Developing a framework for using face recognition in transit payment transactions

تطوير إطار مفاهيمي لاستخدام التعرف على الوجوه في معاملات الدفع العابرة

by

ORABI MOHAMMAD ABDULLAH HABEH

Dissertation submitted in fulfilment

of the requirements for the degree of

MSc INFORMATION TECHNOLOGY MANAGEMENT

at

The British University in Dubai

November 2021

DECLARATION

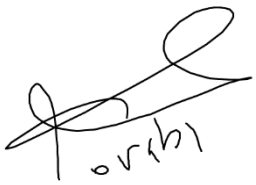
I warrant that the content of this research is the direct result of my own work and that any use made in it of published or unpublished copyright material falls within the limits permitted by international copyright conventions.

I understand that a copy of my research will be deposited in the University Library for permanent retention.

I hereby agree that the material mentioned above for which I am author and copyright holder may be copied and distributed by The British University in Dubai for the purposes of research, private study or education and that The British University in Dubai may recover from purchasers the costs incurred in such copying and distribution, where appropriate.

I understand that The British University in Dubai may make a digital copy available in the institutional repository.

I understand that I may apply to the University to retain the right to withhold or to restrict access to my thesis for a period which shall not normally exceed four calendar years from the congregation at which the degree is conferred, the length of the period to be specified in the application, together with the precise reasons for making that application.



Signature of the student

COPYRIGHT AND INFORMATION TO USERS

Abstract

Nowadays, significant number of people relays on public transportation to commute to their final distention due to the increase of the private cars cost, traffic jam, toll gates, high petrol charges and other factors, which create a huge pressure on the public transportion infrastructure in general and the fare collection system in specific. Therefore, transit operators are continuously keen to identify different solutions to reduce that pressure and improve the travel experience by upgrading its fare collection system to the advanced state-of-the-art account based ticketing system in order to achieve better flexibility to offer smooth and convenient payment options for the passengers to choose.

On the other hand, a tremendous advancement has been noticed in the human face detection and recognition technology which mainly used to authenticate and identify person face from a group of people through detecting a unique feature of the face and ignore the background image then compare the outcomes with the registered faces in the database to identify the person.

This dissertation proposes a framework which aims to offer face recognition technology as a new payment option inside metro station. The proposed framework involves the hardware, software, algorithms, and system specification requirements. Further, it provides a detailed end-to-end systems integration and transaction flow between the account-based ticketing, face recognition, and banking systems. It's worth to mention that the proposed framework is built based on the outcomes of three dimensions, including a systematic literature review, users' surveys, and experts' surveys. 84% of the users expecting an improvement to their travel experience if the face recognition access offered. In addition, the experts supported the users' survey results by claiming the optimum technical feasibility to implement the face recognition access inside metro station.

The framework offers two state-of-the-art solutions. The first solution is proposed based on integrating the existing surveillance camera systems with the recommended "Banking Payment Context- Account Based Ticketing System" to offer face recognition access entry to the passenger inside metro station. A number of combined algorithms and classifiers are proposed to use in this solution based on the encouraging outcomes observed from the systematic literature review and experts' survey, including Local Binary Pattern descriptor, Haar-Like Descriptor, Ada Boost, Cascade classifiers, Affine Transformation, Histogram Equalization, Gaussian Filter, Principal Component Analysis which are embedded in OpenCV or MATLAB application. The argued face recognition accuracy between 98%-99.2% and average processing

time including metro gate opening time ranges between 1114-1400 milliseconds. This solution considers an effective cost-based solution.

The second solution is proposed based on implementing a dedicated full HD face recognition stereo camera system on top of each metro gate and integrate it with the recommended "Banking Payment Context- Account Based Ticketing System" by using the MFcoface face recognition method which results from the systematic literature review and experts' outcomes. The argued face recognition accuracy ranges between 99.3%-100% and average processing time including metro gate opening time ranges between 200-400 milliseconds. This solution considers an efficient performance-based solution.

ملخص

في الوقت الحاضر ، يعتمد عدد كبير من الأشخاص على وسائل النقل العام للانتقال إلى وجهتهم النهائية وذلك لأسباب عدة منها: زيادة تكلفة السيارات الخاصة والإزدحام المروري على الطرق وبوابات التعرفة المرورية ورسوم الوقود المرتفعة وعوامل أخرى، مما يخلق ضغطًا كبيرًا على البنية التحتية للنقل العام بشكل عام وعلى نظام تحصيل الأجرة بشكل خاص؛ لذلك يحرص مشغلو الخدمة باستمرار على إيجاد الحلول المختلفة لتقليل هذا الضغط وتحسين تجربة السفر من خلال ترقية نظام تحصيل الأجرة إلى نظام التذاكر المتطور المعتمد على اللإقتطاع الفوري للأجرة من الحساب وذلك من أجل تحقيق مرونة أفضل في النظام لتقديم خيارات دفع مريحة للركاب.

من ناحية أخرى، لوحظ تقدم هائل في تقنية التعرف على الوجه البشري والتي يتم من خلالها المصادقة والتعرف على وجه شخص ما من بين مجموعة من الأشخاص وذلك من خلال اكتشاف الميزات الفريدة للوجه وتجاهل كافة المعالم الأخرى المحيطة بالصورة ثم مقارنة النتائج مع الوجوه المسجلة في قاعدة البيانات لتحديد هوية الشخص.

تقترح هذه الرسالة إطارعمل يهدف إلى توفير تقنية التعرف على الوجوه كخيار دفع جديد داخل محطة المترو. حيث يتضمن إطار العمل المقترح على مواصفات الأجهزة والنظام والبرامج والخوارزميات المطلوبة؛ بالإضافة إلى ذلك، فإنه يوفر نموذجاً مفصلاً لعمليات الربط بين الأجهزة والأنظمة المعنية وآلية تدفق المعاملات من خلال نظام تحصيل الأجرة المعتمد على الحساب، نظام التعرف على الوجه والنظام المصرفي. من الجدير بالذكر أن الإطار المقترح بني على أساس ثلاثة محاور رئيسية حيث تتضمن مراجعة منهجية لكافة الأبحاث المتوفرة في هذا المجال،ونتائج إستبيان المستخدمين والخبراء. 84٪ من المستخدمين يتوقعون تحسنًا في تجربة السفر في المترو إذا تم توفير خدمة الدفع باستخدام تقنية التعرف على الوجه، وتدعم نتائج استبيان الخبراء هذه النتائج من خلال اقتراح التقنية والأنظمة الأمثل لتوفيرهذه الخدمة .

يقدم إطار العمل حليين كالاتي: الحل الأول يعتمد على دمج أنظمة كاميرات المراقبة الحالية في محطات المترو مع نظام تحصيل التذاكر المحدث والموصى به (بانكينج بيمنت كونتكست)، وذلك لتوفير خدمة التعرف على الوجه للراكب من خلال أنظمة المراقبة المتوفرة.

الخوارزميات التالية التي تم إستخدامها في تطوير هذا الحل: (وصف هار لايك،وصف النمط الثنائي المحلي، وصف أ.د.أ بوست، المصنفات المتتالية، التحويل الأفقي، معادلة الرسم البياني ، مرشح غاوسي ، خوازمية تحليل المكونات الرئيسية) واللتي تم تضمينها في إحدى تطبيقات (اوبن.سي.في) أو (مطلب). حيث تم إعتماد هذه الخوارزميات بناءًا على نتائج الدراسات والأبحاث المنهجية المنظمة في هذا المجال بالإضافة إلى نتائج الإستبيان.

تتراوح دقة التعرف على الوجه ما بين 98٪ -99.2٪ ومتوسط وقت المعالجة بما في ذلك الوقت المطلوب لفتح بوابة المترو ما بين 1114-1400 ملل ثانية، حيث يعتبر هذا الحل حلاً فعالاً من حيث التكلفة.

الحل الثاني يعتمد على تركيب نظام كاميرا استيريو جديدة فوق كل بوابة مترو، ومخصص للتعرف على الوجه بدقة عالية جدًا ودمجه مع نظام تحصيل التذاكرالمحدث والموصى به (بانكينج بيمنت كونتكست) باستخدام خوارزمية (م.ف.كو.فيس) للتعرف على الوجه والتي تم إعتمادها بناءًا على نتائج الدراسات والأبحاث المنهجية المنظمة في هذا المجال بالإضافة إلى نتائج إستبيان الخبراء.

تتراوح دقة التعرف على الوجه ما بين 99.3٪ -100٪ ومتوسط وقت المعالجة بما في ذلك الوقت المطلوب لفتح بوابة المترو ما بين 200-400 ملل ثانية. حيث يعتبر هذا الحل حلاً فعالاً من حيث الأداء.

Dedication

I dedicate my dissertation to whom who wish me success, and to each and every one who supported me during this exciting journey, and in specific to my beloved family, my wife, my kids and my colleagues who helped me from all aspects and plays significant role in my success.

Acknowledgement

First and foremost, I thank Allah for giving me the strength, health, passion, knowledge, and patience to achieve this work.

I am pleased to acknowledge and deeply grateful and thankful to my supervisors, **Prof. Khaled Shaalan and Dr. Mostafa Al-Emran** for their extreme support to make this work possible. Your invaluable prompt advice, guidance and notes carried me all the way to complete this work.

In addition, I would like to acknowledge and sincerely thank **Prof. Sherief Abdullah** for the knowledge I've acquired to complete the proposal of this work.

Table of contents

List of tables

List of Figures

List of appendixes

1 Chapter One: Introduction

This chapter provides an introduction to the dissertation subject, problem definition, research motivations, objectives of this research, dissertation questions and structure.

1.1 Introduction

Today, several transit operators continuously identify the best possible ways to encourage passengers to optimize their trip duration as much as possible in order to reduce the huge pressure and demand on the transit infrastructure; in addition, lower the people crowd inside the stations especially during peaks hours (Handte et al., 2014).

One of the solutions transit operators optimized is the cash payment to ride bus or metro, which was replaced with the transport cards which linked to the automated fare collection system and valid for several years; therefore, passengers doesn't need to buy a ticket or pay cash to ride metro or bus anymore, instead the transport card and tap it to ride. Although, this solution significantly reduces passenger durations inside metro or bus station, but it still has some challenges; for instance, passengers are required to stay in the queues to buy or recharge the transport card with the minimum amounts due to the fear of losing card which holds the electronic balance in it; thus, increase crowed inside the station and add more pressure on the ticket office operators which increase cost of operations.

1.2 Facial detection and recognitions overview

In fact, the key important and essential step of the real-time face recognition is the detection and localization of the human face from the captured image taken from a real-time video camera, followed by image normalization, filtration, noise removal then identifying image features to recognize the face and match it with stored face image records in the database(Awais et al., 2019).

Furthermore, facial recognition access control technology consider relativity new and interesting filed for the researchers to develop and improve it, due to its significant benefits and the wilder use in the basic and complex environments. However, few research's focus has been noticed in specific to claim an efficient utilization of the facial recognition technology as access control in a complex environment; for example, offering metro gate access using face resignation as new service.

1.3 Problem Definition and motivation

Marjory of the countries strives to improve its transportation infrastructure in order to improve its commuter's life style, align with the its smart cities strategies to attract investors to the city.

However, according to several studies, the huge increase of population creates significant demand on the legacy metro AFC systems. Thus, it increase the pressure on the infrastructure which leads to lengthy queues and additional waiting time to prove passenger payment to ride metro (Kumar Sarkar and Jain, 2017).

Moreover, according to Chira-Chavala and Coifman, (2019), passengers may forget or lost their phone/transport card or ticket which are the only payment means to access metro. Thus, it creates a bad travel experience and a new challenge for the transit operators to manage the huge demand of the cards or tickets especially during peaks hours.

On the same note, according to Milioti et al., (2020), transit operators always consider fare evasion as significant threat and revenue lose. Therefore, there's a significant need for a deep dive study to identity the optimum end-to-end solution to be offered to the transit operators in order to mitigate the pressure on the infrastructure for smooth entry to the paid areas inside metro stations. This would improve the travel experience, optimize operation cost, reduce fraud, increase surveillance monitoring, and reduce fare evasion.

1.4 Dissertation Objective

1. Examine the most popular real-time face recognition techniques and algorithm and identify the optimum algorithm and techniques recommended to utilize it in a real-life complex environment based a systematic literature review.
2. Publish an online survey targeting transit users and an expert questionnaire targeting face recognition experts in order to collect passengers and experts' feedback about the current real-life business and technical challenges associated to the existing transport card or ticket payment options; in addition, collect potential requirements, challenges and risks of enabling facial recognition access control technology as a new payment option inside metro station.
3. Build a framework which present the end-to-end solution based on the systematic literature review, online survey and expert's questionnaire outcomes, with the argument of utilizing the framework as a pilot inside metro station, and the potential to apply it in similar access control complex environment for future work.

1.5 Dissertation questions

The following research questions are the primary focus to address in this dissertation:

Question 1: What are the most popular real-time face detection and recognition techniques and its key challenges?

Question 2: Which are the most recommended face detection and recognition algorithms might be applicable to implement in real-life complex environment (Metro)?

Question 3: What are the passengers and transit expert's feedback on enabling face recognition as new payment mean to access and ride metro?

Question 4: What is the recommended end to end architecture framework that provides the best outcomes to be utilized in a real-life environment?

1.6 Dissertation Structure

This dissertation has been divided into five chapters as per the following:

1. Chapter one present a brief overview of the research including problem definition, research objectives and motivations, dissertation questions and structure.
2. Chapter two provides a systematic literature review which contains a set of the most common literatures in the context of face recognition access control in metro and account based ticketing system definition. The outcomes of this chapter should address the first and second dissertation questions.
3. Chapter three present research methodology and data analytics; in addition to the results of the online survey and expert's questionnaire. The outcomes of this chapter should address the third dissertation question.
4. Chapter four present the conceptual framework as a result of the systematic literature review, online survey and expert questionnaires. the outcomes of this chapter should answer the fourth dissertation question.
5. Chapter five provides a conclusion of the dissertation which consist of a brief answer to each dissertation question, contributions, practical implication, limitations and future work.

2 Chapter Two: Systematic Literature review (SLR)

This chapter discusses the state-of-the-art face recognition methods and account based ticketing system; in addition, it highlights the key challenges of this technology throughout a systematic literature review.

2.1 Method

Method planned to utilize in the Systematic Literature review (SLR) will be based on Kitchenham, (2007) approach which aimed to collect and evaluate all available resources to answer the SLR questions within the research area; moreover, the steps of the SLR are followed Kitchenham, (2007) approach as per the following stages:

1- Planning
2- Collecting
3- Analyzing
4- Selecting
5- Report finding

2.2 Planning stage

This stage details the objectives of the research and state the research questions as per the following:

2.2.1 Objectives and research questions

Nowadays, majority of the countries are continuously trying to identify the optimum solutions to upgrade its fare collection systems to decease the pressure and overcrowd inside metro stations through upgrading the automated fare collection system and facilitate the face detection and recognition technology as new payment mean to access the paid area's; thus, create effective, efficient and smooth transit payments eco-system to improve people's lifestyle (Elhamshary et al., 2018).

Therefore, objectives of the SLR to identify the relevant research papers, compare and contrast the selected research papers, in order to validate the most relevant state-of-the-art real-time face detection and recognition techniques which capable to implement in a real-life complex environment; for instance, face recognition access inside metro, and answer the following research questions:

1. What are the studies clearly stating the problem and challenges of face detection and recognition technology?

2. What are the studies illustrating the methods or techniques used for the face detection and recognition technology and supported by an experiment?
3. What are the studies use method comparison approach to strengthen its claimed resolution and recommendation?

2.3 Collecting stage

2.3.1 Search strategy

The search database, journals and search keywords are prepared and identified according to the research questions and the illustration of the research objectives and its topic; for example, science direct, IEE and springer(Zahedi et al., 2016).

2.3.2 Search criteria – Keywords identification

Search criteria implemented in this systematic literature review used the below approach:

- First string: Real time face recognition, facial recognition through surveillance camera, transit fare with facial recognition, real time biometric payment systems in metro with, face recognition challenges, account based ticketing system.
- Second string: real time face recognition methods, real time face detection methods, face recognition techniques, face recognition experiment, solutions of the real time face recognition challenges.

Search plan created according to the stated strings and applied in the following journals and database resources:

- Google scholar
- science direct
- IEEE
- EBSCO
- ProQuest
- Springer
- British university in Dubai library

Keywords used based on the stated strings, either as a combined strings or separately, also keyword search targeted the research title and/or abstract, and/or full text; for instance, (ab:“real time face recognition in metro”, ab: “real time face recognition challenges”, ab & ti: “real time face recognition”, ab & ti: “real time face recognition challenges”, ab & ti: “real time face detection challenges”, ab or ti: “face recognition access control”, ab or full: “real time

face recognition", ab or full: "real time face recognition solution", ab or full: "real time face recognition payment", ab or full: biometric payment in metro, ab or full: "transit fare with facial recognition", ab or full: "metro payment with face recognition", ab or full: "account based ticketing system").

Although, keywords selection was based on the two strings stated above, the SLR questions are taken into consideration while identifying the keywords (Kitchenham, 2007).

2.3.3 Inclusion/exclusion criteria

Inclusion and exclusion criteria stage consider one of the most significant step of the SLR stages; moreover, filtering and selecting the relevant research papers will highly dependent on this stage; therefore, inclusion and exclusion criteria must be very precise and relevant to the SLR objective and research questions (Kitchenham, 2007).

As a result, the following Table 1 illustrate in depth the inclusion and exclusion criteria's relevant to the SLR objectives and research questions:

Inclusion criteria	Exclusion Criteria
Should include face recognition/ Biometric method or technique	Systems or algorithms not used for real time face recognition
Can include face recognition in transit systems	Object detection systems not used for Face recognition
Should Include face recognition experiment or survey	Experiment without dataset or survey without sufficient sample
Should be written in English language	Studies used languages other than English

Table 1:Inclusion and Exclusion Criteria

2.4 Analysing and evaluating stage

2.4.1 Quality assessment

Quality assessment of the research papers plays significant role in evaluating the selected papers, along to the inclusion and exclusion criteria stage (Al-Emran et al., 2018). Table 2 present 6 checklist criteria which used to assess the quality of the selected research; however, the presented checklist was not designed to disqualify any research studies in any means (Kitchenham, 2007).

Questions
1. Are the objectives of the research paper clearly stated?
2. Is the research paper use a scientific statistical method to argue the outcomes of the experiment or survey?

3.	Are the claimed face recognition techniques clearly applied in the experimental?
4.	Did the proposed solution or conclusion achieve research objectives and solve the claimed problem?
5.	Are the methods and techniques used in the experiment clearly stated?
6.	Are the datasets used in the experiment sufficient enough to conduct the experiment and claim the argued outcomes?

Table 2: Quality Assessment Chick List

In fact, and as highlighted in Table 3, a score assigned to each research question based on three-point groups. The first group "Yes" equals to 1=100% which means the selected paper can fully answer the stated SLR questions, and second group "Partially" equals to 0.5=50% which means the selected paper can partially answer the stated SLR questions, and the third group "No" equals to 0=0% which means the selected paper cannot answer the stated SLR questions.

Research questions	Yes	Partially	No
Q1	1 = 100%	0.5 = 50%	0 = 0%
Q2	1 = 100%	0.5 = 50%	0 = 0%
Q3	1 = 100%	0.5 = 50%	0 = 0%

Table 3: Groups Scoring formula

** Qualification formula: Total score >= 80%

2.5 Selecting stage

2.5.1 Data Filtration and extraction

Papers filtration and selection mechanism shown in Figure 1 reflects the end-to-end process of the search activities which results to N=988 studies identified excluding published studies before 2016 and based on the search criteria section highlighted previously; moreover, and after excluding duplicate studies N=547.

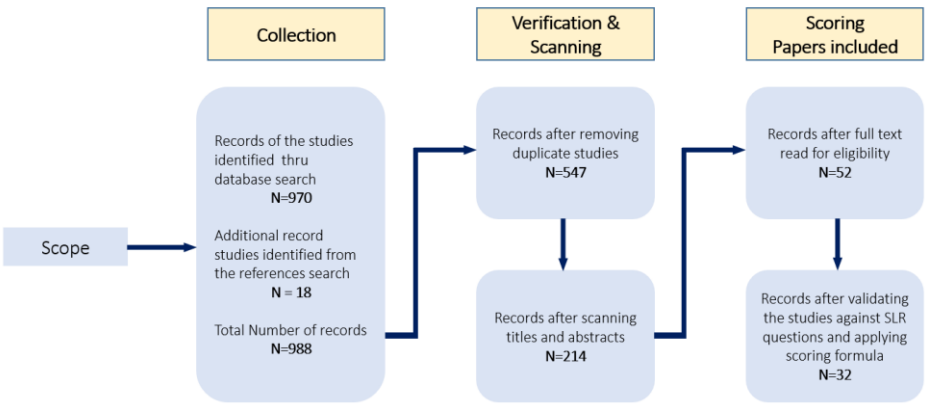


Figure 1: Filtration Process

After skimming through the title, abstract and conclusion N=214, and after reading and assessing the full text and applying the inclusion and exclusion criteria N=52; finally, after verifying and validating each research study against the scoring formula based on the SLR questions presented in Table 4 N=32.

In fact, the qualification mechanism of the final round of selection was based on the scoring formula presented in Table 3, where the total score of each study selected and qualified for further analyses must be equal or more than 80%.

