DEVELOPMENT OF A MULTI-INSTANCE CONTINGENT FUSION ALGORITHM FOR THE VERIFICATION OF INFANT FINGERPRINTS

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D) DEGREE IN COMPUTER ENGINEERING IN THE DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING, COLLEGE OF ENGINEERING, COVENANT UNIVERSITY, OTA, OGUN STATE, NIGERIA

FEBRUARY, 2024

ACCEPTANCE

This is to attest that this thesis is accepted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy (Ph.D) in Computer Engineering in the Department of Electrical and Information Engineering, College of Engineering, Covenant University, Ota, Nigeria

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DECLARATION

I, ODU, TIWALADE OLUBUKOLA (CU023010092) declare that this thesis is a representation of my work, and was written and implemented by me under the supervision of Dr. Moses O. Olaniyan and Dr. Isaac A. Samuel of the Department of Electrical and Information Engineering, Covenant University, Ota, Nigeria, and Professor Tokunbo Ogunfunmi of the School of Engineering, Santa Clara University, Santa Clara, U. S. A. I attest that this thesis has in no way been submitted either wholly or partially to any other university or institution of higher learning for the award of a Doctor of Philosophy degree. All information cited from published and unpublished literature have been duly referenced.

ODU, TIWALADE OLUBUKOLA

Signature and Date

CERTIFICATION

This is to certify that the thesis titled **"DEVELOPMENT OF A MULTI-INSTANCE CONTINGENT FUSION ALGORITHM FOR THE VERIFICATION OF INFANT FINGERPRINTS"** is an original research work carried out by **ODU, TIWALADE OLUBUKOLA (CU023010092),** in the Department of Electrical and Information Engineering, Covenant University, Ota, meets the requirements and regulations governing the award of Doctor Philosophy (Ph.D) degree in Computer Engineering and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to the Almighty God who strengthened and helped me through this programme, the memory of my father, Dcn. Moses Akano Majekodunmi and my ever-supportive family. I am grateful for the privilege to make you proud.

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LIST OF ABBREVIATIONS

AUC	Area under the ROC curve
EER	Equal Error Rate
FBI	Federal Bureau of Investigation
FMR	False Match Rate
FMR100	The lowest FNMR for FMR <= 1%
FMR1000	The lowest FNMR for FMR <= 0.1%
FNMR	False Non-Match Rate
IAFIS	Integrated Automated Fingerprint Identification System
ppi	Pixel per inch
ROC	Receiver Operating Characteristic
SDG	Sustainable Development Goal
UNICEF	United Nations Children's Fund
WHO	World Health Organisation
ZeroFMR	The lowest FNMR for FMR = 0%
ZeroFNMR	The lowest FMR for FNMR = 0%

ABSTRACT

Birth registration is a fundamental right for children, but approximately 237 million children below the age of 5 lack proper documentation, making them vulnerable to identity theft, newborn swapping, and child abduction. Traditional birth certificates are not reliable as they can be falsified or stolen. To address this issue, biometric birth registration, specifically using fingerprints, offers a digital identity that can last a lifetime. While other biometric traits like face, iris, palmprint, and footprint have been explored, fingerprints are the most widely accepted due to their ubiquity, ease of acquisition and widespread acceptance. However, challenges in infant fingerprint recognition include intra-class variation, the need for robust algorithms for low-resolution fingerprint images, and a lack of publicly available demographic infant fingerprint datasets. Therefore, this study aims to create a relevant dataset of infant fingerprints and develop a multi-instance contingent fusion algorithm to verify these fingerprints. The study involved obtaining fingerprints from 250 infants aged 1 day to 10 months using a fingerprint reader with a resolution of 500 ppi. The acquired fingerprints were pre-processed, and minutiae features were extracted using the MINDTCT algorithm. The extracted features of the enrolment and query fingerprints were compared using the BOZORTH3 matching algorithm, and a match score was obtained. This match score was compared to a threshold, with scores below the threshold resulting in the rejection of the infant's identity and scores above the threshold accepting it. The multi-instance contingent fusion algorithm was developed to accommodate situations where a baby's identity cannot be verified with one finger. It allows for verifying the baby's identity using a second finger. If both fingers fail to verify the identity, the match scores from both fingers are fused and compared to a predetermined threshold. The infant's identity is considered genuine if the fused score surpasses the threshold. Conversely, the baby's identity is only denied if the fused score falls below the threshold. The uniqueness of contingent fusion is that the match scores are only fused when neither of the two fingers can verify the infant's identity, thereby reducing computational complexity. The results show that for infants between 0 – 3 months old at the time of enrolment, without the multi-instance contingent fusion algorithm, the system generated verification accuracies of 34.1%, 35.71% and 11.9% for time-lapses of 1 month, 3 months and 6 months respectively, between enrolment and query fingerprints while the multi-instance contingent fusion algorithm generated verification accuracies of 73.8%, 69.05% and 57.14% for time lapses of 1 month, 3 months and 6 months respectively, between enrolment and query fingerprints. In conclusion, a dataset of infant fingerprints with a resolution of 500 ppi was developed, and the identities of babies older than 6 months were successfully verified with the fingerprint images acquired when they were younger than 6 months by employing the developed multi-instance contingent fusion algorithm. Longitudinal acquisition of infant fingerprint images and the inclusion of ancillary information, like gender and ethnicity, are therefore recommended to improve the accuracy of the verification system.

Keywords: contingent fusion, digital identity, infant fingerprint dataset, intra-class variation