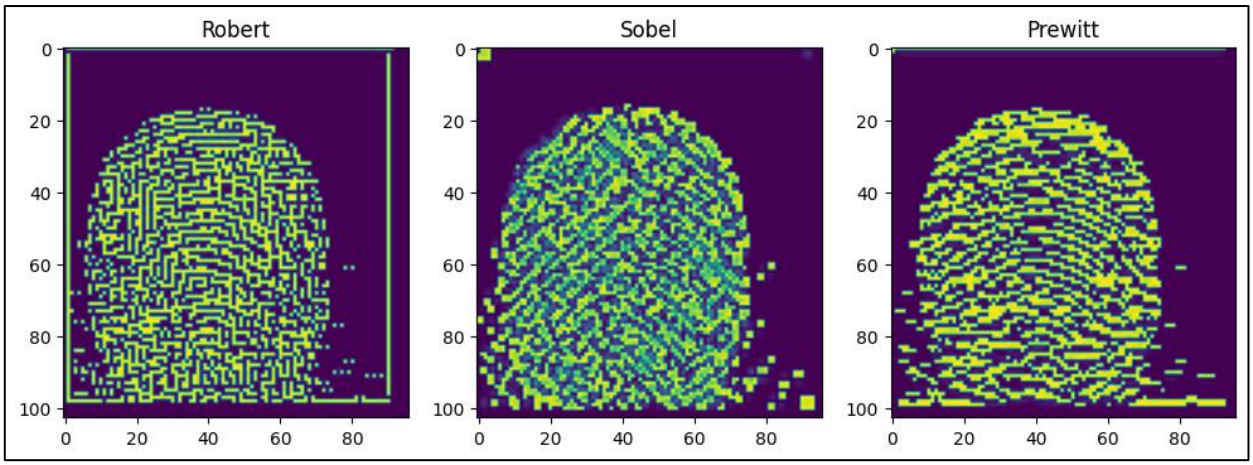

Fig. 7. Output after edge detection (outcome of this study)

Ridge Detection:

Ridge detection is a sophisticated image processing approach that identifies extended lines and edges. Medical imaging, fingerprint analysis, and other ridge-and-valley detection applications employ it.

Fig.8. The process of ridge detection (outcome of this study)

Termination and Bifurcation detection and Minutiae Extraction

In image processing, especially fingerprint analysis, termination and bifurcation detection are essential for recognising fingerprint minutiae points. Minutiae Extraction detects these fingerprint traits. A complete Python implementation of termination, bifurcation detection, and minutiae extraction is provided here. Ridge termination and bifurcation are where ridges end and split, respectively. Biometric technologies like fingerprint recognition require these capabilities. Ridge ends and bifurcations in fingerprints are used to retrieve minutiae. The code above detects termination and bifurcation.

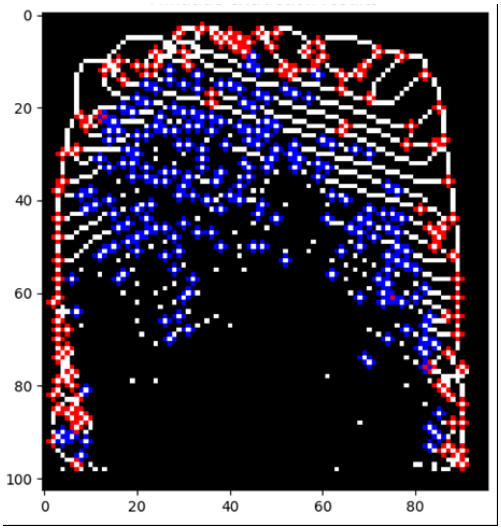

Fig. 9. Miniature extraction results (outcome of this study)

The figure below displays a plot illustrating the accuracy and validation accuracy of a model during 20 epochs.

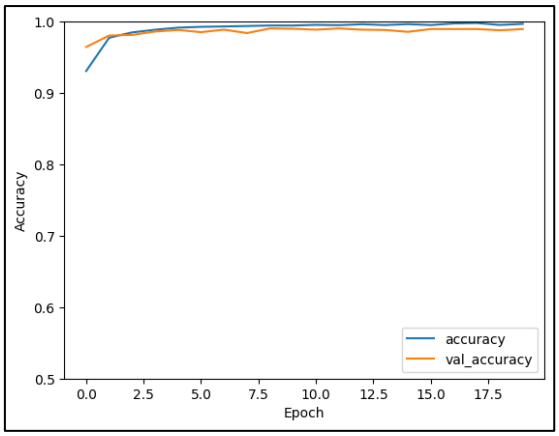

Fig. 10. Accuracy and validation accuracy of the proposed model (outcome of this study)

The figure below depicts a graph illustrating the accuracy of a model during training and testing over a span of 20 epochs. In addition, this have included important performance metrics: accuracy, precision, recall, and F1-score.