Study	Study Title	Q1: Challenges	Q2: Methods Techniques	Q3 : Experiment/ Comparison	Total	Percentage	Status
S1	Real-Time Surveillance Through Face Recognition Using HOG and Feedforward Neural Networks	1	1	0.5	2.5	83%	In
S2	ArcFace: Additive Angular Margin Loss for Deep Face Recognition	1	1	0.5	2.5	83%	In
S3	CNN Based Key Frame Extraction for Face in Video Recognition	0.5	1	1	2.5	83%	In
S4	CosFace: Large Margin Cosine Loss for Deep Face Recognition	1	1	1	3	100%	In
S5	Multi-Order Statistical Descriptors for Real-Time Face Recognition and Object Classification	1	1	1	3	100%	In
S6	Object Detection in Videos by High Quality Object Linking	1	0.5	1	2.5	83%	In
S7	Minor Privacy Protection Through Real-time Video Processing at the Edge	1	1	0.5	2.5	83%	In
S8	SFace: An Efficient Network for Face Detection in Large Scale Variations	1	0.5	1	2.5	83%	In
S9	Analysis and fast feature selection technique for real-time face detection materials using modified region optimized convolutional neural network	0.5	1	1	2.5	83%	In
S10	A Comparison of CNN-based Face and Head Detectors for Real-Time Video Surveillance Applications	1	1	0.5	2.5	83%	In
S11	Faster Than Real-time Facial Alignment: A 3D Spatial Transformer Network Approach in Unconstrained Poses	1	0.5	1	2.5	83%	In
S12	Biometric Bus Ticketing System In Mauritius	1	1	0.5	2.5	83%	In
S13	Distributed Video Surveillance Using Smart Cameras	1	1	0.5	2.5	83%	In
S14	Face detection and tracking: Using OpenCV	0.5	1	1	2.5	83%	In
S15	Development of Real Time Face Recognition System Using OpenCV	1	1	0.5	2.5	83%	In
S16	Face Recognition at a Distance for a Stand-Alone Access Control System	1	1	1	3	100%	In
S17	Face recognition with Bayesian convolutional networks for robust surveillance systems	1	1	0.5	2.5	83%	In
S18	FaceSurv: A Benchmark Video Dataset for Face Detection and Recognition Across Spectra and Resolutions	1	1	0.5	2.5	83%	In
S19	Fare Calculation System Using Face Recognition	1	1	0.5	2.5	83%	In
S20	Towards Facial Recognition Problem in COVID-19 Pandemic	1	1	0.5	2.5	83%	In
S21	Improved Viola-Jones face detection algorithm based on HoloLens	1	0.5	1	2.5	83%	In
S22	Video-based person re-identification via spatio-temporal attentional and two-stream fusion convolutional networks	1	1	1	3	100%	In

S23	Optimal face templates: the next step in surveillance face recognition	1	0.5	1	2.5	83%	In
S24	Ordered Weighted Aggregation Networks for Video Face Recognition	1	1	0.5	2.5	83%	In
S25	FaceBoxes: A CPU Real-time Face Detector with High Accuracy	1	1	1	3	100%	In
S26	Real-Time Face Detection and Recognition in Complex Background	1	1	1	3	100%	In
S27	Face Detection using Deep Learning: An Improved Faster RCNN Approach	0.5	1	1	2.5	83%	In
S28	Influence of low resolution of images on reliability of face detection and recognition	1	0.5	1	2.5	83%	In
S29	A novel facial image recognition method based on perceptual hash using quintet triple binary pattern	1	1	0.5	2.5	83%	In
S30	YOLO-face: a real-time face detector	1	1	1	3	100%	In
S31	SwiftFace: Real-Time Face Detection	1	1	0.5	2.5	83%	In
S32	MFCosface: A Masked-Face Recognition Algorithm Based on Large Margin Cosine Loss	1	1	1	1	100%	In
S33	A Review of Big Data Applications in Urban Transit Systems	1	1	0	2	67%	Out
S34	Research on the application of face recognition system	1	1	0	2	67%	Out
S35	Facial Recognition in the Public Sector: The Policy Landscape	0	1	1	2	67%	Out
S36	Track recognition algorithm based on neural network for rail transit	1	0.5	0.5	2	67%	Out
S37	Raspberry Pi assisted face recognition framework for enhanced law-enforcement services in smart cities	1	0	1	2	67%	Out
S38	Deep face recognition using imperfect facial data	0	0	1	1	33%	Out
S39	Deep face recognition: A survey	0	1	0.5	1.5	50%	Out
S40	Recent development in face recognition	0	0.5	1	1.5	50%	Out
S41	Cross-resolution learning for Face Recognition	0.5	0.5	0.5	1.5	50%	Out
S42	Sparse graphical representation-based discriminant analysis for heterogeneous face recognition	0.5	0.5	1	2	67%	Out
S43	A survey on techniques to handle face recognition challenges: occlusion, single sample per subject and expression	0	0	0.5	0.5	17%	Out
S44	An Adaptive Non-Symmetric Fuzzy Activation Function-Based Extreme Learning Machines for Face Recognition	1	1	0	2	67%	Out
S45	Classical and modern face recognition approaches: a complete review	1	1	0	2	67%	Out
S46	Efficient covering of target areas using a location prediction-based algorithm	0	1	1	2	67%	Out
S47	Real Time Automatic Attendance System for Face Recognition Using Face API and OpenCV	1	0.5	0.5	2	67%	Out
S48	Unconstrained Face Detection: State of the Art Baseline and Challenges	1	1	0	2	67%	Out
S49	3-D face recognition: features, databases, algorithms and challenges	0	0.5	1	1	33%	Out
S50	Scalable biometric travel token without barriers to access	0	0	0.5	0.5	17%	Out
S51	3D face recognition: a survey	0	0.5	1	1.5	50%	Out
S52	Low-resolution face recognition with single sample per person	0.5	0.5	0.5	1.5	50%	Out

Table 4: Evaluation and Selection of the research studies

2.5.2 Research study analyses and Data coding

Research methodology and quality assessment adopted of the selected research studies are outlined based on the following Data coding aspects and detailed in table 5:

1. Research method used.
2. Method of collecting data.
3. Type of data Analysis.
4. Year of publication.
5. Number of citations.
6. Journal Rating

Research Method	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32
Case Study																																
Comparative causal mapping																																
Experiment	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Survey												√																				
Focus Group																																
Discussion	√				√					√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√		√	√	√
Unclear																																
Qualitative																												√			√	√
Quantitative	√	√		√	√			√	√				√		√	√			√	√	√			√	√	√			√	√	√	√
Mixed			√				√			√	√	√		√			√	√				√					√					
Unclear																																
Study Setting																																
Academic												√																				
Industry																															√	√
Interview												√																				
Dataset (Data Science)	√	√	√	√		√		√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Archival Record										√	√	√	√					√														
Observation														√			√					√	√									√
Questionnaire																																
Workshop																																
Focus Groups																																
Not available																																
Unclear																																
Year of publication	2019	2019	2018	2018	2018	2020	2020	2018	2021	2017	2017	2019	2019	2017	2017	2020	2019	2019	2019	2020	2019	2019	2020	2021	2017	2017	2018	2016	2020	2021	2020	2021
Citation	9	1873	1066	14	13	3	4	17	2	17	93	3	18	35	8	13	22	5	3	7	15	28	1	0	152	26	343	63	4	41	3	2
Journal Rating (SJR) -H - Index	127	406	406	20	127	13	46	NA	47	41	279	18	53	8	325	172	40	10	7	15	40	157	55	157	21	29	143	70	70	13	9	52

Table 5: Data coding selected papers

In addition, a brief summary of each selected paper outlines based on the following data coding aspects, and detailed in table 6 (Appendix 1)

1. Problem statement/objectives.
2. Approach/Key points.

3. Results/Findings
4. Dataset/Evaluation
5. Dataset/sample size.
6. Research recommendations.

2.6 Literature review

In the recent years, and according to several studies real time face detection and recognition technology becomes more popular and extensively utilized in the video surveillance cameras to offer different security services, which creates significant demand to improve this technology and mitigate the accuracy, performance, heavyweight computational requirements challenges observed in this technology and application; for example, large-volume video footage and live video surveillance; moreover, and according several studies the most popular architecture methods used for face detection and recognition is the convolutional neural network(CNN) (Qi et al., 2018).

Significant portion of the literature review investigate and analyse the different state-of-the-art claimed solutions, application, algorithms or methods applicable to enable and use it as an access to the unpaid area's using customer faces as a key authentication method to deduct the exact fare.

In fact, and based on the selected studies the efficiency of the face detection and recognition methods are vary based on several factors; for example, video image resolution, image illumination, image pose, gender, age, skin color, detection and accuracy level required to extract the image from the real time video then detect the face from the image, processing speed required to recognize the face and match it with the current database to come-up with the desired outcomes, and the most recent challenge is the facemasks which becomes a mandate to wear it all the time due to Covid-19 pandemic.

Each selected studies included in the SLR concentrate in one or many strengths based on four pillars (face detection, face recognition, processing speed and account based ticketing system); however, and in specific to "face detection, face recognition and processing speed " the intention of the SLR discussion not to disqualify any study, but to compare and contrast the selected studies while highlighting the strength of each one under one of the following pillars; therefore, it's obvious and acknowledged that most of the studies includes its face detection, recognition and processing speed pillars but the strength may highlighted in one or two or all of the pillars.

2.6.1 Face Detection

Face detection consider the first and foremost essential step of the facial recognition technology where most of the challenges exist on the first step; for instance, low resolution and poor-quality images and video's, face pose, changes in the lights or shadow and motion blur; however, its significant to ensure this step processed efficiently to avoid an impact on the performance and the effectiveness of the facial recognition step.

Therefore, Awais et al., (2019) propose a novel method to combine the histogram of oriented gradients method and feedforward neural network method to use them in the face detection step as classifiers in order to provide the maximum possible performance for images and videos.

In fact, movement of face and body creates variation in real time videos; however, during the experiment its claimed that the variation by enabling four movement sequence technique which assigned by the feedforward neural network method will significantly reduce the variation; moreover, the experiment targeted the offline face detection which tested on two different datasets (CheckPoint and AT&T) and argues 97.5%-99% face detection accuracy and 90%-99.8% on the proposed real time face image dataset and both results consider significant; however, the proposed method doesn't recommend to utilize it the real life environment due to limited dataset size 25 facial images used to prof the accuracy of the claimed real-time face detection and recognition result (Awais et al., 2019).

Similarly, and in order to improve face detection accuracy in optimum processing speed, Ramos and Morales, (2020) proposed the SwiftFace method which is built based on YOLO algorithm and the existing CNN face recognition architecture. The result claims 78.6% accuracy through processing 16067 images in 470s (39.5 FPS); however, although, the proposed method improves classification processing speed, it states its limitations in the accuracy area which requires more development to be utilize in real-life environment.

In fact, object detection in videos consider more challenging due to the degraded image qualities; therefore, Tang et al., (2020) argues significant improvement on image classification processing technique in the real time video data which is the core part of the face detection stage by enabling three different components: short tubelet linking, cuboid proposal network and short tubelet detection, then experiment the same on the famous VID database; moreover, the approach claims 8.8% improvement in comparison with 9 different methods in the same domain and on 30 different class of the video data; however, this approach is limited to one face detection at the same time with some boundary issues which requires more improvement to detect multiple faces or object within the same frame.

Tuncer et al., (2020) followed similar approach by tackling the classification processing efficiency through proposing the quintet triple binary pattern (QTBP) algorithm which is built based on perceptual hash to pre-process and extract the image.

The proposed method was compared with 10 different methods and claims 100% accuracy from At&T dataset, 99.4% from AR dataset and 97.1% from LFW dataset (Tuncer et al., 2020). However, and in order to maintain the detection performance and reduce the processing speed a novel method proposed named "ordered weighted average (OWA)" operators which consist of two different sub-operators: Ordered weighted aggregation network (OWANet) and the Weighted Ordered weighted aggregation network (WOWANet); both operators depends on the average aggregation operator instead of relying only on the weighted mean operator step, an example illustrated in figure 2 (Rivero-Hernández et al., 2021).

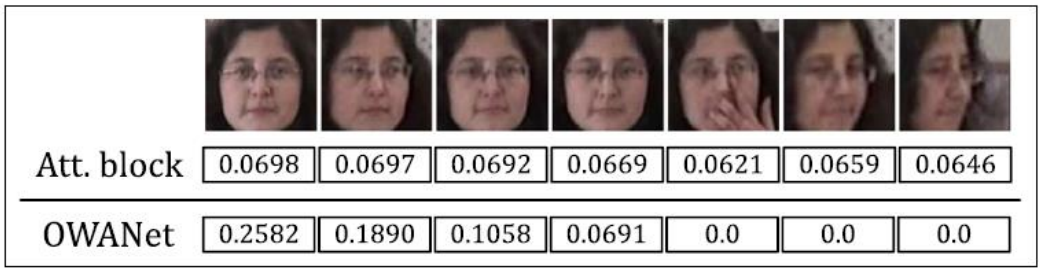


Figure 2: Example between OWANet and NAN attention network (Rivero-Hernández et al., 2021)

The proposed method obtains the relevance vector from the attention block, followed by an order of that feature set based on vector relevance and finally, by using the proposed method "ordered weighted average" aggregate the ordered feature set which extracted from the linguistic quantifier. 98.35% accuracy in 6.24 milliseconds has been claimed from the-state-of-the-art comprehensive experiment in comparison with 7 different methods in the same domain using 3 different popular datasets (YouTube Faces: 3425 videos, COX images: 1000 subjects, the IARPA Janus : 500 images);furthermore, it recommends to utilize it the real life complex environments (Rivero-Hernández et al., 2021).

On the other hand, Marciniak et al., (2015) stated that the main cause of the low resolution images is the distance between the face and camera; therefore, a eigenfaces approach argues its state-of the-art performance through analysing and mitigating image low resolution challenge during face detection and identification process, by correcting the extraction and identification of the image; furthermore, the proposed approach claims its efficiency even with 21 × 21 low resolution pixels through an the experiment conducted based on four popular datasets in the same domain, and the results indicates that only 21 pixels required for detection and recognition; thus, faces can be detected from large distance while depending on the existing

basic camera surveillance system and adhering to the European norm system presented in Figure 3 (Marciniak et al., 2015).

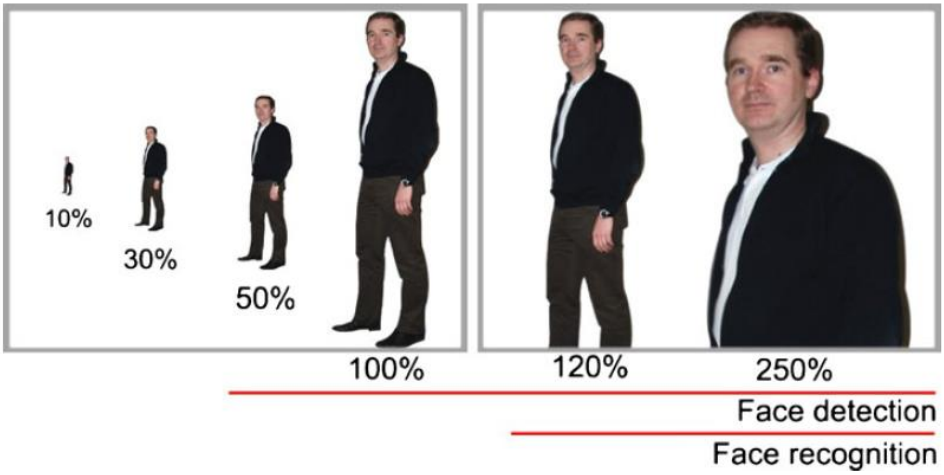


Figure 3 recommended minimum size according to European norm "EN 50132-7: CCTV (Marciniak et al., 2015)

Although, image resolution and face/body movements are significant factors which impact face detection efficiency, latency and slowness, it considers a supporting factor impacts detection performance and accuracy (Huang et al., 2019).

Indeed, this problem has been noticed in Microsoft Hololens product and a proposal was to improve the Viola-Jones algorithm which used in this product while depending on the Haar-like rectangle technique by applying the first steps of the face image acquisitions and classifications on the lens level then send the data outputs to the backend system in order to complete the next steps of face detection process (Huang et al., 2019).

Furthermore, the proposed method claims 4% times improvements from the existing method which proved through a comprehensive experiment covering six different datasets contains 4000 face images, but the recommendations to use it was limited to public security and social contact domain, and the accuracy rate was not clearly stated for better visibility (Huang et al., 2019).

However, Ouyang et al., (2019) proposed video-based person reidentification algorithm(TSF-CNN) and claims its 90.7% accuracy on iLIDSVID dataset and 96.7% on PRID 2011 dataset; moreover, and based on a comparison with 12 different methods in the same domain it's argued that video-based face detection accuracy consider more efficient and accurate than image-based face detection accuracy, due to the claimed efficiency of allocating different attention weights for each selected frame within specific sequence; however, no clear statement of its limitation and any recommended use in real life environment.

Nevertheless, Chen et al., (2021) proposed YOLOv3 face detection method which claims its efficiency to be utilize in a controlled environment. The claim concluded based on the results obtain from the experiment which indicates 0.89 AUC detection accuracy in 45 frame per second; however, the argued accuracy may not be sufficient enough to utilize in a crowded environment.

Similarly, Sun et al., (2018) proposed an improvement to the current faster RCNN architecture for real time face detection based on utilizing different features of the FDDB trained dataset through a claimed strategy, such as, hard negative mining and calibration. 98% accuracy result claimed for the proposed method.

Finally, Deng et al., (2021) proposed a novel face detection technique for the masked face images based on large margin cosine loss algorithm, were the face image detected and aligned, followed by gathering the information's about the bridge if the nose and the chin, and consider it as an output for the training dataset template in order to generate masked face image as illustrated in figure 4.

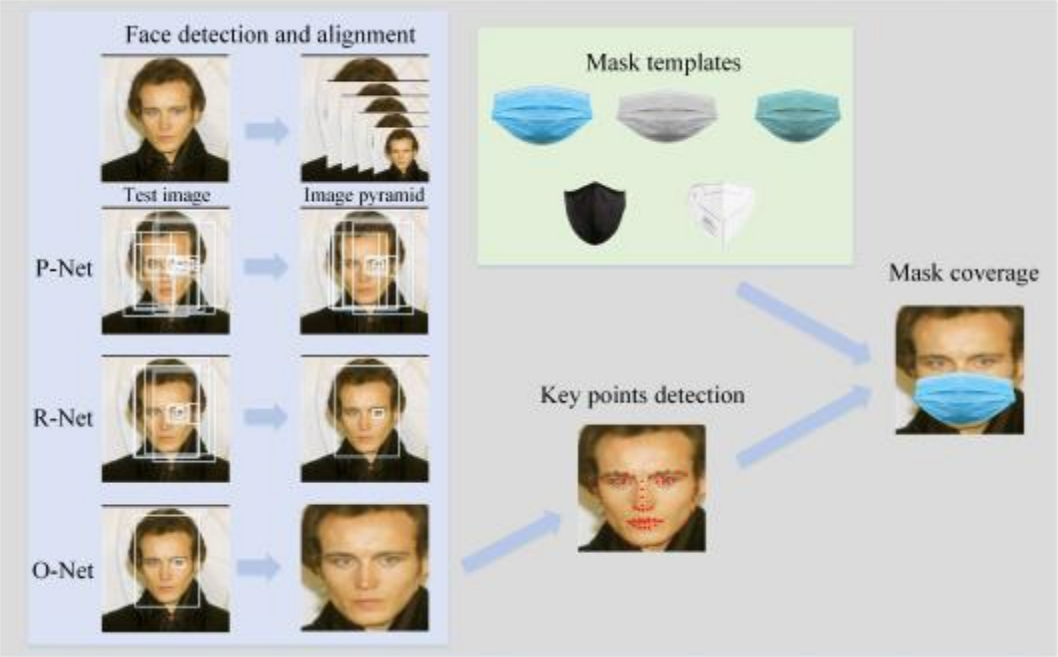


Figure 4: MFCosface Face detection technique (Deng et al., 2021)

2.6.2 Face recognition

Recognizing the face as an output from the face detection process and match it with the existing database consider the next step of face detection and recognition process as illustrated in figure 7 ; therefore, most of the researchers focus to improve this process for better accuracy, processing speed and lower computational requirements.

Although, Image resolutions should be taken into considering during face detection process, but it still indicate significant impact on the face recognition process which may cause a large-scale variation; however, a different methods proposed to claims various techniques and resolution to mitigate this problem; for example, Sface algorithm proposed which is built based on the integration of the anchor-based and anchor-free methods to resolve the large-scale variation issues in the face images, and the result claims 80% recognition accuracy with processing speed of 12.46 milliseconds for the 1080 pixel images (Wang et al., 2018).

Similarly, with the local binary pattern (LBP)-AdaBoost framework which aims to mitigate the image resolution challenge by detecting face and eyes with a support of modifying the Gabor-LBP histogram framework targeting to reduce the illumination challenges, based on employing the K-nearest neighbourhood classifier metric which result to 97.27% recognition accuracy in 5.26 frames per seconds (Lee et al., 2020);

Moreover, Gupta et al., (2019) and Lee et al., (2020) outcomes claimed based on using different datasets through comprehensive experiments; however, selection and utilization of the best dataset for testing and training the data to provide the optimum results from the experiment consider one of the significant principle to prof the outcomes and to strengthen the claim; therefore, Gupta et al., (2019) proposed the FaceSurv dataset which claims its state-of-the-art database to utilize and facilitate an optimum real time face recognition experiment addressing resolutions and spectra challenges and it argue to apply in different algorithms and commercial applications; furthermore, and after applying FaceSurv dataset on the Tiny Face detector it claims precision and recall results as 0.96, 0.99 respectively.

