MULTIMODAL BIOMETRIC AUTHENTICATION SYSTEM USING HUMAN FOOTPRINTS

SUMMARY OF THESIS

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SUMMARY

In this era of rapid technological advancement, global digitization has ushered a new age marked by widespread technology usage and the ubiquity of the internet, shrinking the whole world into a digital planet. The prevalence of digitization and digitalization is evident in almost all aspects of human life, including society, e-commerce, banking, governance, defense, education, health care, entertainment, business, tourism, and social relations etc. This digital transformation has led to the digitization of all operations and raised significant concerns about ever-increasing security demands. So, the need for a fast, reliable, and automated authentication system has become increasingly urgent with the global nascent challenges of identity verification. Biometric technology provides the solution to this budding problem of identity theft.

Biometrics is a combination of two terms: "Bio" (means "Biology", the scientific study of life and living organisms) + "Metrics" (a rule-based system to quantify data). So, biometrics refers to a branch of science that deals with the measurement and analysis of unique biological traits, like fingerprints, face and voice etc. to verify the identity of user based on things they have and are. Biometric recognition technology has seen a significant uptick in usage across various applications worldwide such as secure access control, mobile and commercial applications, international border crossing, criminal investigation, and law enforcement etc.. The high levels of security, speed, user convenience and authentication accuracy that biometric recognition systems provide end users are credited for their growth. There is a prevalence of various types of biological modalities, be it Physiological (e.g. face, iris, retina, fingerprints, palmprints, DNA,

ear etc.) or Behavioral (like gait, gestures, voice, keystroke dynamics etc.) used in diverse biometric recognition systems. Unlike other popular modalities, human footprints have not gained much of the wider acceptance worldwide. Also, limited research has been done in the field of foot biometry which is quite evident through the availability of shallow literature about footprint based personal recognition. This idea drove us to explore and develop inventive foot biometric methods, contributing towards its global recognition.

This dissertation provides a robust and workable concept for an unrestricted footprint recognition system by using various innovative techniques to uncover the identity of a user based on plantar footprint images of individuals. There exist different variations of multimodal biometric systems depending on the number of sensors, traits, and feature sets used like Single Biometric Trait and Multi-Sensorial, Multi-Instance and Multi-Algorithmic; And Multiple Modalities. This research work is confined to two variations: Single biometric trait and Multi-Sensorial; and Single Biometric Trait and Multi-Algorithmic Biometric Systems. In this thesis, we propose the design of a biometric system used for unconstrained footprint based personal recognition system to identify and authenticate an individual. Two datasets are used: One is in-house, created by us using a high-quality camera due to the lack of a publicly available dataset by then, while the other was obtained from Nagwanshi and Dubey's publication, which included scanned grayscale plantar footprint images. We present various novel archetype algorithms for foot feature extraction using plantar footprints based on foot shape, texture and geometry of foot. Further, Machine learning models have also been implemented using the retrieved geometrical features as an input, resulting in outstanding recognition performance for person identification. Additionally, Deep learning techniques, the most recent technological advancement,

have also been used to test their effectiveness for recognizing human footprints. The entire thesis endeavour is comprised of eight chapters, which are briefly summarized below.

CHAPTER 1

INTRODUCTION

This chapter provides a broad overview of biometrics. The basic concepts of biometrics are introduced, including their importance, various modalities, the modes of operation, existing biometric systems, and various multi-modal biometric system types. The numerous core concepts of foot biometrics are also explained, along with motivation and applications in various fields. This chapter also includes a brief description of the principal modules of the footprint biometric recognition system (FPBRS). This chapter presents a brief explanation of the various performance evaluation metrics, such as the confusion matrix and AUC-ROC curve employed in the current study.

CHAPTER 2

LITERATURE REVIEW

This chapter presents the conscientious literature study on footprint biometrics for personal recognition. Different researchers in foot biometry used diverse types of input foot samples like camera based footprint images, scanned footprints, inked footprint impressions or foot pressure distributions. Much of the literature encircles various Foot Shape, Texture and Geometry based feature extraction methods involving an implementation of LDA, ICA, COP algorithms in conjunction with diverse techniques like Hidden Markov Model, SOM, ROI, Neural Networks, Minutiae extraction, ART2, Fuzzy logic and ACO etc. Also, some research involved foot pressure distribution information and inked impressions

of foot, other than plantar footprint images for foot biometrics system. A very little literature is available about the application of machine learning and deep learning methods followed in foot biometrics which motivated us to include these new methods also in our current research work.

- Contents of this chapter are published in the article ***"Multimodal Biometrics for Personal Identification using Human Foot Prints: A Review"*** **in the Proceedings of 2nd International Conference on Advanced Computing and Software Engineering (ICACSE-2019). DOI: 10.2139/ssrn.3350259**

CHAPTER 3

PERSONAL RECOGNITION USING EIGENFEET & NEW DISTANCE METRIC

This chapter proposes an implementation of Eigenfeet approach for personal recognition using human footprints and integrating a new distance metric for matching during authentication process. On the basis of minimum distance (between test image and all the images in training image set) and recognition time elapsed, the performance of four types of distance metrics are evaluated, namely Euclidean, Manhattan, Mahalanobis and the proposed distance metric during the matching phase. According to experimental findings, when PCA and Eigenfeet are used for footprint recognition, the suggested distance metric performs much better than Euclidean, Manhattan, and Mahalanobis distance metrics. This makes it a novel and innovative endeavor. In the field of foot biometrics,

- The research work highlighting the same are published in the article ***"Novel distance metric for touch less footprint based identification technique."*** **in International. Journal of Innovative Technology Exploring Engineering**

Exploring Eng., vol. 9, issue 3, ISSN: 2278-3075, pp. 1011-1016, DOI: 10.35940/ijitee.C7967.019320.(UGC Care Listed)

CHAPTER 4

TEXTURE BASED FEATURE EXTRACTION FOR FOOTPRINT RECOGNITION

a) Rotation and Scaling Invariant Feature Extraction

In this chapter, a robust, scale and rotation invariant methodology for footprint biometrics is presented with the chronological usage of two sturdy texture based feature mining methods, namely, LBP and SIFT. LBP is a potent tool to summarize texture description using statistical analysis by thresholding the neighbouring pixels while SIFT is a method to drill down distinguishing rotation and scale invariant features from the images.