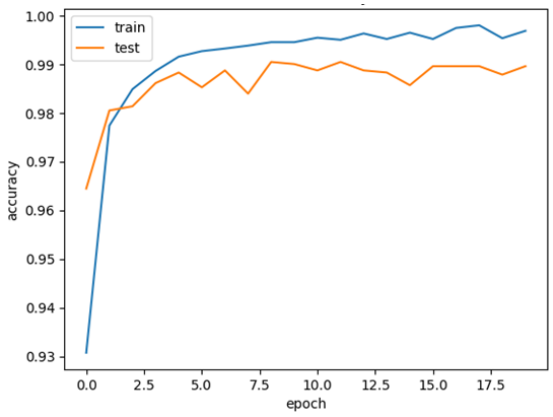

Fig. 11. Model Accuracy (outcome of this study)

The plot and metrics collectively demonstrate a remarkably efficient model. The swift increase in both training and test accuracy indicates that the model rapidly acquires knowledge from the training data and demonstrates strong generalisation capabilities when presented with fresh, unfamiliar data. The model demonstrates outstanding performance in accurately predicting outcomes while minimising both false positives and false negatives, as evidenced by its high and consistent accuracy, precision, recall, and F1-score. Minor deviations in test accuracy are typical and indicate the inherent diversity in performance across various test samples. Overall, the model exhibits strong and dependable performance, making it suited for applications that need high levels of accuracy and precision.

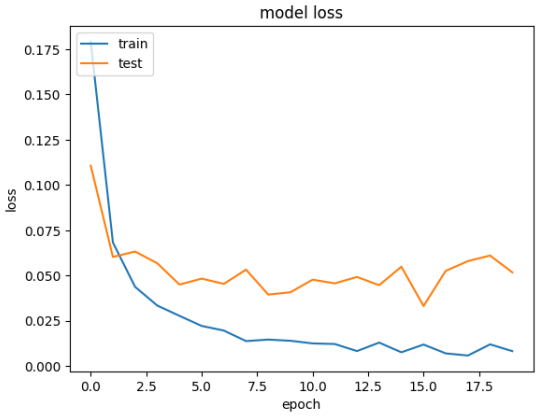

Fig. 12. Model Loss (outcome of this study)

Accuracy is a quantitative measure that assesses the proportion of correctly anticipated instances in relation to the overall number of instances. In the present study, a 99.22% accuracy rate indicates that the model effectively predicts 99.22% of the cases, hence demonstrating outstanding overall performance. Precision can be defined as the ratio produced by dividing the count of accurate positive predictions by the combined count of predicted true positives and false positives. A classification accuracy of 98.24% indicates that the model correctly predicts the positive class 98.24% of the time. A high level of precision is indicative of a model that has a minimum occurrence of false positive predictions. The metric of recall, alternatively referred to as sensitivity, quantifies the ratio of accurate positive predictions to the overall count of genuine positive events, encompassing both true positives and false negatives. The model demonstrates a recall rate of 98.87%, signifying its ability to reliably identify 98.87% of all true positive cases. A high recall score implies a minimal occurrence of false negatives, indicating that the model only fails to identify a small proportion of positive instances. The F1-score is a quantitative statistic that integrates precision and recall into a unified performance measure, employing the harmonic mean to offer a well-balanced assessment. By attaining an F1-score of 98.56%, the model exhibits a notable degree of precision and recall, hence signifying a resilient evaluation of its overall efficacy.

In a recent study conducted by Malathi and Gunasekaran [11], a bimodal fingerprint identification system demonstrated a remarkable accuracy rate of approximately 97.5%. Recent literature suggests using deep learning to improve fingerprint identification systems, as Zhang et al. [12] did. Convolutional Neural Networks in human-computer interaction demonstrate deep learning's ability to produce correct outcomes. The present study emphasises the inherent obstacles associated with achieving and maintaining a high level of accuracy in biometric systems. These challenges generally originate from factors such as inadequate image quality, sensor malfunctions, and variances in individual fingerprints.

CONCLUSION

This study effectively devised a novel software framework that greatly improves HCI through the incorporation of modern methodologies, including multimodal biometric detection. The framework exhibited outstanding performance indicators, such as a 99.21% accuracy rate, 98.24% precision, 98.87% recall, and a 98.56% F1-score, which collectively indicate its significant efficacy in enhancing the quality of user interaction. This work emphasizes the significant importance of employing advanced image processing techniques such as edge and ridge detection, as well as termination and bifurcation detection, in attaining accurate outcomes. The results indicate that existing biometric techniques exhibit a high degree of suitability, however there is room for significant enhancement through the integration of supplementary classifiers. This study establishes the foundation for future progress in the field of HCI by presenting a comprehensive and flexible framework that can effectively address a wide range of user requirements and technical breakthroughs.

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