Furthermore, Qi et al., (2018) large margin cosine loss method proposed to improve interclass variance in order to increase face recognition accuracy through learning the key discriminative face features based on a comprehensive experiment tested using 3 popular datasets and based on the geometrical structure and theoretical interpretation. Experiment result claims 97.96 % verification and 84.26% accuracy.

Furthermore, Yuan et al., (2020) consider age is an area to improve face recognition accuracy especially when recognizing children's faces; therefore, MiPRE algorithm proposed based on multi stages of the DNN architecture and its compared with four different algorithms in the same domain to claim 92.1% recognition accuracy based on 20K children images, and it claims it's novel lightweight minor privacy protection scheme for the children to identify child faces and de-identify it before upload it to the internet to protect child's privacy's. however, the proposed approach is limited to web cameras in non-crowded controlled environment.

On the other note, Prasanna and Reddy, (2017) claims 70% face recognition accuracy by using a combination of the Histogram of Oriented Gradients [HOG], Deep Neural Network [DNN] and Support Vector machine [SVM] algorithms on the OpenCV application with the aim to utilize it on the surveillance camera system, while Zafar et al., (2019) propose the uncertainty-B model to improve the efficiency of the BDCNNs algorithm by using softmax application with the aim to improve the false positive results; thus, increase accuracy which claims 97.5%. results.

In fact, Deng et al., (2021) introduce a novel masked-face recognition technique named: MFCosface which mainly address the current masked face images challenges in the facial recognition technology during COVID-19 pandemic, and the technique is built based on large margin cosine loss algorithm. Different mask templates used to cover face images through utilizing key facial features in order to generate real life dataset which indicate that mask eliminate few of the facial features; in addition, and to mitigate this challenge the attention mechanism is used to ensure more focus on the uncovered face areas to extract the most face features which are mainly positioned in the upper area of the nose as illustrated in figure 5.

The result of the experiment conducted on 5 different datasets contains around 200K face images (mixed of masked and unmasked face images) and in comparison, with 5 different methods, claims 99.33% recognition accuracy which is significant considering masked face image challenges (Deng et al., 2021).

Table 4. Recognition accuracy rate in the noise experiment.

Location	Dataset	Noise Type	Example	Method	Accuracy
UP	LFW	salt and pepper noise (probability = 5%)		FaceNet	84.55
				MFCosface	**97.00**
Down	LFW	salt and pepper noise (probability = 5%)		FaceNet	82.05
				MFCosface	**97.92**
All	LFW	salt and pepper noise (probability = 5%)		FaceNet	77.45
				MFCosface	**95.12**
UP	CASIA-FaceV5	Gaussian noise (Mean = 0, variance = 1)		FaceNet	75.71
				MFCosface	**93.62**
Down	CASIA-FaceV5	Gaussian noise (Mean = 0, variance = 1)		FaceNet	75.58
				MFCosface	**96.47**
All	CASIA-FaceV5	Gaussian noise (Mean = 0, variance = 1)		FaceNet	74.21
				MFCosface	**92.10**
UP	MFR2	random noise (num = 1000)		FaceNet	76.75
				MFCosface	**94.50**
Down	MFR2	random noise (num = 1000)		FaceNet	84.50
				MFCosface	**97.50**
All	MFR2	random noise (num = 1000)		FaceNet	79.25
				MFCosface	**94.50**

Figure 5: MFCosface face recognition experience with noise(Deng et al., 2021)

"Up" represent upper area of the face, "Down" represent lower area & "All" represents noise to the entire image.

Similarly, a novel method proposed to mitigate masked faces challenges by utilizing the supervised learning concept along with the in-depth neural network in order to improve the detection and recognition accuracy. an experiment conducted based on a special dataset named" VGGFACE2" and result claims 97% masked faces accuracy (Mundial et al., 2020).

On the other hand, Vijaya Kumar and Mahammad Shafi, (2021) proposed the Grammatical Evolution (GE) method which is built based on the Region Fully Conventional Neural Network (R-FCN), where GE will search and identify the best set of the R-FCN parameters; for example, in figure 6 the GE is able to identify and set the main points, left and right eyes, nose in the middle, right mouth in a corner and left mouth in the other corner; therefore, theirs not need to depend on the ad hoc tricks and lengthy process to setup the RFCN parameters which will significantly reduce dataset training time. Experiment conducted on the WIDER face and FDDB datasets claims 99.1% accuracy and 0.97 precision-recall, with a recommendation to

utilize the proposed method in a complex life environment (Vijaya Kumar and Mahammad Shafi, 2021).

Figure 6: Face landmark location & face image (Vijaya Kumar and Mahammad Shafi, 2021)

2.6.3 Processing speed (face detection and recognition)

Processing speed for real time face detection and recognition technology consider an important pillar to maintain and ensure its high efficiency especially if the aim is to utilize this technology in a very crowed and demanded services; for instance, accessing metro gates in the transit eco-system; for example, 79% of Tokyo city commuters are using trains daily and the volume rapidly increase during peak hours to 250% as overcrowds noticed in the Metro car parks (Elhamshary et al., 2018).

Thus, imagine the pressure inside metro station if the fare collection service using face recognition technology is not sufficient enough to overcome such crowded environment.

Therefore, Deng et al., (2019) proposed the Additive Angular Margin Loss algorithm to get a highly discriminative features and performance for face recognition in a comparison with different algorithms through comprehensive experiment tested on 14 datasets and claims 0.99% accuracy with roughly processing speed of 25 milliseconds.

However, Mahmood et al., (2018) claims 100% accuracy within 5.28 seconds from Honda/UCSD dataset and based on the multiorder statistical descriptors method, where the accuracy of the proposed method compared with 11 different methods and based on 6 famous datasets claims its state-of-the-art method to utilize in a complex life environment.

Similarly, Zhang et al., (2018) FaceBoxes detector algorithm proposed and it claims its state-of-the-art method in real time face recognition with a lightweight computational requirement, high accuracy claimed at 96% and processing speed of 20 FPS and can be accelerated to 125 FPS (roughly processing speed of 25 milliseconds); interestingly, the proposed algorithm consist of Multiple Scale Convolutional Layers (MSCL) aims to handle faces of various scales

and Rapidly Digested Convolutional Layers (RDCL), which argue to utilize it in a real-world scenario.

Qi et al., (2018) tackled the accuracy and processing speed through proposing key-frame extraction engine algorithm integrated with a graphic processing unit for acceleration and the claimed results archive 0.943 accuracy in 11.05 seconds processing time which is significant considering the low image resolutions and legacy camera surveillance system where the method is targeting.

Moreover, Nguyen-Meidine et al., (2018) proposed comprehensive comparison of the single pass CNN architectures based on two different famous datasets which led to the results presented in Table 7, and it argues to use PVANET and SSD architectures in the real time face recognition environment, due its efficiency and accuracy; however, although its efficiency and accuracy are claimed but limited to a certain environment and cannot be utilize in a complex environment; for instance, inside metro station due to in insufficient accuracy result:

Method	AUC	Time	GPU
VJ & VJ-CRF	0.66	5.6	2.8
HeadHunter & DPM	0.77	5.0	2.0
SSD	0.77	45.8	0.7
Faster R-CNN	0.92	223.9	2.1
R-FCN	0.93	132.1	2.4
R-FCN 101	0.92	186.6	3.1
PVANET	0.91	40.1	2.6
Local-RCNN	0.78	1206	2.1

Table 7: Accuracy comparisons with existing algorithms based FDDB dataset (Nguyen-Meidine et al., 2018)

Moreover, and due to the complexity of the metro station environment which aims to offer the service in it, Zhang et al., (2017) proposed a solution to integrate different algorithms which uses signal processing methods for better outcomes such as: (Principal Component Analysis (PCA), Local Binary Pattern (LBP), cascade classifier, Ada Boost, Haar-like features), and the claimed solution tested on one of the most popular dataset named "MIT CBCL" which contains 2492 faces and 4548 non-face images, and the results argues 99.2% accuracy; furthermore, and as stated earlier this method consist of a combination of Local Binary Pattern descriptor and Principal Component Analysis algorithms which are used in order to extract the facial features required as an input for the face detection and facial image patterns, then counted and encoded to construct the spatially histogram which represent the local primitive. The detailed flowchart illustrated in the figure 7 represent the end-to-end high-level flow of the real-time face detection and recognition process using the proposed methods:

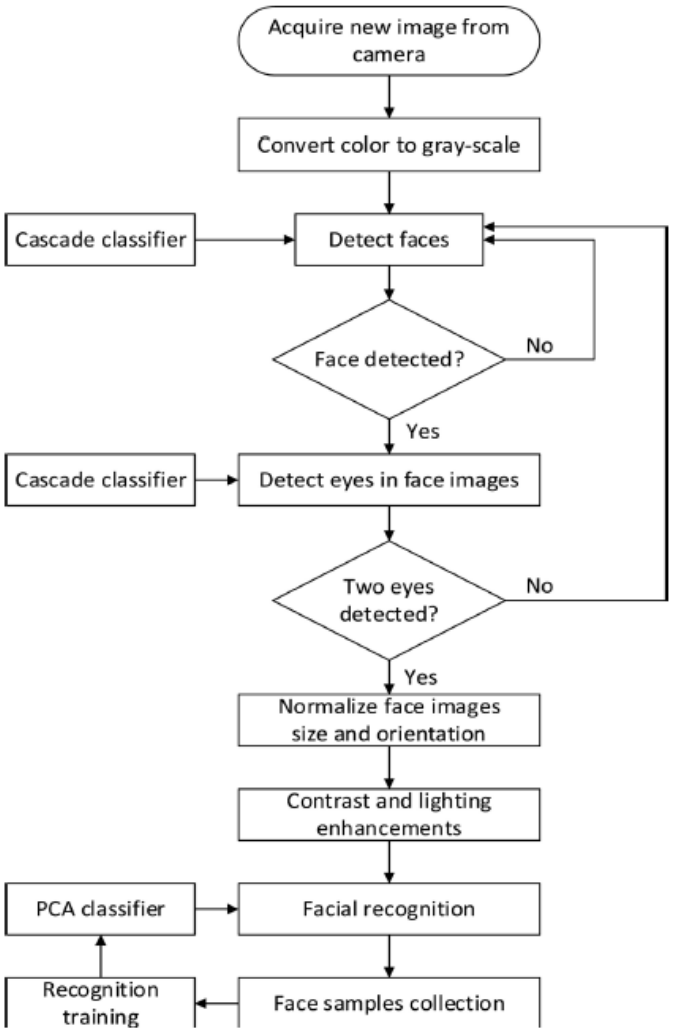


Figure 7: Real time face detection and recognition flowchart (Zhang et al., 2017)

Moreover, Figure 8 represent the detailed flow of the PCA algorithm recognition technique where of D = 100 as (A value) which known as number of principal components and represent the collected sample. 100 dimensions is the max size of the new face, where the coordinate system contains 100 principal components representing the maximum new face features, and the collected facial image projected value are constructed to 100 dimensional column vector which characterise the training sample; as a result, if there's a huge difference between the new face and reconstructed face which reached above the threshold limit (T= 0.4), then the new face won't be found in the database and it will be consider as "unknown", else its identified as "known" with the closest match. Results of the proposed method claims 99% accuracy with roughly processing speed of 11.4 seconds (Zhang et al., 2017).

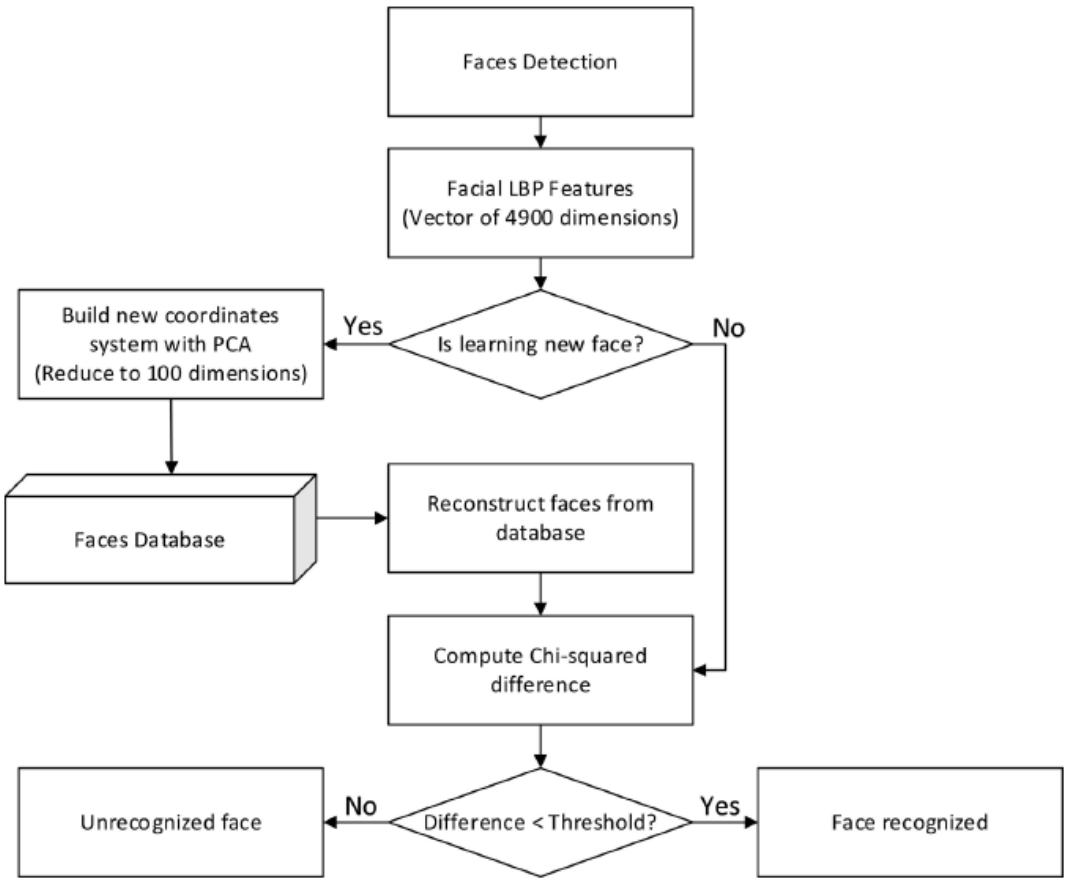


Figure 8: PCA algorithm flowchart (Zhang et al., 2017)

Nevertheless, Veerajay et al., (2019) proposed a method through targeting public transport riders to recognize their faces as an authorization mechanism to travel in the bus and bus fare will be deducted from their account by using Principal Component Analysis (PCA) algorithm based on using the statistical method which integrated with Biometric Bus Ticketing system (BBTS) as it considers the front-end system. The claimed approach supported by a survey outcome which obtained from 50 customer aiming to get feedbacks on the current service and gain customers appetite to use the proposed service by enhancing the current system through the proposed approach.

Result of the survey shows significant positive feedback from different aspects towards implementing the proposed approach (Veerajay et al., 2019).

In addition, Kavalionak et al., (2019) supports similar claim with regards to the surveillance systems by proposing a model which aims to minimize the face recognition operational load on the existing surveillance camera while using (PCA) algorithm in order to decrease the load required on the backend system by using the weighted KNN algorithm, and the result of the experiment claims 0.81 accuracy and 50% backend system load reduction with roughly

processing speed of 450 milliseconds, where the result consider better than INN algorithm outcomes.

Haar Cascades algorithm claimed to be the most efficient in terms of performance and time consumption in comparison with the other algorithms on the surveillance system domain, and it's argued to use the OpenCV application among MATLAB due to low expense cost and better outcomes, but the proposal doesn't state the desire level of accuracy and processing speed from the experiment outcomes (Goyal et al., 2017).

Similarly, (Malach and Pomenkova, 2020) support (Veerajay et al., 2019) claim mentioned above and proposed the higher quantile method (HQM), in order to improve the overall performance of face recognition in surveillance systems in terms of (time, accuracy and cost) and based on utilizing a low computational power while using the nearest neighbor classifier. This method claims 0.9 accuracy and 10% processing speed improvements (roughly processing speed of 150 milliseconds) among similar methods used in the same domain based on an experiment used the IFaViD dataset, which consider the only dataset represent a real surveillance video image. The claimed method proposed three integrated algorithm stages to recognize the face as per the following figure 9 (Malach and Pomenkova, 2020).

Algorithm 1 Preliminary analysis

1: Construction of histograms of feature values
2: Preselection of possibly suitable PDFs
3: Fitting of preselected PDFs to all histrograms
4: Computation of discrepancy measures among all histograms and all fitted PDFs
5: Discrepancy evaluation using RSS and χ^2 metric
6: Assessment of discrepancy metrics
7: Identification of optimal PDF for feature description

Algorithm 2 Template creation

1: Construction of histogram of feature values for each individual
2: Fitting of the selected PDF to all feature value histograms
3: Extraction of quantiles from PDF
4: Concatenation of quantiles to face template

Algorithm 3 Recognition stage

1: Image acquisition
2: Face detection and alignment
3: Feature extraction
4: Classification using nearest neighbor i.e. computation of dissimilarity metric (modified χ^2) between feature vector being identified and all templates.
5: Comparison of dissimilarity with threshold and selection of template ID with minimal dissimilarity.

Figure 9: Face recognition steps (HQM)(Malach and Pomenkova, 2020)

However, and in relation to the face and body movements challenge (Awais et al., 2019), distance between face and surveillance camera may considers one of the key factors which impact image resolution, illumination and image pose rate during face detection stage; therefore, the results of the claimed method is vary from scenario A to B presented in figure 10, where in scenario A face recognition accuracy was 0.80 and scenario B accuracy 0.9 (Malach and Pomenkova, 2020).

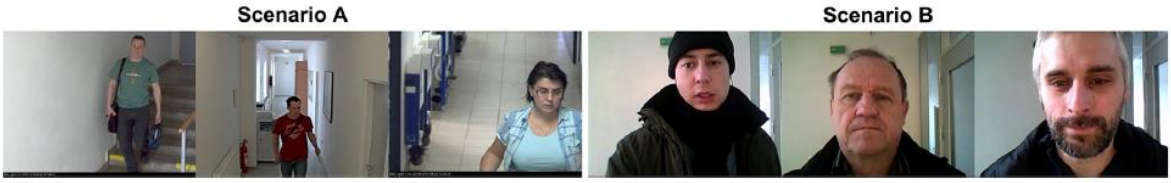


Figure 10: Dataset image scenarios (Malach and Pomenkova, 2020)

On the same note, Celin et al., (2017) proposed novel end-to-end framework to use face recognition technique as replacement of the smart cards to pay and travel with metro. The solution proposed based on the OpenCV application to process the Images through an integration between PCA and KNN algorithms in order to classify, detect then recognize the faces, and the AES algorithm complement the framework by adding an additional security layer to the claimed framework. Main assumption of the proposed framework that users must register their faces, and connect its wallet to the registered account, but the framework doesn't explicitly state the desire level of accuracy and processing speed.

2.6.4 Account Based ticking system

Account based ticketing (ABT) system which is the advanced version of the "central clearing house system" and in other studies and industries named as the advanced version of the "card-based ticketing system (CBT)".

Nowadays, many public transport systems implement the smart card-based ticketing system with different business rules and characteristics which are based on an offline deduction of the fare from the e-purse wallet loaded in the transport card; therefore, fare deduction intelligence falls between metro gate and transport card application, and deduction speed around 300-500 milliseconds which known as closed loop payment (Costa et al., 2019).

However, and due to the challenges, limitation and inflexibility of the CBT technology and customers continues demands to enable other convenient, cashless and quicker payment means; for instance, acceptance of the contactless bank card or mobile pay's (apple, google, Samsung,

alipays) as an alternative or replacement of the closed loop card; nevertheless, ABT fare collection system consider as a key prerequisite to offer similar new payment means. In short, upgrading from CBT to ABT means moving the fare deduction intelligence from the card based to the account based; however, an offline first level of authentication will still be performed between the new payment mean and metro reader, followed by the other the levels of fare calculation and account wallet deduction(Zamer, 2018).

Moreover, many transit authority start upgrading its current CBT fare collection system to ABT system in order to absorb customer demand and expand payment services beyond transit; improve their current operation, reduce the operation cost and increase revenue; for instance, Singapore, London and Moscow transit authority's upgraded its system to ABT(Zamer, 2018).

In fact, and stated earlier ABT system consider a prerequisite to offer face detection and recognition access to Metro rider; therefore, and in order to recommend the optimum face detection and recognition method, a detailed proposal of the account based ticketing system framework illustrated in figure 11(Brumercikova et al., 2020), which provide the flexibility to the consumers to connect there electric ID(EID) card or its Europay, MasterCard® and Visa (EMV)(*EMVCo,* 2021) contactless bank card to the account stored in the Backend system; moreover, passenger can register his family members under the same account for easier access and account management.

Finally, if in any case face recognition technology fails to identify passenger face, as mitigated action passenger can instantly tap their E-ID or EMV bank card on the metro gate reader to check-in. Once face recognition authentication or a successful contactless card tap completed the transaction journey sent to the ABT Backend system for fare collection (Brumercikova et al., 2020).

In fact, and according to several studies, the optimal aggregation of the trip value occurs at the end of each day, followed by a deduction of the outstanding amount from the passenger account at the end of that day.