- Contents of this chapter's section are published in the article ***"Footprint Recognition Using Invariant Feature Extraction Techniques"*** **in Far East Journal of Electronics and Communications 24(2) (2021), 81-108. DOI: 10.17654/EC024020081**

b) Comparative Analysis of Texture based Feature Extraction Methods

A meticulous exploration of four texture-based feature extraction methods, namely, LBP, LPQ, SIFT, and SURF using footprints, is performed followed by matching and recognition process. Afterward, a comparative study and an analysis are carried out to check the performance of these methods for footprint recognition system. Experimental outcomes reveal that implementation of SIFT feature extraction method shows the best performance results with respect to Detected feature points, Matching

feature points, Feature matching time and Recognition accuracy in comparison with LBP, LPQ and SURF methods.

- Contents of this chapter's section are published in the article **"*Comparative Analysis of Texture based Algorithms LBP, LPQ, SIFT and SURF using Touch less Footprints*." In International Conference on Artificial Intelligence and Sustainable Engineering (AISE-2020) (pp. 423-439). Springer, Singapore**

CHAPTER 5

GEOMETRY BASED FEATURE EXTRACTION

A novel tactic for geometrical feature extraction in foot biometrics is presented in this chapter. In the proposed approach, 20 features based on foot shape geometry, are extracted that included maximum Foot Height Line (FHL), maximum Foot Width Line (FWL), and 18 other geometric features based on these two features. Finally, feature reduction technique is applied to reduce feature set into 5 dominant element feature vector followed by normalization and matching processes. The experimental results confirm a very good recognition accuracy and average matching time (less than half of a second) of proposed approach in comparison of other state of art methods.

- Contents of this chapter's section are communicated in the article entitled *"Footprint Recognition using PCA based Geometrical Feature Extraction",* to the journal: **International Journal of Image, Graphics and Signal Processing (IJIGSP) (Scopus indexed)**

CHAPTER 6

MACHINE LEARNING MODEL USING GEOMETRICAL FEATURE DESCRIPTORS

This chapter presents a novel archetype scheme for footprint recognition by amalgamating feature extraction and machine learning algorithms. The working proposal can be broadly divided into two parts; drilling down Geometrical foot Features followed by the application of supervised machine learning techniques. At first, 20 hand crafted geometric foot features are extracted from each sample footprint image which are fed into the machine learning algorithms as an input foot feature vectors in the second part of proposed technique. In this paper, three supervised machine learning methods namely regression, classification and ANNs have been applied for predicting the recognition outcomes. To measure the effectiveness of proposed algorithms, the biometric performance is tested by calculating False Accept Rate (FAR), False Reject Rate (FRR), Accuracy, Precision, Sensitivity, Specificity, F1-Score and Training Time.

- Contents of this chapter are published in the article entitled *"Machine learning based Footprint Recognition"*, **Journal of Tianjin University: Science and Technology 25(12), 914-937. doi: 10.17605/OSF.IO/DX6ZS (Scopus indexed)**

CHAPTER 7

FOOTPRINT RECOGNITION USING DEEP LEARNING

In this chapter a deep learning approach is proposed for footprint recognition. Instead of extracting handcrafted foot features (as mentioned in chapter 5), this method uses well known VGG19 deep learning model for automatic foot feature extraction using

footprint images. Afterwards, four machine learning classifiers: Gradient Booster, KNN, Random Forest and ANN are utilized and tested to govern the best accuracy. Also, a deep learning model using customized RESNET-50 is used to extract the deep features of footprints for personal recognition.

- Contents of this chapter are published in the article entitled " *Deep learning based Footprint Recognition",* **Journal of Jilin University: Engineering and Technology 42(08), 80-97. doi: 10.5281/zenodo.8255585 (Scopus indexed)**

CHAPTER 8

CONCLUSIONS AND FUTURE SCOPE

This chapter wraps up the research study by summarising the major findings concerning the study's objectives and exploring their importance and contributions. To sum up, the goal of the current research study is to create a prototype of the FPBPR (Footprint Biometric Recognition System), which will automate the identification of individuals using their footprints. This study utilizes the distinctive ability of footprints as a distinctive uniqueness feature to identify a person, similar to how other biometric modalities do, and it aids in developing a strong solution to the emergent ever-growing global issue of identity theft in today's digital world. The present research introduces cutting-edge methods for extracting and recognizing unique characteristics from human footprints. These innovative techniques will revolutionize the field and provide invaluable insights into human identification. Additionally, it examines the current research study's weaknesses and suggests areas for future research.

The current work can be further extended to newer algorithms based on modern computational methodologies with the integration of statistical and physical

features of human footprints. To create a more robust and reputable biometric system in the near future, the proposed scheme can be integrated with other feature modalities. Future research may reveal more personality traits such as gender, region-specific traits, height, weight, age, and health status etc.