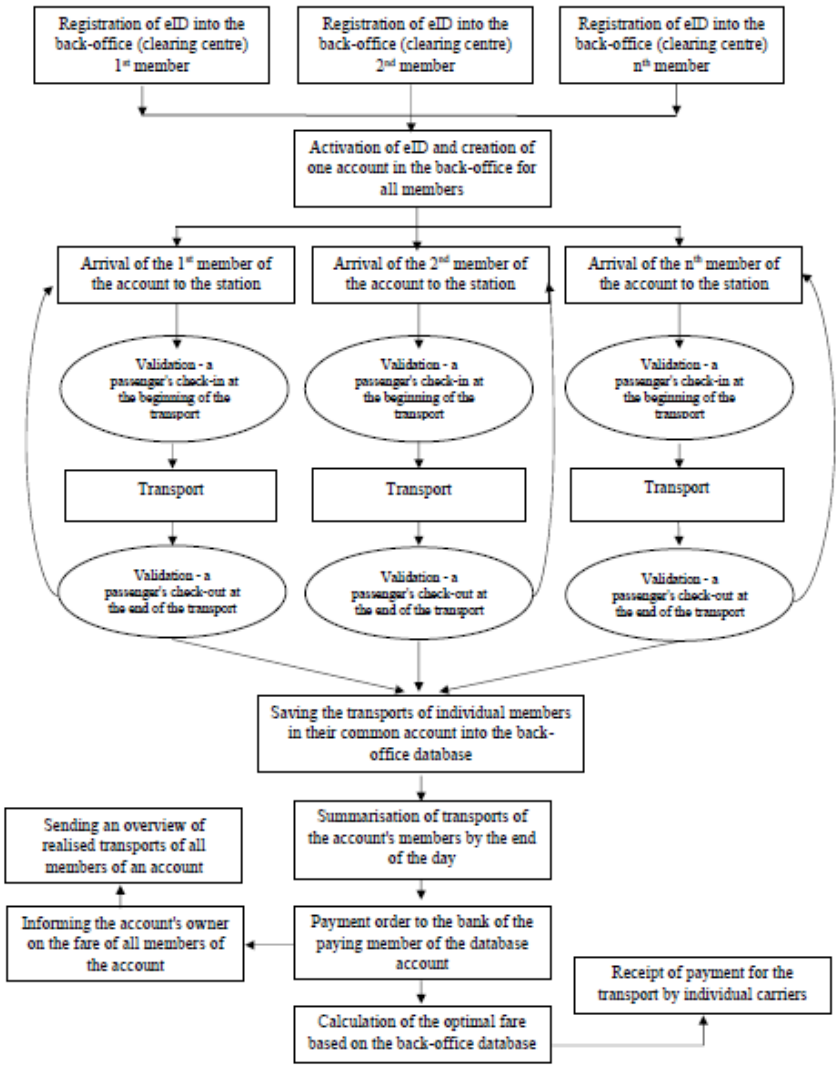


Figure 11: Account based ticketing model illustration (Brumercikova et al., 2020)

The illustrated framework can be used by replacing EMV/EID cards with the face recognition system and add biometric registration requirements as part of the passenger registration criteria's before using the service.

2.7 SLR Results

According to the selected studies highlighted in Table 6 which published between 2016 and 2021 in the context of face detection and recognition technology and potential aim of utilizing this technology as payment access inside metro station. The following section shall address the systematic literature review questions as a key result of the SLR.

2.7.1 Answer to the first SLR question

RQ1. What are the studies clearly stating the problem and challenges of face detection and recognition technology?

In fact, there are various problems and challenges of the face detection and recognition technology presented from the selected studies as illustrated in table 8; however, the key common problems and challenges noticed from the selected studies presented in table 9 which are related to insufficient face detection and recognition accuracy, processing speed, image classification gaps, image Illumination, image pose or body movement, low resolutions of the images or video and high computational power requirements.

S	Problem/challenge
S1	Reduce the security threats, with high Computational power
S2	Improve classification, power of discrimination and recognition accuracy
S3	Lacks the power of discrimination
S4	large variations in video streams
S5	The noisy image captured from video
S6	low resolution image when object detected from real time video's
S7	Children privacy protection from face recognition
S8	Large-scale variations in high resolution images
S9	Huge number of features requires for detect & recognize face
S10	Variation in the appearance of people faces, complexity of the image background and obstruction process
S11	Ignorance of the pose or movement of the visible boundaries which cause to insufficient face recognition accuracy.
S12	Long queues to obtain the Metro ticket.
S13	Current Surveillance cameras limitations
S14	Improve face detection using open CV
S15	Facial Expression Change, Spectacle's presence or absence, illumination Change, scaling factor, Aging Pose change, scarf or mask obstacles
S16	Lights and illumination challenge with real time face recognition
S17	face expression, varying pose, low resolution, illumination
S18	Low resolutions and spectra
S19	Misuse of the smart card for payment in metro system, lengthy queues and frauds
S20	facemask essentials Due to Covid19 pandemic
S21	Latency and slowness of the face detection

S22	poor results from Image based face detection method
S23	Low Accuracy and performance of face recognition on surveillance systems and high Computational power
S24	weighted mean operator for classification lead to low performance
S25	limitation to achieve a real-time high speed on the CPU while maintain high performance. High Computational power
S26	Difficulties to implement face recognition system in complex and uncontrolled environment
S27	Gaps in the classification process of the Faster RCNN algorithm
S28	Low resolution images, low lighting, illumination, part of the face hidden
S29	Gaps in the classification process
S30	lack of detecting small objectives and face variation
S31	Low accuracy of face recognition and high Computational power
S32	Masked faces challenges on the facial recognition

Table 8: List of key problems identified for each study

Problem/challenge	Study numbers
Security and privacy	[S1], [S7]
Image classification gaps	[S2], [S27],[S29],[S24]
Image variations	[S4], [S8]
Image noisy	[S5]
Low Resolution	[S5];[S17],[S8],[S18],[S28]
Slow processing speed	[S9],[13],[S14],[S17],[S21]
power of discrimination	[S2],[S3]
Image background	[S10]
Pose or movement	[S11],[S15],[S17]
Facial Expression Change	[S15],[S17]
illumination	[S15],[S16],[S17],[S28],[S25]
Low Lighting	[S16],[S28]
Facemask, scarf	[S15],[S20],[S32]
Lengthy queues and frauds	[S12],[S19]
Low accuracy of face detection	[S22],[S9],[S13],[S24],[S30]
Low accuracy of face recognition	[S23],[S25],[S26],[S31],[S2]
High Computational power	[S1],[S23],[S25],[S31]

Table 9: List of key problems and challenges identified for each study

In fact, and according to the pie chart presented in figure12, low resolution and illumination of the image, slow Detection speed, low accuracy of the detection and recognition, image classification gaps and high computational power requirements consider the most common challenges and problems identified; however, masked face challenges consider relatively new due to Covid-19 pandemic and the essential for the public to wear facemask all time; therefore, two recent studies identify this challenge with a proposed solution to mitigate.

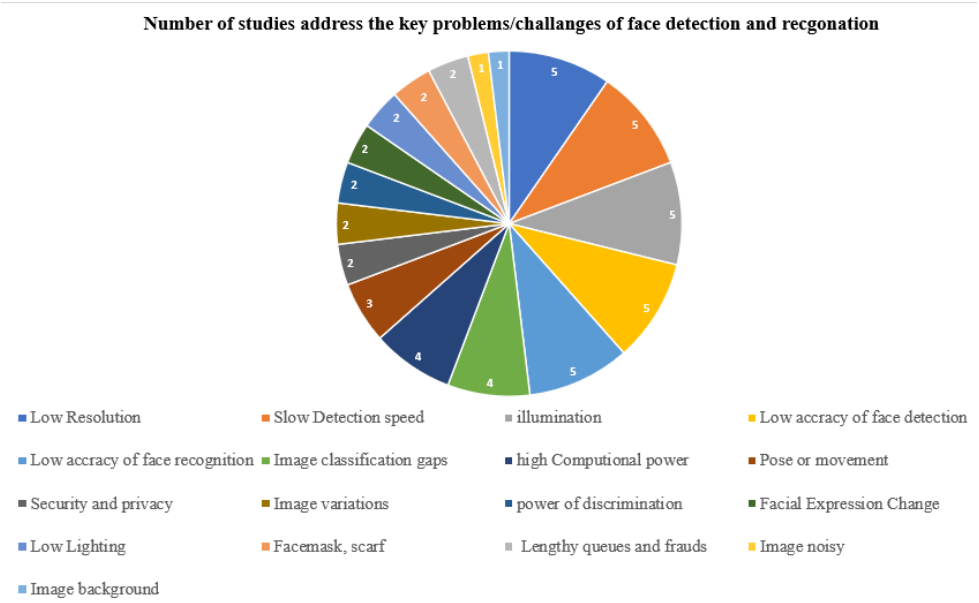


Figure 12: Pie chart present total number of studies addressing each problem

2.7.2 Answer to the second SLR question

RQ2. What studies illustrates the methods or techniques used for the face detection and recognition and supported by an experiment?

According to the literature review section all selected studies aims to improve the face detection and recognition technology from different angles by proposing various techniques and methods to overcome the stated challenges and achieve the highest level of accuracy and processing speed at the lowest computational cost.

Therefore, the selected studies have been categorized based on three different key criteria's 1) face detection results 2) face recognition results 3) processing speed results (face detection and recognition).

2.7.2.1 Face detection results

Figure 14 below illustrate the studies which focus on identifying and improving face classification, normalizing and detecting process by proposing different methods and techniques in order to achieve the optimum accuracy claimed based on a comprehensive experiment. Therefore, and as per figure 14 [S1] HOG/FNN recognized to claim the best accuracy result: 99.8% ; however, and according to figure 13 dataset size used in the real-time face detection and recognition experiment of HOG/FNN method consider extremely small 25 facial images which may not be sufficient enough to prove the claim in comparison to dataset size used for the OWA method (5,900 images) which claims 98.4% accuracy.

Furthermore, [S32] MFcoface claims 99.3% accuracy based on a dataset size(85,000 images) which includes masked face images; thus, and due to Covid-19 pandemic which creates the

essentials to improve the existing algorithms in order to cater the masked face challenge, and due to the nature of this algorithm which focus in mitigating this challenge we can argue and recommend to consider MFcoface algorithm to use in the framework.

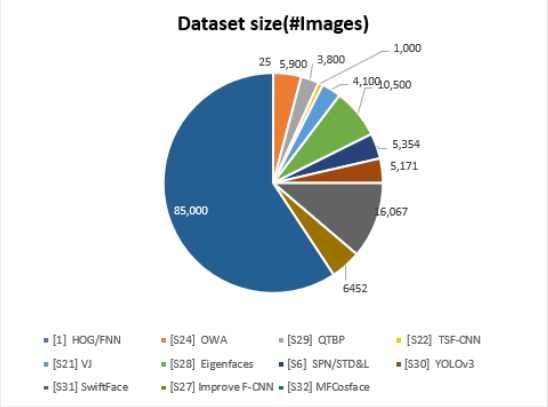


Figure 13: Detection Dataset size

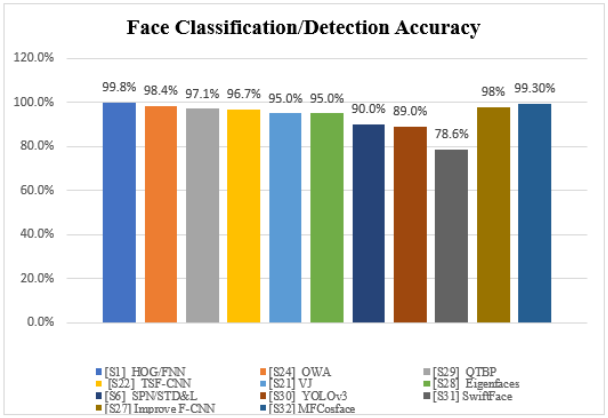


Figure 14: Detection accuracy result

2.7.2.2 Face recognition results

According to Figure 16 [S3],[S7],[S8],[S9],[S16],[S18],[S20] and [S32] are the studies selected which emphasis on identifying, proposing or improving face recognition techniques based on a comprehensive experiment in order to achieve the novel accuracy percentage at the lowest cost, and as per figure 15 [S20] dataset size of the SLC algorithm consider the largest one (3.13 million images) among all studies included in this research and it claims high accuracy:97%; however, while taking a large dataset into consideration the accuracy result may not be sufficient enough to implement in a complex and crowded environment.

Moreover, [S9] GE method claims higher accuracy 99.1% based on dataset size of 258,380 images with specific focus on using the proposed method in the surveillance system environment; however, the study doesn't clearly state the processing speed; finally, and as presented in figure 16 MFcoface algorithm claims 99.3% face recognition result based on a dataset size of 200,000 images which includes masked and unmasked face images with processing speed of 25 FPS; thus, MFcoface detection method can be consider for the framework.

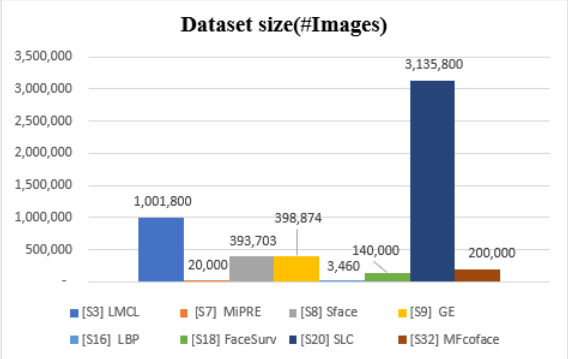


Figure 15: Recognition Dataset size

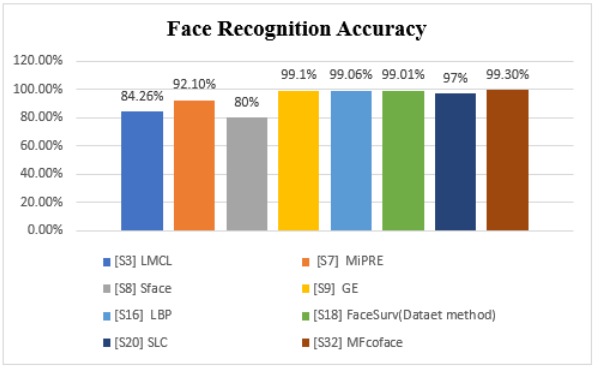


Figure 16: Recognition accuracy result

2.7.2.3 Processing speed results (Face detection & Recognition)

Figure 17 illustrated below, represent the accuracy results of the combined face detection & recognition process, while figure 18 represent the processing speed required to detect and recognize one face from multiple frames, and figure 19 represent dataset size of the selected studies.

In fact, [S13] KNN method claims 113 milliseconds processing speed which is the minimum among all studies; however, it claims 81% accuracy which is not sufficient for the crowded and complex life environment; furthermore, [S26] PCA/LBP/AB/HR method claims the second highest face detection and recognition accuracy 99.2% based on an experiment contains a dataset size of 7000 images according to figure 19; in addition, and as shown in figure 17 and figure18 [S26] processing speed is:1114 milliseconds which consider extremally high; however, and according to the SLR literature review section the combined classifiers, detectors algorithms used in this method claims its state-of-the-art efficiency to be utilize on the surveillance system in a real life complex environment with the lowest computational requirements; thus, its recommended to consider in the framework.

Finally, and according to figure 17 and figure18 MFcoface method claims the highest face detection and recognition accuracy in 180-200 milliseconds processing speed at true/false positive rate of 0.99974 based on a comprehensive experiment which consist 4925 images as presented in figure 19. The claimed result is significant; therefore, MFcoface face detection and recognition method can be consider in the framework.

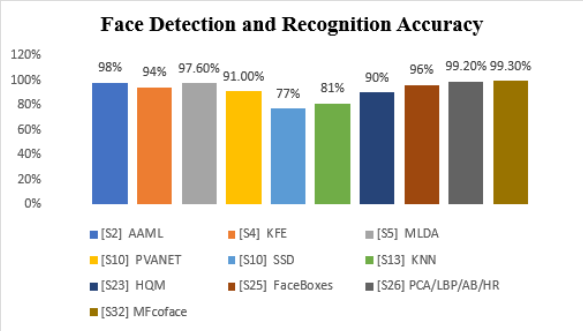


Figure 17: Detection & recognition accuracy

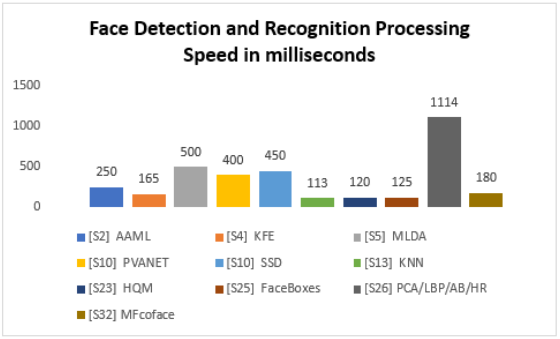


Figure 18: Detection & recognition speed

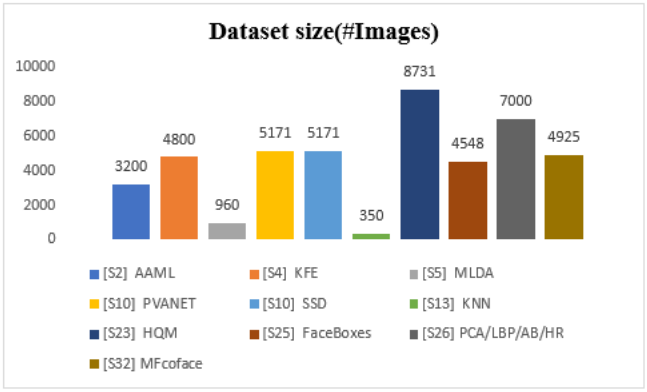


Figure 19: Detection & recognition accuracy

2.7.3 Answer to the third SLR question

RQ3. What are the studies used method comparison approach to strengthen its claimed resolution and recommendation?

In fact, comparing the results of the proposed method with the other argued methods in the same domain consider in the literature one of the essential strengths to claim the recommendations; however, it cannot be consider as the only key success factor to recommend one method among the other, due to the fact that most of the claimed methods are not implemented in the real-life environment; in addition, most of the common methods are using almost similar datasets type to claims the results.

Nevertheless, and according to figure 20 [S1],[S30] records the highest number of methods (14 methods) which are compared against the results of its claimed methods , followed by [S2],[S22] and [S11]. Moreover, [S1] data size (3500 images) used in the experiment may consider insufficient to claim the accuracy results in comparison with other studies.

Similarly [S30], although the results of the proposed method have been compared with 14 methods, but the accuracy result: 84% which consider insufficient in comparison to other studies.

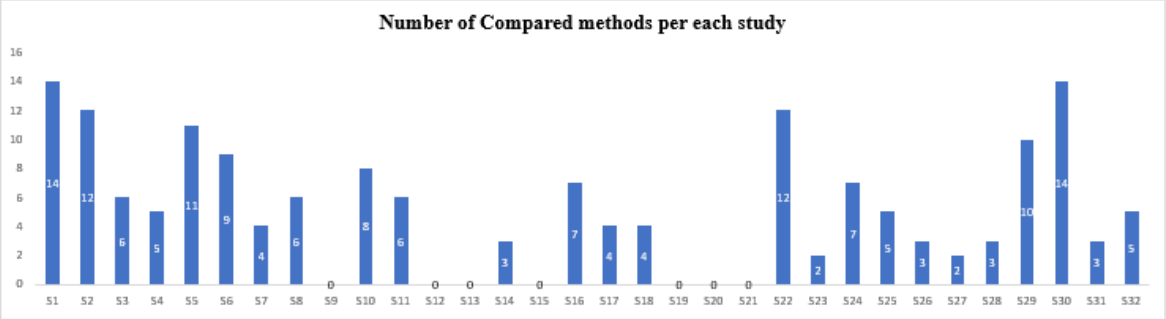


Figure 20: Total number of compared methods in each study

2.8 Chapter two summary

Several challenges have been tackled in the SLR and a proposed solution have been claimed for each challenge through proposing various methods and techniques stated for each study; however, the most common challenges noticed between the studies is the image quality which consider the key essential prerequisite to identify and position the human face from the image frame for further reprocessing; for instance, low resolution, pose and illumination;
in addition, to the low processing speed time and high computational requirement challenges which are also consider a common challenge where the researchers address with a proposed solution; finally, masked face challenge which becomes more popular due to the recent Covid-19 pandemic and the essential need for the public to wear a mask.
One the other hand, the most common methods and algorithm noticed from the SLR which address the challenges stated previously are built based on the neural convolutional network architecture and named: local Binary Pattern descriptor, Haar-Like descriptor, Ada-Boost, Cascade classifiers, Affine Transformation, Histogram Equalization, R-FCN, KFE, KNN, INN, Multi-order Statistical descriptors, Grammatical Evolution, ordered weighted average, Viola Jones, Tiny Face detector, Fast Face Detector, gaussian filter, Cosine, Eigenfaces, Sface, Cosine, F-CNN, YOLOv3, MFcoface, PCA and KNN.

However, due to the needs of an algorithms to utilize in the framework which aimed to implement in a very crowded and complex environment (Metro station), and based on the results of the SLR result, the recommended algorithms to utilize are as per the following:

1. Mfcoface method: It claims 99.3% accuracy of face detection and recognition with a key focus on the masked faces; in addition, the key rationale of selecting this method

due its claimed strength of accuracy and processing speed (180-200 milliseconds) in detecting and recognizing the full face and masked faces which mitigate the preliminary challenges of facemasks noticed due to Covid-19 pandemic.

2. PCA/LBP/AB/HR methods: It claims 99.2% accuracy of face detection and recognition in acceptable processing speed of 1114 milliseconds, in addition, the key rationale of selecting this method is due to the common claims noticed from the literate review addressing the strength of the combined algorithms and classifiers which are together forum the stated method; furthermore, the recommended use of the combined algorithms and classifiers address the real-time face detection and recognition algorithm on the surveillance systems in the complex environment.

Finally, it has been noticed that 80% of the selected studies compared its proposed method/techniques with other ones in the same domain to strengthen the claimed results; therefore, and according to the literature review its significant to perform the stated comparison to strengthen the results; however, it cannot be considered as the only key success factor to recommend one method from the other.

3 Chapter Three: Research methodology and data analyses

This chapter present the methodology utilized in order obtain passengers and experts feedback on proposing facial recognition access control as a service in metro. Aim of this chapter to address the third dissertation question, and to clarify the methods and process used to build the survey and collect the data; finally, analyse and conclude the results.

3.1 Introduction

In order to achieve the desire objectives of this dissertation an online survey and expert interview questionnaire approach were adopted to collect passengers and expert feedback.
Aim from the targeted participants to respond to the online survey and similarly, for the experts to answer the online questionnaire through an online interview.

3.2 Methodology

Research used the survey and questionnaire technique to obtain passengers feedback on the potential to use face recognition as new payment mean inside metro station, in addition to collecting experts' feedback on the optimum algorithm, solution and expected reliability and efficiency of the proposed service.

3.3 Data collection technique

Online survey and expert questionnaire have been proposed and data collected as per the following:

- Online survey: Created based on a quantitative method (close ended questions) and used for data collection with a sample size of 258 participants, and transit users considered as the target audience. "QuestionPro" website used as a survey tool to create and distribute the survey to the targeted audience through a URL link, and collect the results through the same tool for further analyses.
- Expert questionnaire: Created based on qualitative and quantitative methods (mix of open ended and close ended questions) and used for data collection with a sample size of 8 experts selected from the same domain. "QuestionPro" website used as questionnaire tool to create and distribute the questionnaire to the selected experts. 30 minutes online interview conducted for each expert to clarify the questionnaire and collect a detailed answers of each question and submit the results.

3.4 Ethical Considerations

Data collected from the online survey and expert questionnaire are used for of this dissertation only, while ensuring participants privacy. The questions are built to be answer by anonymous without asking for any personal information's; moreover, consent form was included in the

online survey and expert questionnaire stating the confidentiality statement and asking participant permission to utilize the collected data for this research with a stated option to withdraw from the survey at any time as presented in figure 21

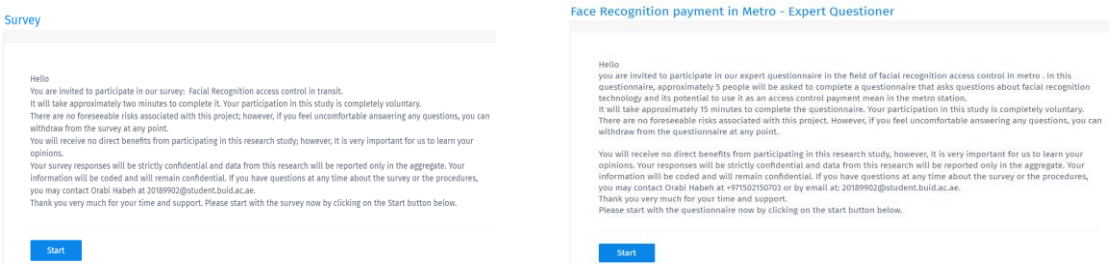


Figure 21: Survey consent form

3.5 Online survey analyses

3.5.1 Sample criteria

Results collected from the online survey was based on eighteen questions provided to a selected customers who used Dubai Metro, and the selection of the participants was based on the following criteria:

- Individuals who woks far from the residence location and doesn't have a private car.
- Individuals who claim its frequent use of public transport.

Online survey distributed to three different corporates within the emirates of Dubai (one private corporate and two government entity's).

3.5.2 Online survey questions

Table 10 Present the questions and multiple-choice options for participant to select and answer each question.

#	Question	Options
1.	Gender	Male Female
2.	Age Group	Less than 14 15-25 26-30 31-40 41-50 Above 50
3.	Educational background	No formal education High school Diploma/Advanced Diploma Bachelor's degree Master's degree Doctoral degree

4.	How often do you use public transportation?	Daily Weekly Monthly Occasionally
5.	Which mode of transportation do you use most often?	Bus Tram Metro Water Bus
6.	Do you have difficulty buying your transport card or transit ticket?	Yes No
7.	Do you have trouble recharging your transport card or transit ticket?	Yes No
8.	How many times your transport card or ticket was not working properly?	Never Once Twice Three times More than three times
9.	Do feel any risk of fraud while using your transport card or ticket?	Yes No
10.	How long do you typically stay inside a metro station before you ride the Metro?	Less than one min. 1-5 mins. 6-10 mins. 11-15 mins. 16-20 mins. Above 20
11.	How frequently do you lose your transport card or ticket?	Never Once Twice Three times More than three times
12.	Do you feel comfortable using your transport card or ticket?	Highly comfortable comfortable Somehow comfortable Not comfortable.
13.	Do you have a bank account?	Yes No
14.	Do you have a bank card (debit or credit)?	Yes No
15.	In your opinion, what is your overall travel experience using transport card or ticket to pay for metro ride?	Scale (1 to 5)
16.	If we introduce a new way for you to pay in public transportation using face recognition technology, will you use it?	Yes No
17.	Do you think the new Metro payment method will be more convenient and secure than the transport cards or tickets?	Yes No
18.	In your opinion, will using “face recognition” as a new payment option improve your travel experience?	Yes No

Table 10: online survey questions

3.5.3 Rationale of the survey questions

Online questions created to gather participants feedback based on the following criteria’s:

- Usage of public transport, to understand participants frequency of using public transport.
- Losing transport card or ticket, time consumed to ride metro or potential fraud may occur from the transport card, to understand participants challenges from the existing payment mean.
- Overall satisfaction with the current payment means offered to access metro station and ride metro, to understand overall participants level of satisfaction and if any room for improvement of the existing payment mean.
- Availability of the bank card or bank account, to understand participants capability to link their bank account to the transport account if the facial recognition technology service offered as new payment mean.
- Overall potential satisfaction of the facial recognition technology offered as new payment mean to the participants, to understand participants knowledge of this technology and verify its interest to use it if it's offered.

3.5.4 Sampling method

According to figure 22 258 completed the response out of 313 individuals with 82.43% completion rate. Survey average time to complete is 2 minutes; furthermore, Survey respondents are based on different geography as presented in figure 22 where 82% of the respondents are based on the United Arab of Emirates(UAE) and the remaining responded from different country's; however, and as stated earlier the targeted audience where selected from three different UAE based entity's; therefore, the 18% of respondents may responds from their origin or visited country's where they stays in temporary and respond at the time of the survey distribution.

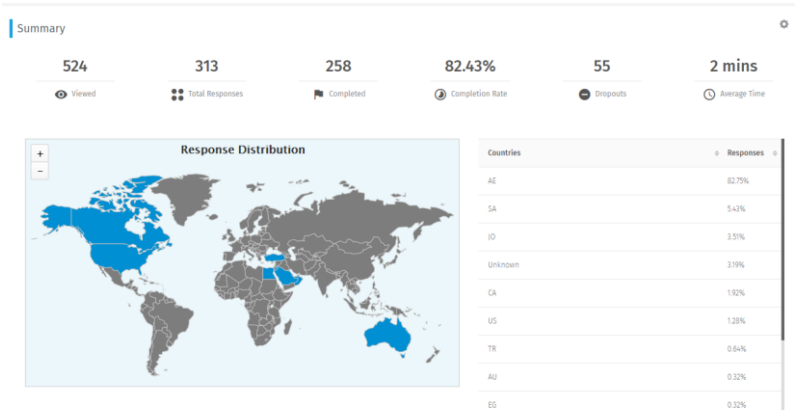


Figure 22: Survey summery and coverage

3.5.5 Online survey results

3.5.5.1 Participant's gender and age group

According to figure 23, 57% of participants are male and the remaining females, which provides general indication that both genders are almost equally using public transportation with a confidence interval of 95% and mean of 1.426; therefore, the collected data of this survey reflects the majority of both genders. Moreover, and according to figure 24, interestingly, 86% of the participants ages are more than 26 years old. Thus, majority of the participants argued to be consider as a workers; on the other hand, 8% of participants represent the age between 15 and 25th years old where this segment may consider part of an internship or training program of the selected organization, and 5% of the respondents who selected the age less than 14 years old can be consider as standard error of the survey selection due to the clear target audience where expected age of the participants who works or engaged in the selected organizations expected to be more than 15 years old.

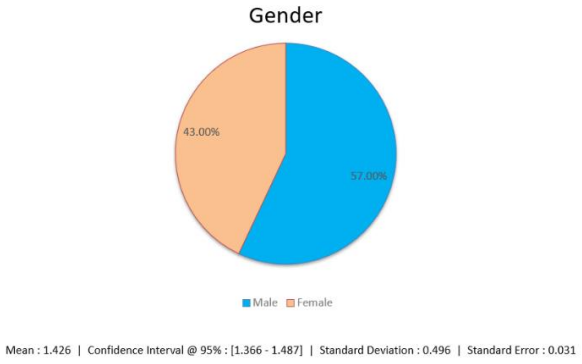


Figure 23: Gender

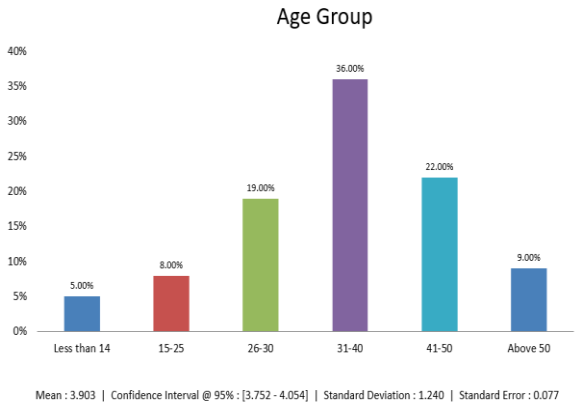


Figure 24: Age group

3.5.5.2 Educational background

According to figure 25, majority of the respondents has high level of education background where around 75% of the participants has the bachelor degree or higher. This as an expected results due to the distribution of the survey among the stated organizations where majority of the respondents categorized under office worker segment, who shall hold bachelor degree or higher to work in these organizations.

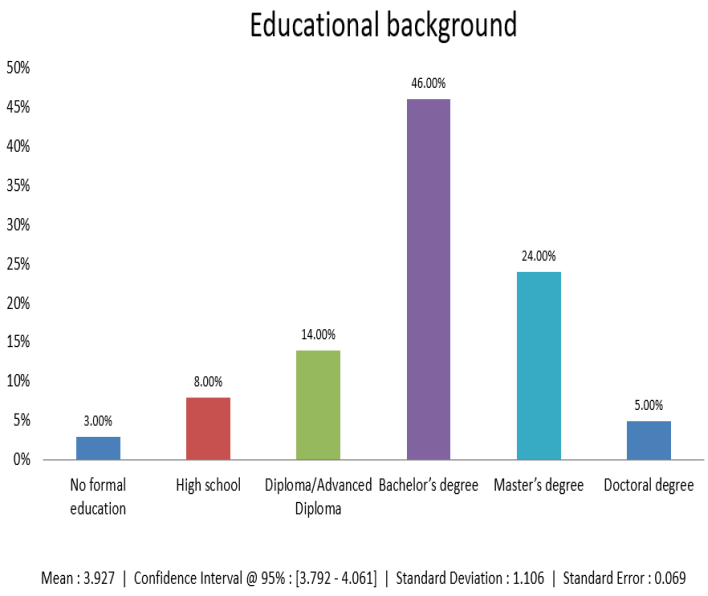


Figure 25: Educational Background

However, remaining 25% of participants who may under graduated and holds diploma, high school or doesn't have any formal education which categorized under the blue colour worker's segment; blue colour workers examples: labour, cleaner, nurse, house maid, student..etc.

In fact, this result indicates the majority of segments who's using public transport responded to the survey.

3.5.5.3 Public Transport usage

Figure 26 present 32% of the participants who occasionally using public transport due to its utilization of their private cars; however, 68% of the participants are using public transport frequently, where 27%,21% and 20% are using it on weekly, daily and monthly basis respectively.

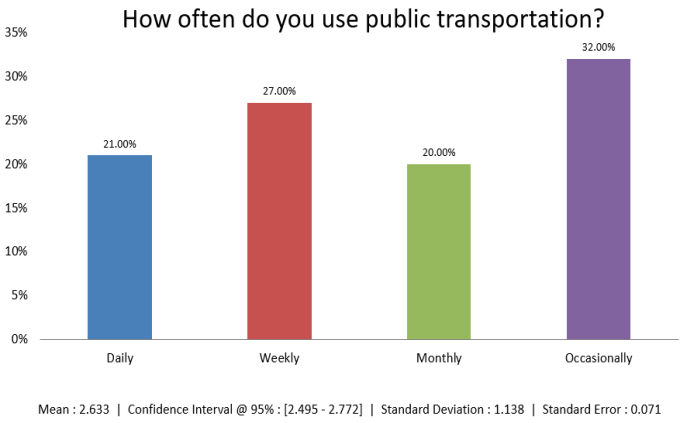


Figure 26: Public transport usage

This result indicates the frequent utilization of public transport across survey participants which may provide valuable inputs to identify existing gaps and challenges; in the other hand, identify the limitations and challenges of not using public transport for the 32% occasional users.

3.5.5.4 Transport mode usage

Figure 27 present the most often transport mode used among participants, where 67% of the participants are using metro followed by 20% for public bus's and 11% for tram.

In fact, these results clearly indicate majority of participants dependencies on metro services due its smooth and convenient infrastructure where participants are benefiting from it.

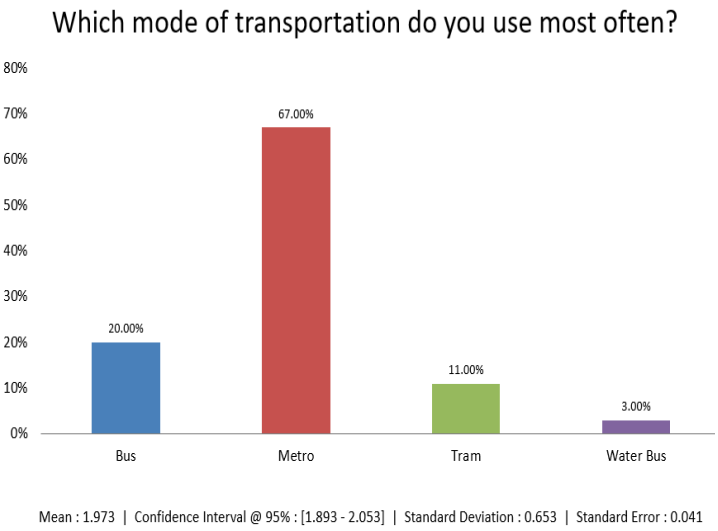


Figure 27: Transport mode usage

In addition to the reasonable tariff of metro fare structure in comparison to the usage of the private cars. Moreover, it's also an encouraging result to identify the challenges with the existing metro fare collection system and suggest various approach of improvements.

3.5.5.5 Challenges to buy transport card/ticket

An interesting result presented in figure 28, where 45% of the survey participants identify challenges to buy the transport card/ticket, these challenges may refer to various reasons; for instance, low number of sales points, unavailability of the plastic cards during peaks hours due to the high demands, technical problem-

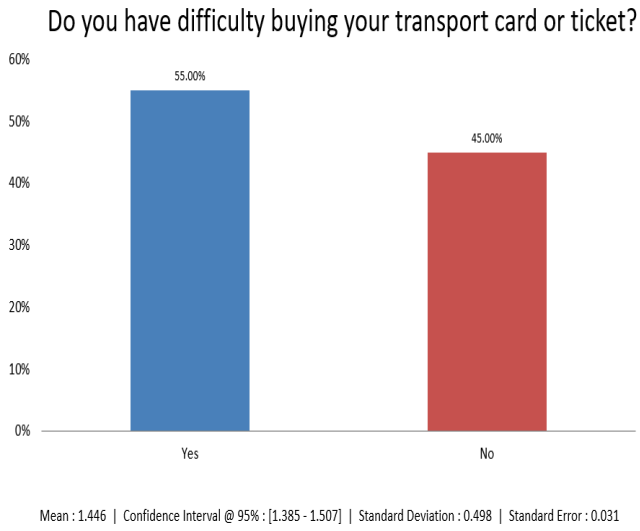


Figure 28: Challenges to buy transport card/Ticket

with ticket vending machines to issue a transport card or ticket**,** nonavailability of the online channels..etc; therefore, this result indicates a significant need to improve the current fare ticketing system by offering new means of payment to the passenger.

3.5.5.6 Challenges to recharge transport card/ticket

Similarly, and in addition to the previous result stated on 4.5.5.5 section above, 49% of the survey participants struggle to recharge their transport card or ticket as presented in figure 29; however, this result may occur due to different reasons; for instance, limited number of recharge channels-

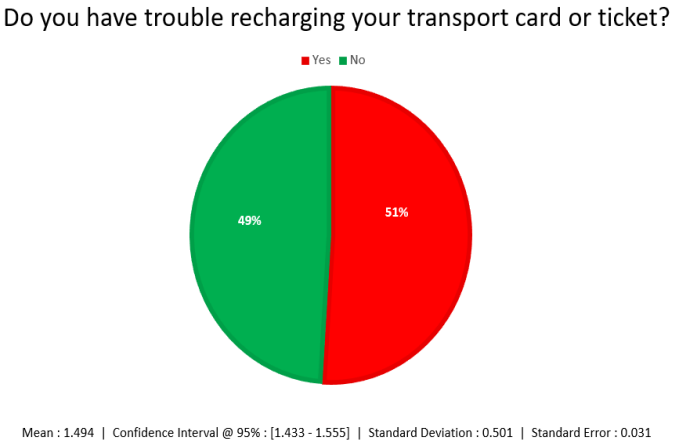


Figure 29: Challenges to recharge transport

cash only might be accepted in some recharging points and no real-time online recharging channels; therefore, this result strengthen the overall challenges of manging the transport card or ticket.

3.5.5.7 Transport card/ticket not working

According to figure 30 69% of the survey participants stated that their transport card or ticket didn't work properly at least once; however, as frequent users it might be still accepted if the card or ticket doesn't work properly for one or two times.

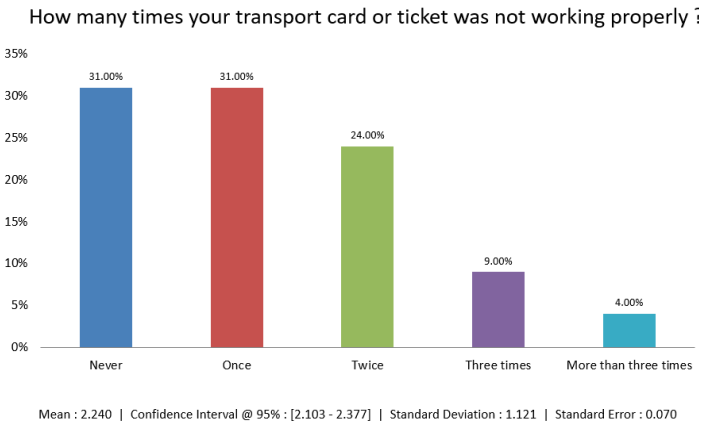


Figure 30: Transport card/ticket not working

However, 11% of participants stated that their transport card didn't work properly for three times and more. This result indicates a complex technical challenge for the transport operator to identify and resolve it.

In fact, its s complex problem in nature due to different transit systems involve; for instance, error with the transport card application or software reader crash or metro gate mechanical failure...etc; moreover, this result might be considered as one of the frequent passengers complain where transit operator requires to resolve by improving its current fare ticketing system and increase passenger satisfaction.

3.5.5.8 Transport card/ticket fraud

According to figure 31 53% of the respondents are afraid of any potential fraud which may cause to their transport card/ticket; therefore, passengers tend to recharge their transport card/ticket with low amounts which equal to their day trips only to avoid such fraud.

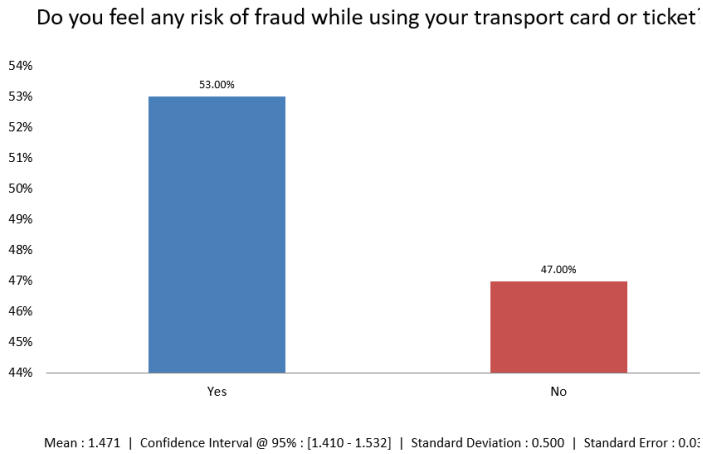


Figure 31: Transport card/ticket fraud

In fact, this result indicates a low trust with current fare media which results to daily pressure on the recharging points and an increase of the operation cost; therefore, it should provide significant red alert to the transit operator to identify and mitigate, in order to gain passenger's trust and reduce operation cost.

3.5.5.9 Waiting time inside Metro station

In fact, and according to several studies the theoretical average waiting time of passenger from entering metro station till reaching metro platform ranges between 1 to 5 minutes which depends on several factors.

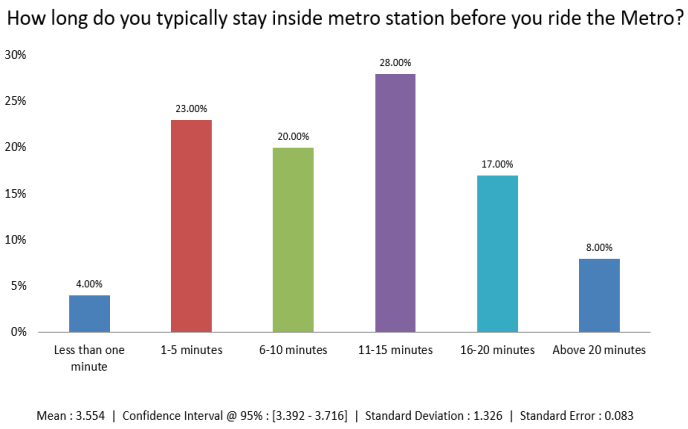


Figure 32: Waiting time inside Metro station

For example, waiting time required to buy or recharge transport card/ticket, waiting time to stay in the queue to tap the transport card or ticket on the metro gate, waiting time to reach office operator and request trip charge from point A to B to recharge the transport card based on that..etc.

According to figure 32 28% of respondents average waiting time ranges from 11 to 15 minutes and 19% of respondents average waiting times are more than 16 minutes which is significant; moreover, the overall result indicates that 73% of respondents average waiting time inside metro station is more than 6 minutes which may prof the challenges passengers are facing as stated earlier; therefore, transit operators shall analyse this result by identifying the gaps and challenges to improve passenger experience

3.5.5.10 Loss of the transport card/ticket

According to figure 33 72% of respondents lost their transport card/ticket at least once which is significant. 17% of respondents lost their transport card/ticket three times.

In fact, these lost card/ticket may have remining amounts saved in the card/ticket electronic purse which are lost forever in addition to the plastic card cost; therefore, this result indicate inconvenience to the passengers.

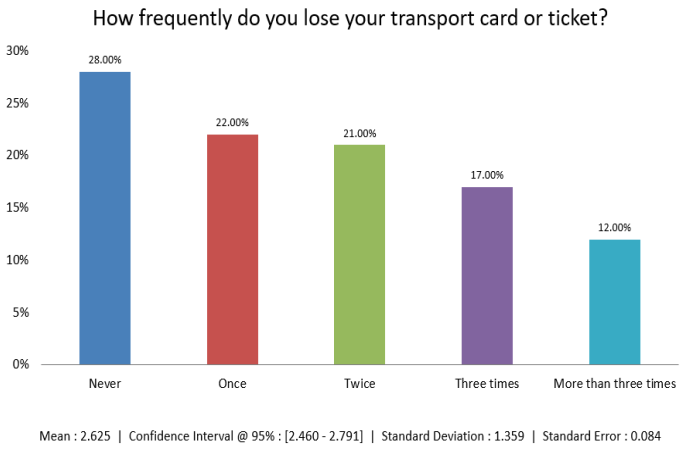


Figure 33: Loss of transport card/ticket

3.5.5.11 Comfortability rate

According to figure 34 13% of respondents are not comfortable with the current transport card/ticket experience due to the challenges and issues stated earlier; moreover, 41% of respondents are somehow comfortable; therefore, several challenges may still exist and occur randomly.

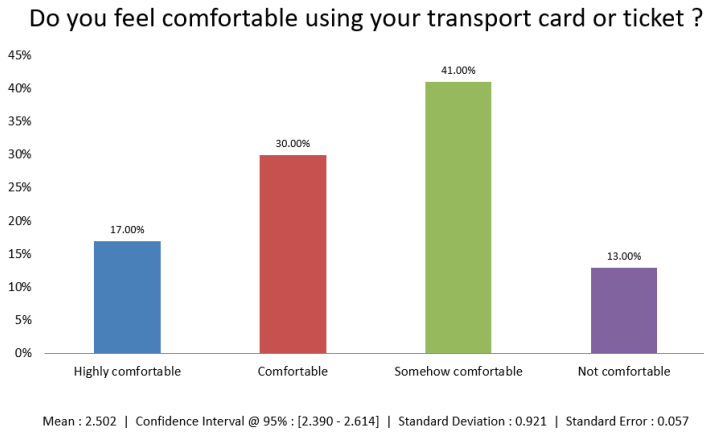


Figure 34: Customer comfortability rating

For instance, average waiting time during peaks hour may reach to more than 20 minutes which leads to difficulties of recharging/buying the transport card inside metro station or even to get a chance to inquire about a trip fare from the ticket office operator due to long queue and significant crowds inside metro station..etc.

3.5.5.12 Availability of the bank account or credit/debit card

According to figure 35 and figure 36 around 85% of respondents have bank accounts or debit/credit cards which are an encouraging indicator for the transit operators to consider if they are planning to improve its current fare media by offering new media option linked to the passenger's bank account or credit/debit card.

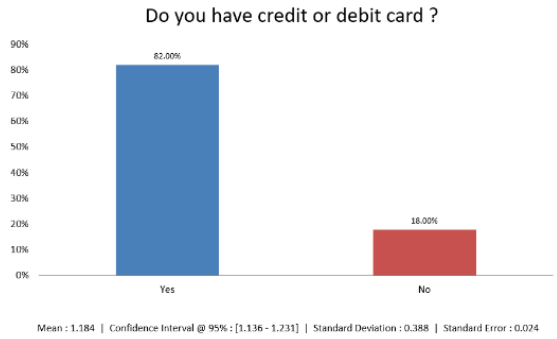


Figure 35: Credit/debit card availability

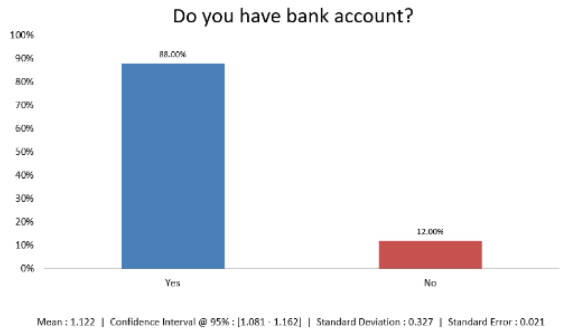


Figure 36: Bank account availability

3.5.5.13 Overall customer satisfaction

In fact, all the results noticed from the previous charts reflect significant challenges of the current transport card/ticket services; similarly, and according to figure 37 and based on the average mean and standard deviation 59% of the respondents are satisfied with the current service and-

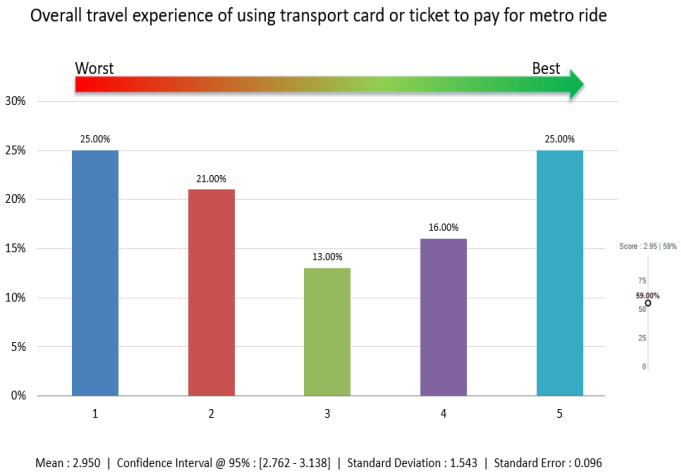


Figure 37: Overall customer satisfaction

39% are not, which indicates the significant needs from the transit operator to consider, and mitigate the challenges stated earlier.

3.5.5.14 Facial recognition expected use

According to figure 38 88% of respondents will use the facial recognition technology as new payment mean to access metro gate which indicate customers' needs and its assumptions that the new proposed service will resolve the current challenges of the transport card/tickets.

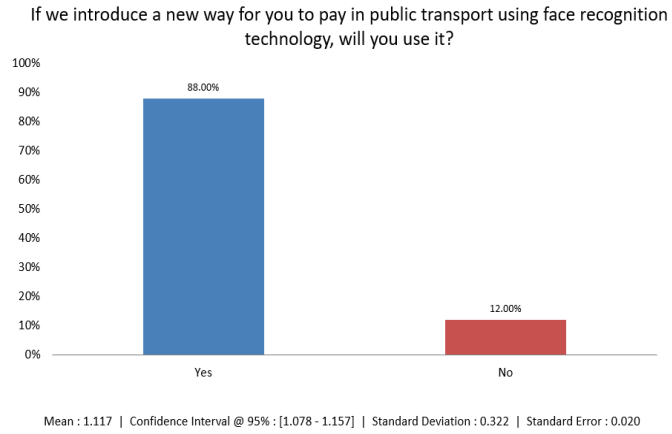


Figure 38: Face recognition expected use

3.5.5.15 Facial recognition expected conveniency

Similarly, 86% of respondents expecting more connivance from the facial recognition access instead of the existing transport card/ticket as presented in figure 39. Thus, this result indicates passengers needs for smoother, convenient, secure and reliable access to metro.

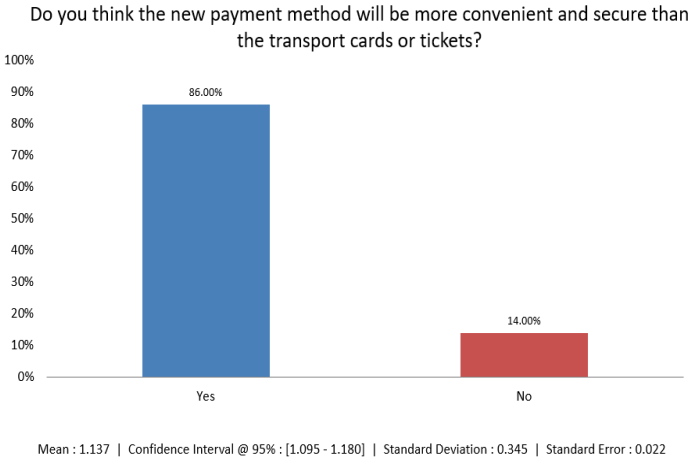


Figure 39: Face recognition expected conveniency

3.5.5.16 Facial recognition technology improves travel experience

Finally, and as presented in figure 40 as a last question of the online survey, the respondents indicate its significant needs to improve the current travel experience with the assumption that the proposed facial recognition technology will achieve that.

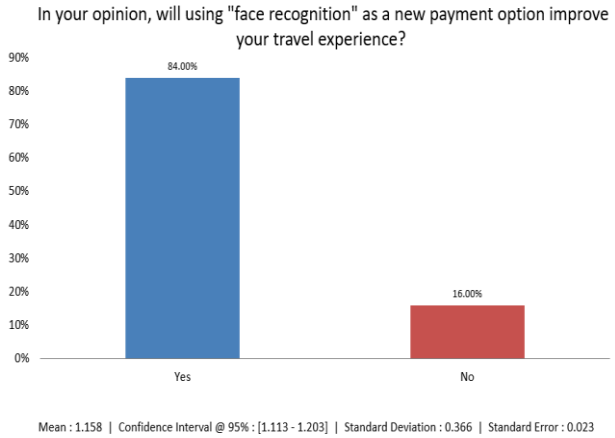


Figure 40: Face recognition improve travel experience

In fact, 84% of the participants expecting an improvement of the travel experience. Moreover, this result strengthens our argument to identify the best solution to offer the facial recognition

access control inside metro station as an alternative payment option to be offer by the transit operator and mitigate the stated challenges.

3.6 Expert questionnaire analyses

3.6.1 Sample criteria

Results collected from the experts was based on ten questions provided to a selected experts who had a vast experience in the image recognition field, and the selection of the experts was based on the following criteria:

- Individuals who have vast technical experience on the image recognition field
- Individuals who have vast project management experience on implementing facial recognition projects in the field

Experts identified and selected from four different face recognition companies based on Russia, United states and united Arab of emirates.

3.6.2 Expert questions

Table 11 Present the questions and multiple-choice options for the experts to select and answer each question.

#	Question	Options
1	What is your educational level?	Diploma/Advanced Diploma Bachelor's degree Master's degree Doctoral degree
2	How many years of experience do you have in the technical field?	Less than a year 1-5 years 6-10 years 11-15 years 16-20 years Above 20 years
3	Do you have experience in developing image recognition systems?	Yes No
4	How many years of experience do you have in the project management field?	Less than a year 1-5 years 6-10 years 11-15 years 16-20 years Above 20 years
5	Do you agree with the statement that providing face recognition as a new payment option in the transit eco-system will reduce consumers' time and transit operators' operational costs?	Strongly agree Agree Neutral Disagree Strongly disagree
	Please comment on your answer, and give any examples if possible.	
6	Do you think it's possible to integrate face recognition technology with the current automated fare collection system?	Yes, I think so. No, I don't think so
	Please comment on your answer, and give any examples if possible.	
7	Which of the following account-based ticketing systems do you think would be more reliable,	Atlas system. – [Provider: Conduent] Base2 system. – [Provider: Network International] OCHS system – [Provider: Octopus]

	compatible, and easy to integrate with face recognition technology?	BOS System – [Provider: VivaTicket] Thales-ABT system - [Provider: Thales] Cubic-ABT system – [Provider: Cubic] BPC-ABT system – [Provider: BPC] Others, Please Specify…..
	Please comment on your answer, and give any examples if possible.	
8	Which face recognition system and CNN technique would be more reliable, secure, and efficient to integrate with the account-based ticketing system easily? Please provide options for the selected methods.	Angular Margin Loss key-frame extraction Multi-order statistical descriptors Weighted K-Nearest Neighbor Higher quantile method FaceBoxes Principal Component Analysis Local Binary Pattern Cascade classifier, Ada Boost Large margin cosine loss Grammatical Evolution Faster – CNN Histogram of oriented gradients & Feedforward Neural Networks Video-based person reidentification YOLOv3 Ordered weighted average FaceSurv Dataset method Quintet triple binary pattern Other
	Please comment on your answer, and give any examples if possible.	
9	Which of the following major challenges would you consider applicable to implementing a new payment option using facial recognition technology in the transit eco-system?	High cost to upgrade current infrastructure. Complexity to integrate different systems. Customer resistance to change. Organizational changes [Operational and business process]. Complexity to trace system issues. Lack of knowledge of the new technology. Technology maturity and reliability High maintenance cost. High operational cost. Others, please specify…
10	Which of the following major risks would you consider applicable to implementing a new payment option using facial recognition technology in the transit eco-system?	High cost to upgrade current infrastructure. Complexity to integrate different systems. Customer resistance to change. Organizational changes [Operational and business process]. Complexity to trace system issues. Lack of knowledge of the new technology. Technology maturity and reliability High maintenance cost. High operational cost. Others, please specify…

Table 11: Expert questions

3.6.3 Rationale of the questions

Expert questions created to gather its practical feedback based on the following criteria's:

- face recognition reduction of passenger time and operation costs, to understand the real-life impact on the overall travel experience and operations.
- face recognition integration with the automated fare collection system, to understand the capability's, complexity and challenges angles to do such integration.
- Best account-based ticketing (ABT) system, to understand the optimum and certified ABT system to integrate with the face recognition system.

- Best face recognition algorithm, to understand the optimum face recognition system and CNN technique to be used in a complex environment.
- Major challenges and risks to be consider when implementing a new payment option using facial recognition technology, to understand and highlight the most applicable challenges and risks to be consider while implementing such technology.

3.6.4 Sampling method

According to figure 41 8 experts completed the questionnaire out of 12 interviewed individuals with 66.67% completion rate. Interviews average time is 30 minutes and questionnaire average time to complete is 15 minutes; furthermore, experts' respondents are based on different geography as presented in figure 41 where 75% of the respondents are based on the united Arab of emirates and the remaining are from Russia; however, and as stated earlier the targeted experts were selected from four different specialized face recognition companies based on Russia, United states and united Arab of emirates, were the expert represents the United States based company responded from its office in Russia.

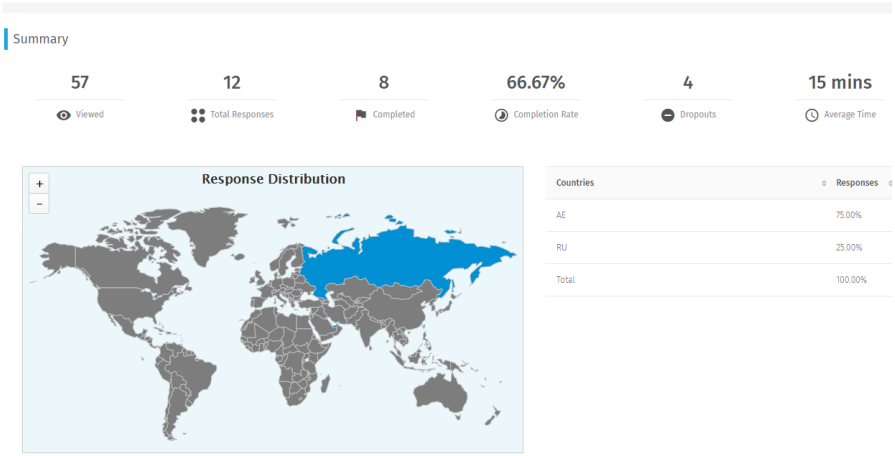


Figure 41: Expert questionnaire summery and coverage

3.6.5 Expert questionnaire results

3.6.5.1 Educational level

According to figure 42 experts who holds master degree are 5 out of 8 experts which reflects 63% of the respondents and the remining 3 experts are holding bachelor degree.

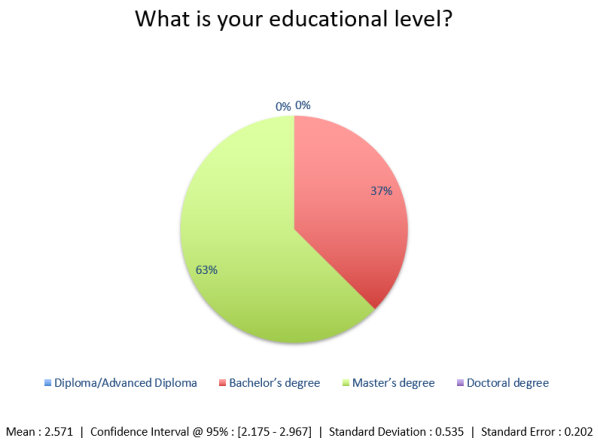


Figure 42: Educational level

This as an expected results due to the criteria of the sampling method, where respondents must have vast expertise in the project and technical management on the facial recognition field. Thus, and in order for the respondents to adhere to the criteria they must hold at least bachelor degree or equivalent.

3.6.5.2 Expertise level in the development, technical and projects management

Expertise in the image recognition development considers the most significant skill for the expert's selection criteria; however, and according to figure 44 seven out of eight experts answered with "Yes", and during the interview one expert acknowledge that he selected "No" by mistake. Similarly, on-site technical and project management expertise's consider the 2nd important criteria which is a must to have; therefore, and as presented in figure 43 five experts have between 1-5 years of experience in managing actual face recognition projects in various industries, and the remaining three experts have more than 6 years of experience which is invaluable and relatively significant for a new technology.

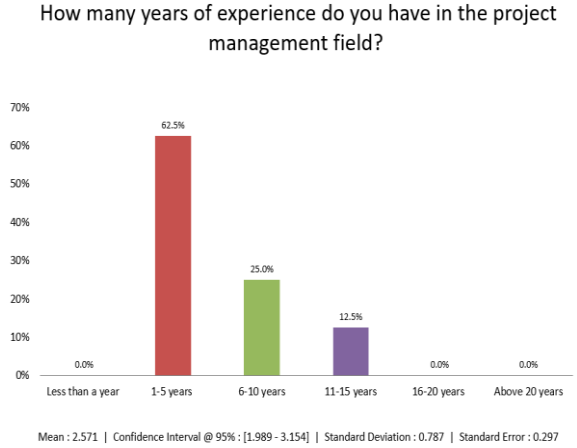


Figure 43: Project management expertise

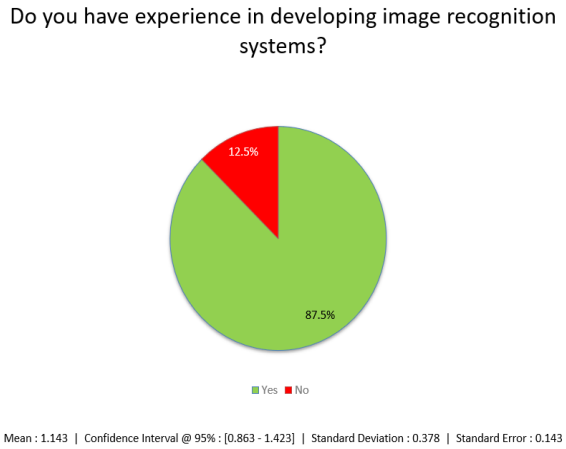


Figure 44: Image development expertise

in addition, and according to figure 45 75% of the experts have 1-5 years of experience in the facial recognition systems and algorithms and 25% have more than 6 years of experience. In fact, the educational background and experience presented-

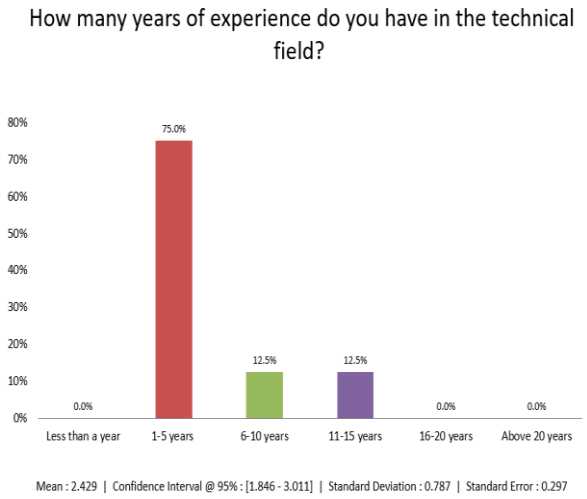


Figure 45: Technical management expertise

in figure 41,42,43 and 44 proofed that the interviewed experts from different specialized companies in face recognition technology are efficient enough to add significant value to this dissertation and claim the proposed solution based on their feedback.

3.6.5.3 Impacts on passenger waiting time and operation cost

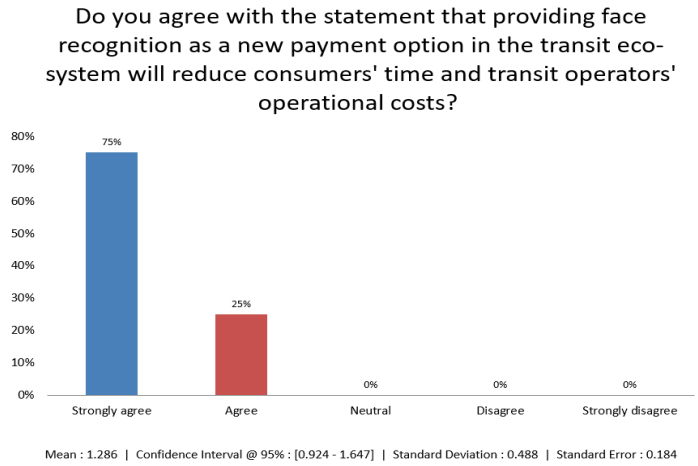


Figure 46: impacts on passenger waiting and operation

Please comment on your answer, and give any examples if possible

Response ID	Response
58428341	Customers can always forget their smart card, or requires time to recharge their cards. with facial recognition technology both challenges are mitigated. Transit operator will increase the revenue by setting more control's on the check-in and check-out entry's which decease the number of passengers who access metro platform without paying.
58425322	Decrease number of manned ticket office Decease passenger time to reach metro platform
58424923	Reduce the cost and operations of manufacturing transit cards and tickets. Reduce cash management operation cost.
58178348	FacePay by VisionLabs was recently introduced on 240 metro stations in Moscow. So far, majority of the customers are satisfied, as it is quick and easy to use. You just need to download the Metro APP and link your photo with your transport card and credit card.
58097205	I believe this will decrease time and work in a efficient way to maximize resources and optimize processes.
57890522	Facial recognition will be able to identify in motion individuals, so it can save time, especially when not requiring people to go through the wallets, unlock their phones, etc.

Figure 47: Comments on the impact of passenger waiting time and operation cost impact

According to figure 46 five out of eight experts strongly agrees that enabling facial recognition as payment access on metro will reduce passengers time consumed inside metro station; moreover, and as an overall experts comments presented in figure 47, passengers will no longer be require to buy or recharge their transport cards or even check the fare required for the ride; thus, decrease passenger average waiting time and transit operators' operations and associated cost of printing tickets and transport card-

In addition, reduce the pressure on the manned and unmanned ticket office operator and vending machines.

In fact, expert results gathered from their onsite experience which strengthens and aligned with the online survey result; thus, it's an additional encouraging reason to identify the optimum and easy to implement face recognition framework to achieve the desired benefits.

3.6.5.4 Integration between Face recognition and fare ticketing systems

Fare ticketing systems are varied in types, architectures, capabilities, operating systems and transaction processing flow; therefore, it's essential to understand the challenges and best techniques to integrate the argued front end payment means using face recognition with the existing fare ticketing systems in a minimum system change.

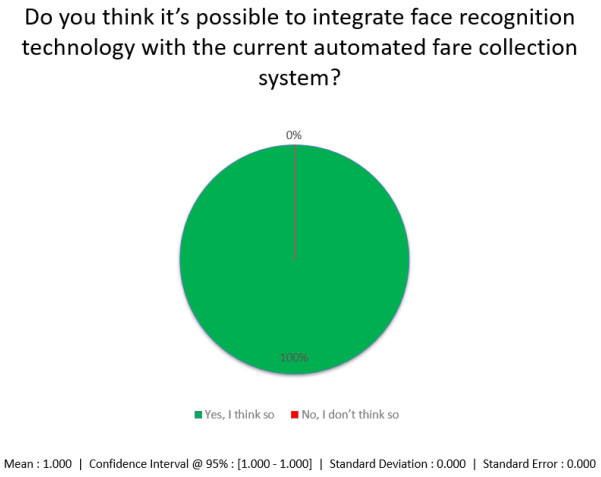


Figure 48: Integration between face recognition and AFC systems

Please comment on your answer, and give any examples if possible:

Response ID	Response
58428341	Face recognition technology setup on the metro gate level, which gives the order to the gate to open or not only. so once metro gate opens then normal transaction generated and sent to Backoffice for automated collection system process and bank account deductions.
58425322	Automated fare collection designed to calculate and deduct the right tariff received based on passengers check-in and out regardless of the fare media used. it can be smart card or bank card or QR code or biometric.
58424923	Customize systems components to ensure compatibility with both systems. its a doable and a must action to preform the integration.
58178348	It can be integrated via APP for example.
58097205	The system is mature and the current infrastructure can accommodate advanced technologies.

Figure 49: Comments on the Integration between face recognition and AFC systems

Thus, and according to figure 48 100% of experts assured the possibility to integrate the front-end payment (face recognition) with the existing backend system (fare collection system); moreover, and according to figure 49 majority of the experts' comments elaborate on the integration possibilities between the face recognitions system and AFC system. Comments highlighted the dependencies of each system were a compatible middle layer system component suggested to add it in order to connect the front end for passengers' payment authorization with the back-end system for the fare calculation and wallet deduction.

3.6.5.5 Account based ticketing system reliability for facial recognition access control

Account based ticket (ABT) system consider one of the essential prerequisites to enable face recognition technology as authorization access entry to metro due to the fact that the fare calculation of the journey must be performed on the backend system and the banking financial transactions proposed to be processed through ABT system.

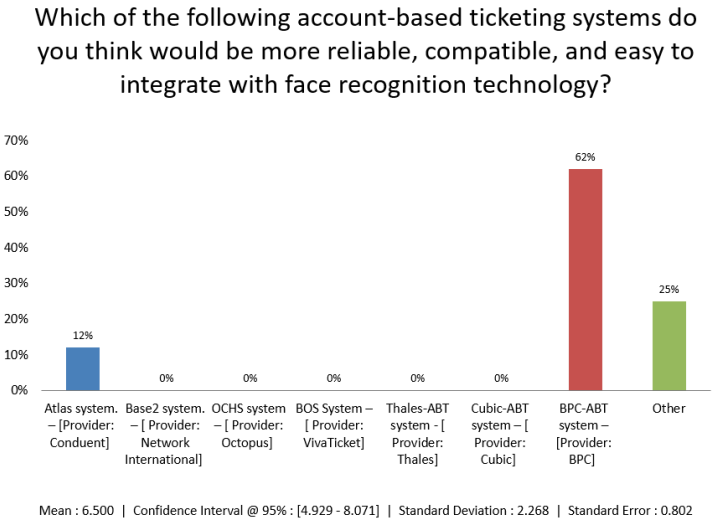


Figure 50: Account based ticketing systems

Please comment on your answer, and give any examples if possible:

Response ID	Response
58428341	Atlas consider fast and reliable transaction processing backend system
58425322	BPC System specification adheres to the banks system security standards to process financial transactions.
58424923	BPC ABT system used in different projects thru processing the EMV bank contactless transactions under PCI DSS compatible and secure environment.
58097205	BPC is compliant and its proven thru testing and studies.
57890522	BPC is PCI DSS compliant

Figure 51: Comments on the account based ticketing

Therefore, and according to figure 50 62% of the experts recommends the commercially named "Banking-Payments-Context(BPC) account based ticketing system" (*Automated Fare Collection | BPC |*, 2020),based on their on-site experiences, and according to figure 51 experts rationale of selecting the "BPC account based ticketing system" falls under the security standards and transaction processing efficiency elements.

Moreover, and based on the assumptions that the financial transactions are expected to be sent from the front-end system, then to be processed through ABT system, experts claims that the "BPC account based ticketing system" is the most reliable, complaint and certified ticketing system to perform the desire financial transaction processing, which adheres to the "Payment Card Industry-Data Security Standard (PCI-DSS)" organization.

In additions, and according to figure 50 25% of the experts stated others and during the interview its claimed that any ABT should adhere and comply with the PCI-DSS standards to ensure proper transaction security and system efficiency in place.

3.6.5.6 Suitable Face recognitions algorithm for Metro access

Based on the experts interview feedback, identifying the optimum face recognition techniques and algorithms to build the face recognition system consider the most essential and complex decision to make in any face recognition company; moreover, and in order to gain clients trust with the proposed face recognition system-

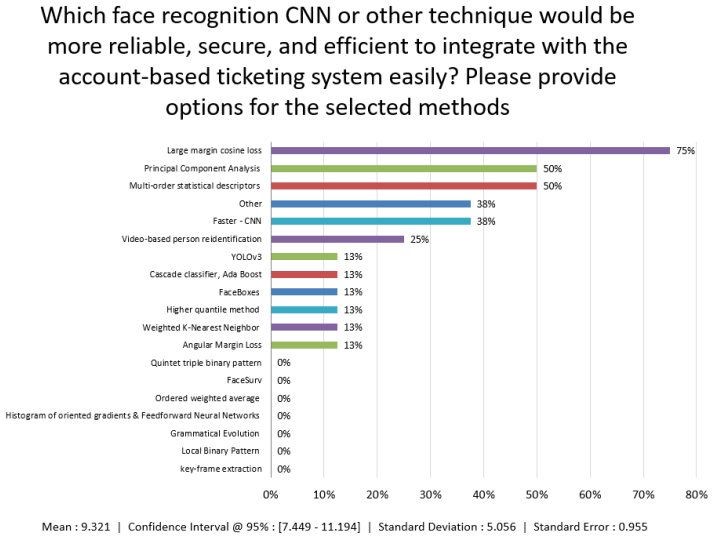


Figure 52: Face recognition algorithms

Please comment on your answer, and give any examples if possible:

Response ID	Response
58428341	Accuracy 99 - 100% , processing speed: 200-400 milliseconds. computational powers standard.
58425322	The selected CNN's works efficiently together thru face recognition process.
58424923	Multi-order statistical descriptors & Principal Component Analysis used to classify and detect the face. and Large margin cosine loss used to recognize the face full operation processing speed 200 milliseconds - 99.3% accuracy
58097205	High accuracy and processing speed
57890522	Speed of a 200 ms, and accuracy 98% nearing to ~100% based off distance, lighting conditions, motion blur and other potential face occlusions.

Figure 53: Comments on the selected face recognition algorithms

The product must by comply and certified by the most worldwide famous test authority hub "The National Institute of Standards and Technology (NIST), where the certification must cover face recognition vendor test (FRVT) and computer vision and pattern recognition (CVPR)"(*National Institute of Standards and Technology | NIST*, n.d.).

However, expected answers from figure 52 question is built based on one or more than one algorithm selected from the checklist.

In fact, and according to figure 52 75% of experts consider the large margin cosine loss algorithm the most accurate and efficient algorithm to utilize in a complex environment due to the claimed on-site results of 98-100% facial recognition accuracy in equal or less than 200 milliseconds processing speed and the accuracy level depends on several factors; for instance, distance, image resolution and motion blur.

However, four experts (50%) recommend the principal components analysis (PCA) algorithm and multi-order statistical descriptor (MSD) algorithm to be used due to its efficient accuracy

observed in the surveillance systems based on low computational requirements with a claimed 200-400 milliseconds processing speed as presented in figure 53.

Similarly, two experts from UAE recommends to use video-based person identification algorithm for image classification to support the cosine algorithm in order to reduce image illumination, improve image resolution and quality as an input to cosine algorithm; however, and during the interview the two exerts claims that this technique is costly due to the high computational power required to achieve the desired 100% accuracy in 200 milliseconds processing speed; therefore, they claimed that such system is currently used in a very restricted area's and for a sensitive security investigation industries.

Moreover, and according figure 52 38% of experts selected the faster CNN algorithm due to its efficient technique in image framing and classification; finally, 38% of experts selected others, and they comment during the interview that other customized algorithms has been built based on different set of algorithms and has it's owned new commercial name; for instance, the commercially named "LUNA face recognition" system which mainly built based on the (Cosine and MSD) algorithms.

3.6.5.7 Challenges of the face recongation technology

According to figure 54 66% of experts consider the lack of knowledge of the face recognition technology and customer resistance to change are the most significant challenges which requires organization and company's attentions to mitigate. In fact, face recognition considers relatively new technology to the world which takes time in nature-

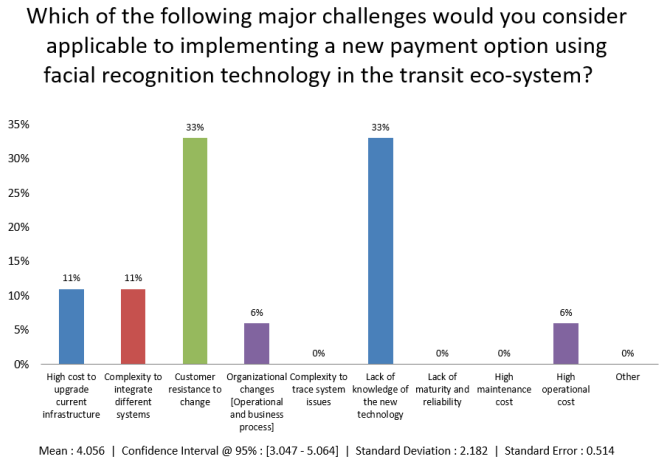


Figure 54: Challenges of face recognition

If other, please specify:

Response ID	Response
58097205	.
57890522	Key stakeholders that are unfamiliar with the current state-of-the-art technology, and process

Figure 55: Face recognition challenges comments

to trust and adopt by the individuals and associated stakeholders; however, this result indicates a great potential for the companies and originations to consider while enabling face recognition technology into their eco-system and services.

similarly, and according to figure 55 one expert elaborated further on the stakeholder lack of awareness and knowledge of this technology which requires significant attention to consider. Moreover, and according to figure 54 11% of experts pointed out that "the high cost to upgrade the current infrastructure" consider as a challenge to enable face recognition inside metro station. However, this is due to the legacy AFC systems were most of the transit operators are currently operates, where the key challenge assumed is to enable a state-of-the-art face recognition technology in a such legacy AFC system.

3.6.5.8 Risks of the face recongation technology

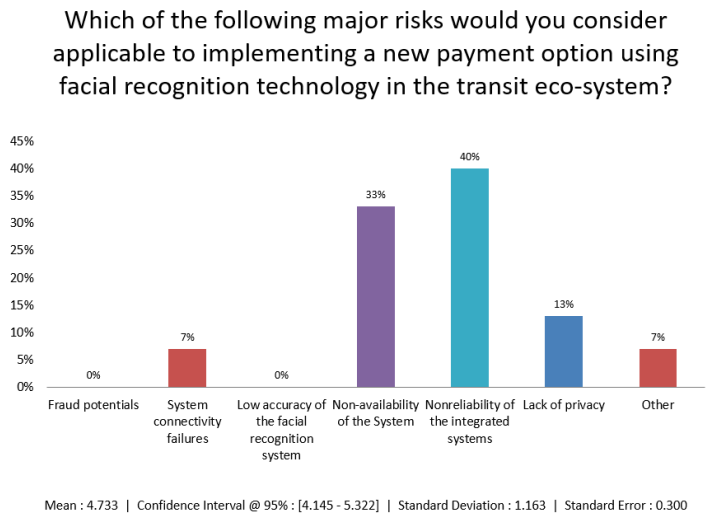


Figure 56: Risks of face recognition

If other, please specify:

Response ID	Response
58097205	Facial recognition systems are reliable in nature but could be integrated with less reliable systems and therefore this would affect the overall process of the addition of facial recognition technology to the Transit sector.
57890522	Integration, means there are multiple systems working in conjunction with each other and they have to be able to operate without difficulty.

Figure 57: Face recognition risk comments

According to figure 56 40% of the experts consider the "nonreliability of the integrated systems" one of the significant risks; however, this is due to the legacy AFC systems which may impact the integrations if not customized to adhere to the system integrations criteria. On the other hand, and due to the complex architecture and multiple systems integrated with each other's to offer one service-

33% of the experts are concerned of the non-availability of the system and consider it as a major risk to monitor; for instance, any of the components from the integrated system may become non-available during the day or peaks hours which impact the whole system and stop the service. Similarly, and according to figure 57 experts are more concerned of the transit AFC systems reliability to operate in efficient and quick manner with the state-of-the-art facial recognition systems.

3.7 Online survey and expert questionnaire summery results

In fact, online survey results highlighted significant gaps of the existing payment method used in the transit eco-system (transport card or tickets) which creates the needs to offer an alternative easy to use and efficient payment mean; in addition, results indicates respondents high potential and willingness to use facial recognition technology as an alternative and easy to use payment mean to access metro due to the assumptions that it will mitigate the current gaps and challenges, save time and passenger hassles.

In the other hand, expert questionnaire results strengthen the online survey results by advising on the optimum face recognition and account based ticketing systems to utilize, and highlighting the risks in advance; for instance, nonreliability of the integrated systems and non-availability of the system; in addition, experts highlighted “lack of knowledge of the face recognition technology” and “customer resistance to change” as a key challenge to consider.

Therefore, experts recommended the following face recognition algorithms and ABT system which suits to implement in the transit complex environment:

- large margin cosine loss algorithm, principal components analysis and multi-order statistical descriptor (MSD) algorithms.
- BPC account based ticketing system.

Finally, online survey and expert questionnaire outcomes answers the third dissertation question.

4 Chapter Four: Conceptual Framework

This chapter present the argued framework which consist of the state-of-the-art end-to-end solutions proposed to offer face recognition access as new payment option to use inside metro station with the potential to expand it to other transit modes and propose it to any other complex environment.

4.1 Introduction

4.1.1 Definition

The conceptual framework defined as variety of key factors or variables which have strong relations between each other's, which provides an explanatory approach to the real-world environment based on existing environmental phenomenon where multiple literatures influence and support that phenomenal. Therefore, framework source data should be collected from different types of articles, interviews, surveys and practices (Jabareen, 2009).

4.1.2 Objective

The aim of the framework to provide a comprehensive solution of the face recognition technology to be use as a passenger authentication to access metro gate and ride metro which consist of the following:

1- Hardware and software specification minimum requirements.
2- End-to-end system integration diagram.
3- End-to-end transaction flows.

In addition, elaborate on the strength of the framework to encourage transit operators to utilize it in the real-life environment.

4.2 Methodology

The proposed framework is built based on the SLR review and expert questionnaire results and recommendations; therefore, the framework consider as an output of the theoretical and practical results and recommendations in order to argue the state-of-the-art solution.

The framework presents the following two solutions where each solution consists of different systems and all together are integrated to offer face recognition service as new payment mean inside metro station:

1. First solution: This solution integrates existing surveillance camera, face recognition algorithm and system, front-end, middleware, ABT, payment gateway and bank systems

2. Second solution: This solution integrates dedicated HD face recognition camera, face recognition algorithm and system, front-end, middleware, ABT, payment gateway and banks systems.

4.3 Framework of the first and second solutions

4.3.1 First solution- Existing surveillance camera system

4.3.1.1 Hardware and operating system requirements

4.3.1.1.1 Surveillance CCTV camera

Surveillance camera's which are equipped inside metro station and its system used for monitoring purposes are targeted to extend its use for facial recognition services; however, the following are the minimum hardware and operating system requirements expected in the surveillance camera:

- Camera resolution: 2 MegaPixel. (SentiVeillance 8.0 SDK)
- Memory: 8 GB of RAM
- GPU: NVIDIA GeForce GTX 1080 GPU
- PC: x86-64 (64-bit), windows 8,10 and 3 GHz processor

4.3.1.1.2 Front end system

1. Metro gate: Turnstile or swing metro gate equipped with at least 2 gigabytes storage, contactless reader and kernel software which have the capability to connect to the middleware and fare collection system through ethernet cable.
2. AFC station server, video analytics server and database servers. Minimum requirements of each server presented in table 12 as per the following:

• Operating System: Windows 10 64-Bit • Processor: Intel® i7 Quad Core Processor 3.4GHz, 8M Cache • Memory: 8 GB • Network card: Gigabit Ethernet and WIFI • Hard Drive capacity: 2TB • Video Card: high-end graphics card

Table 12: Station server hardware minimum requirements

In addition, its recommended to use the oracle cloud infrastructure as the database system implemented in the database server (Oracle, 2020).

4.3.1.1.3 Middleware integrator

Station server equipped with the minimum hardware requirements as presented in table 12 and an Application Programming Interfaces (API's) are setup in the operating system. This product meant to be the middleware to connect the components of the frontend system with the backend system.

4.3.1.1.4 Account based ticketing system

Multiple station servers are required with the minimum requirements presented in table 12; however, the number of servers and storage required will highly depends on the expected number of transaction volumes and transit infrastructure.

Moreover, "BPC-Account based ticketing system" is recommended to use as the central clearing house backend system for fare calculation, transit business rules, passengers' registration, and an integrated hub for the passenger wallet.

4.3.1.2 Face recognition algorithm and systems

A combination of different algorithms and systems enabled on the surveillance camera's proposed as per the following:

- Local Binary Pattern descriptor - Extract facial features where every histogram sample compared with the histogram template in order to find the threshold of each region as shown in figure 58 (Zhang et al., 2017).
- Haar-Like Descriptor - Extract eye features, where the features of Haar-like descriptor contain multiple rectangular regions as presented in figure 59; in addition, pixel values fall in the black region are subtracted from the white region; thus, total net values are representing the features. it's worth to mention that the best match of the presented features falls in the area with the minimum value(Zhang et al., 2017).

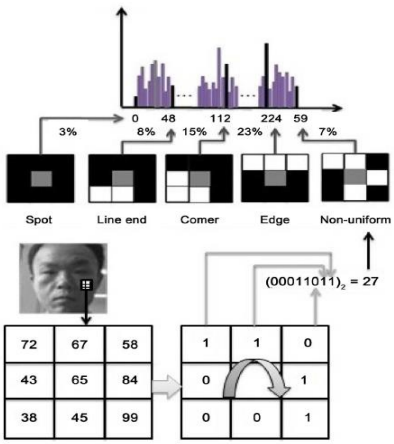


Figure 58: Descriptor encoding
(Zhang et al., 2017)

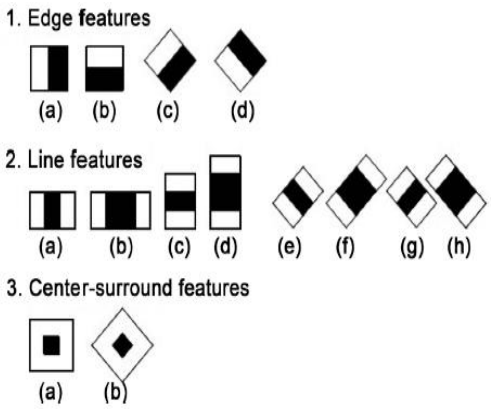


Figure 59: Haar-like features
(Zhang et al., 2017)

- Ada Boost - Extract best features to detect face.
- Cascade classifiers - which trained based on Ada Boost and used to detect the faces and the eyes in different conditions as shown in figure 60 and figure 61(Zhang et al., 2017).

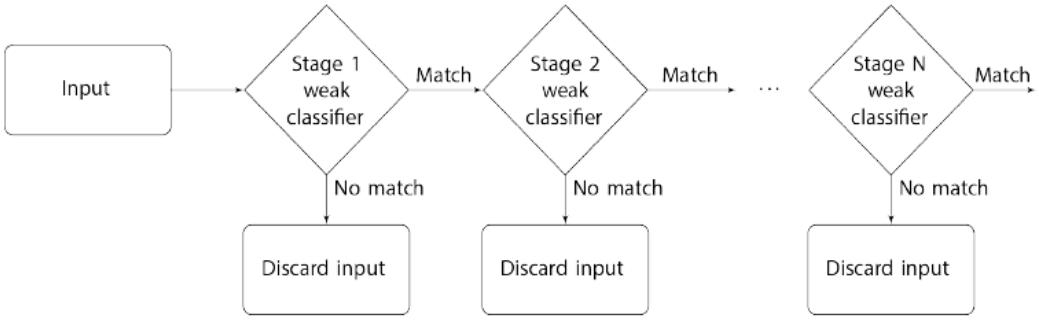


Figure 60: Cascading classifier flowchart
(Zhang et al., 2017)

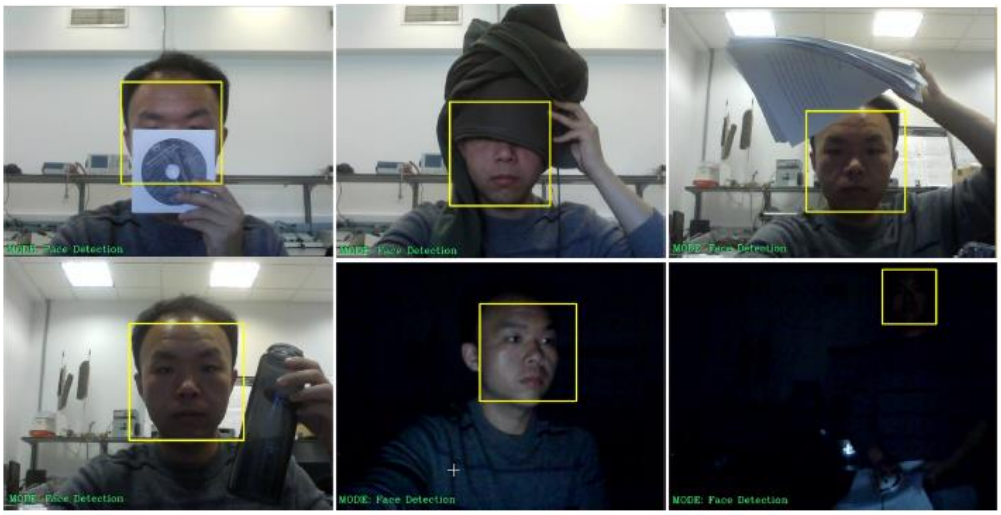


Figure 61: Face detection in different image conditions
(Zhang et al., 2017)

- Affine Transformation - To correct the location and scale of the detected face image as shown in figure 62

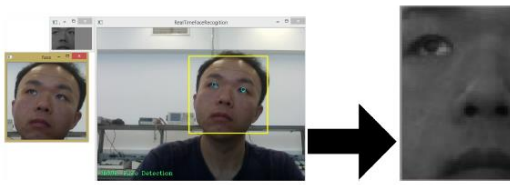


Figure 62: Image after correction
(Zhang et al., 2017)

- Histogram Equalization - Improve contrast of the detected face image lighting conditions (week or strong) as shown in figure 63.
- Gaussian Filter - Remove the noise from the pre-processed face image as shown in figure 64
- Principal Component Analysis - Recognize the high dimensional face image based on few principal components.
- OpenCV or MATLAB application.

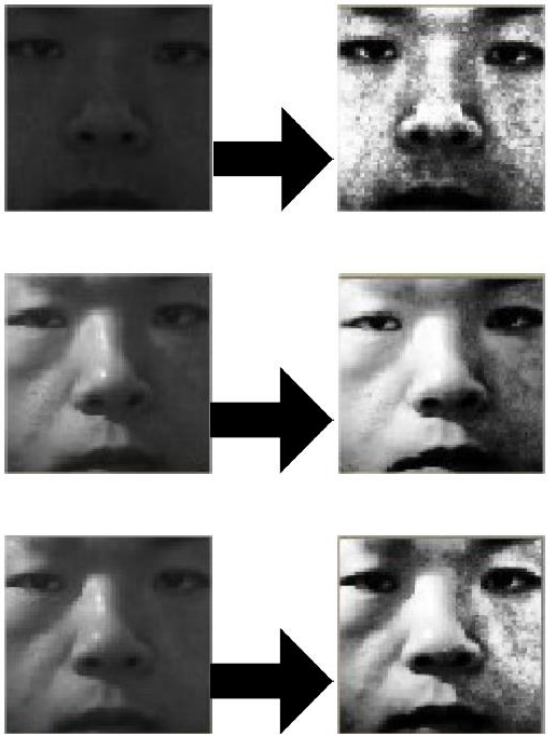


Figure 63: Image after lighting improvement
(Zhang et al., 2017)

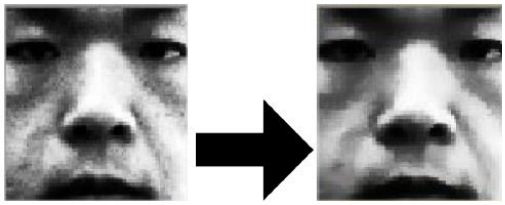


Figure 64: Image after removing the noise
(Zhang et al., 2017)

4.3.1.3 Systems integration flow

1- Installation of the hardware components, operating systems and applications as highlighted previously in section 4.3.1.1

2- Re-position one CCTV camera on the top of each metro gate.

3- Integrate the “Local Binary Pattern descriptor, Haar-Like Descriptor, Cascade classifiers, Affine Transformation, Histogram Equalization, Gaussian Filter and Principal Component Analysis algorithms.
4- Embed the algorithms stated in the previous point into OpenCV or MATLAB facial recognition application.
5- Install OpenCV or MATLAB application in the video analytics server located inside metro station.
6- Connect OpenCV or MATLAB application to all CCTV camera’s equipped inside metro station.
7- Integrate video analytics server with the database server through middleware server API’s.
8- Integrate Metro gate barrier system with the OpenCV application through middleware server API’s.
9- Integrate database server with the AFC server through middleware server API’s.
10- Integrate ABT backend system with the database server through middleware server API’s.

4.3.1.4 Transaction processing flow

1- Collect passenger face frame from the time passenger enters metro station with the aim of capturing the best face image frame at the best possible position with high-resolution image through CCTV cameras.
2- Send face frames from all CCVT cameras to the OpenCV or MATLAB application for image frames processing.
3- OpenCV or MATLAB application begins image frame processing using the “local Binary Pattern, Haar-Like descriptors, Cascade classifiers, Affine transformation, Histogram equalization and Gaussian filter” methods.
4- If the face detection process results to less than 99% accuracy, then OpenCV or MATLAB application maintains the results for monitoring and security purpose only.
5- If the face detection process results to more than 99% accuracy, then OpenCV or MATLAB application record the detected face frames in a temporary database log’s:
    a. Once passenger reach to the designated area and stands in front of the metro gate, the main CCTV camera system which located on the top of metro gate detect passenger face frame, then a lookup process performed to match the

identified face frame with the face frames recorded in the temporary database log's.

b. If the detected face frame image found then in the temporary database logs:
    i. Face recognition process begins using Principal Component Analysis algorithm by recognizing and matching the face against registered biometric records stored in the station server database.
    ii. If the recognized face matches any record, then blacklist validation check performed through the blacklist file stored in the metro gate memory.
    iii. If the blacklist file validation check pass, then metro gate is open and passenger can access, else failure error message display with a peep sound asking passenger to pay with their bank card or mobile phone in case of face recognition process failure or due to an account identified in the blacklist; thus, an alert message display asking passenger to visit ticket office operator for more support.

c. If the detected face frame image not found in the temporary database logs:
    i. Face detection and recognition process reinitiated through OpenCV or MATLAB application in order to detect, recognize and match the face against registered biometric records stored in the station server database while using the algorithms stated in section 4.3.1.2
    ii. Repeat from 5.b.ii to point 5.b.iii

6- Check-in or check-out transaction generated with the passenger information's
7- Trip transaction details sent as a batch file to the AFC station server through middleware.
8- All transactions sent from the AFC metro station server to the account based ticketing system through middleware server end of the day.
9- Account based ticketing system verify the transaction file and calculate the aggregated trips value based on the transit operator business rules.
10- Account based ticketing system sends authorization request to the acquiring bank or wallet owner to deduct the fare from the passenger bank account.
11- If the authorization response fail:
    a. Account based ticketing system adds passenger account as a new record to the backlist file, tell passenger clear his debt.
    b. Passenger request to clear his debt online or in the station.

c. Account-based ticketing system receives the clearness request, and based on that a new authorization request with the outstanding amount sends to the acquiring bank through payment gateway for deduction.
d. Once authorization response pass, account based ticketing system removes the record from the backlist file and update to all metro gates.

❖ **Conditions**

A. Existing CCTV cameras should match the minimum requirements stated in section 4.3.1.1.1
B. Expected processing time till Metro gate open is 600-1200 milliseconds.
C. Expected response for processing new image frame is 40 FPS.
D. Dedicated lane for passengers to guide them in order to walk towards metro gate.
E. CCTV camera's positioned to the dedicated walking lane.
F. Passenger biometric details installed from the ABT backend system to the database station server through middleware server every 10 minutes.
G. Periodic blacklist installed from the ABT backend system to the AFC station server through middleware server every 10 minutes.
H. Passenger must register their biometric details online through transit operator application.
I. Passengers must link their bank account or credit/debit card to their transit account.
J. Passengers must have sufficient outstanding balance in their bank account.
K. Passenger must check-out from the Metro gate by following the same face recognition service to avoid maximum fare deduction.
L. Transit operator must indicate a clear zone for the passenger to stand in for the best and fast face recognition access.
M. Distance between the main camera and passenger face is not more than 2 meters.

Figure 65 present the overall solution flow as described in section 4.3.1.3 and section 4.3.1.4

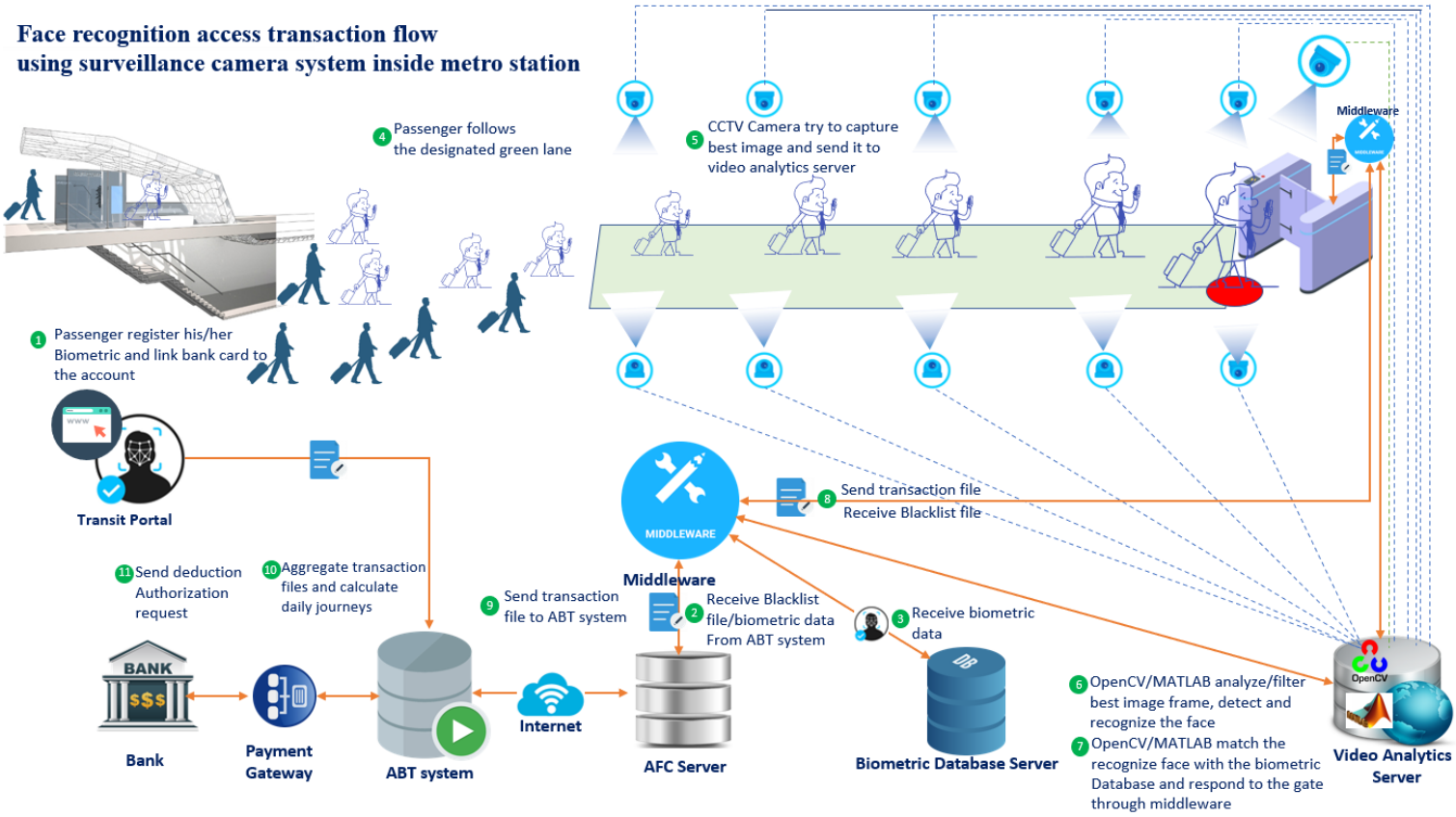


Figure: 65: First solution transaction flow

4.3.2 Second solution - Dedicated face recognition camera

4.3.2.1 Hardware and operating system requirements

4.3.2.1.1 Dedicated camera systems for face recognition

- Setup of a new Dual Full HD (1280 x 800), 25 FPS stereo cameras, and the following table 13 present the detailed proposed technical specifications:

#	Characteristic	Description
1	Body material	Alum. alloy 3.1355
2	Body dimensions HxWxD	119x266x12 mm
3	Base dimensions, HxWxD	65x100x100 mm
4	Support dimensions, HxWxD	10-130x35x30 mm
5	Operating temperature range	From 5 °C to 40 °C
6	Ingress protection rating according to IEC 60529	IP 30
7	Supply voltage	12V
8	Power consumption	Up to 3A
9	Display Size	1024 x 600
10	Recognition time	Less than 200ms
11	Interface and connectivity	Ethernet (RJ45 or WIFI)
12	Encryption protocols	SSL, SHA256,
13	Optional encryption protocol	IPsec VPN

Table 13: Stereo camera technical specification

4.3.2.1.2 Front end system

Same specifications highlighted previously in section 4.3.1.1.2

4.3.2.1.3 Middleware integrator

Same specifications highlighted previously in section 4.3.1.1.3

4.3.2.1.4 Account based ticketing system

Same specifications highlighted previously in section 4.3.1.1.4

4.3.2.2 Face recognition algorithm and systems

1. Proposed face recognition architecture to utilize named: MFCosface which contains the following:
    a. Multi-task cascaded convolutional neural network (MTCNN)(Deng et al., 2021).
        i. Resizing image.
        ii. Generate image pyramids.
        iii. P-Net - To generate candidate frames.
        iv. R-Net - Filter poor frames and perform frames regression to optimize predicted results.
        v. O-Net - Revert features and output the positions of the key features.
        vi. HOG – To identify more features of the masked faces.
        vii. Mask coverage - Use only for the front image of the masked face, to detect the maximum key points features and positions of the face as presented in figure 66. The intra-class distance has been effectively compressed and variation difference has been limited using cosine margin(Deng et al., 2021).

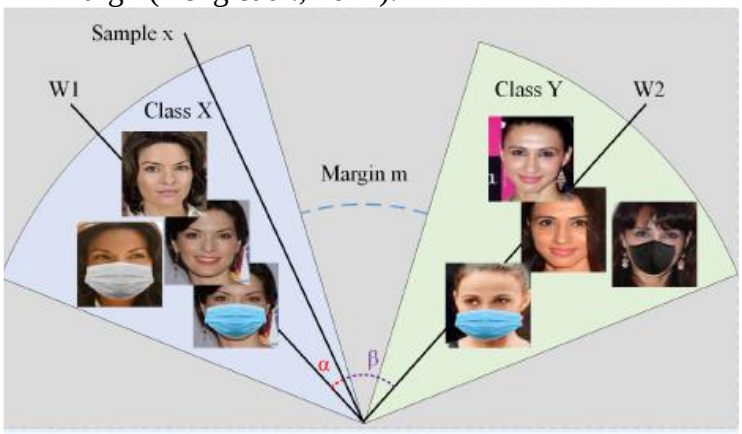


Figure 66: Intra-class distance difference variation margin(Deng et al., 2021)

2. The large margin cosine loss function – To use for better recognition accuracy.
3. Convolutional block attention module (CBAM)- Used to focus on the face features which are not covered by the mask and consist of following two modules:
    a. The channel attention module: this module used to obtain the average and max-pooling features from the average and max-pooling inputs in order to aggregate these features into the shared multi-layer perceptron (Shared MLP) to feed the channel attention mapping as shown in figure 67(Deng et al., 2021).

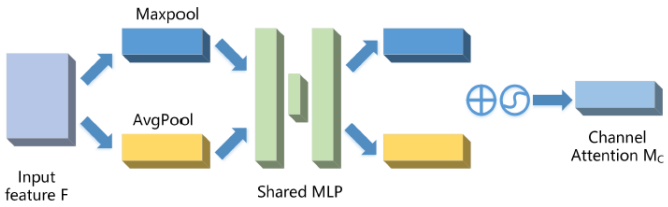


Figure 67: The channel attention module (Deng et al., 2021)

b. The spatial attention module: Outcomes of the channel attention mapping presented in figure 67 are consider as an input feature to the spatial attention module. Moreover, in order to obtain the average and max-pooling features we use the outcomes of the channel attention mapping through performing channel based average and max-pooling process, then outcome features are connected in sequence in order to get the feature mapping of the first dimension as shown in figure 68(Deng et al., 2021).

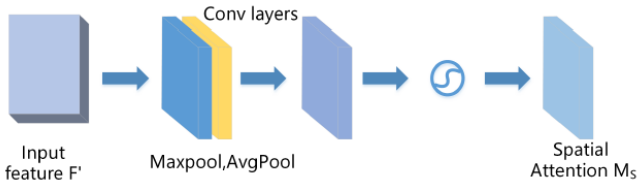


Figure 68: The spatial attention module (Deng et al., 2021)

4. MFCosface network structure

Inception ResNet-v1 network used as basic network to build MFCosface network structure based on it. The Inception-ResNet module which is part of the basic network; however, and in order to add more focus on the effective face features, the inception-ResNet module has been replaced with the attention inception module.

Figure 69 present the proposed network structure, where the same size modules outputs to similar dimension feature map(Deng et al., 2021).

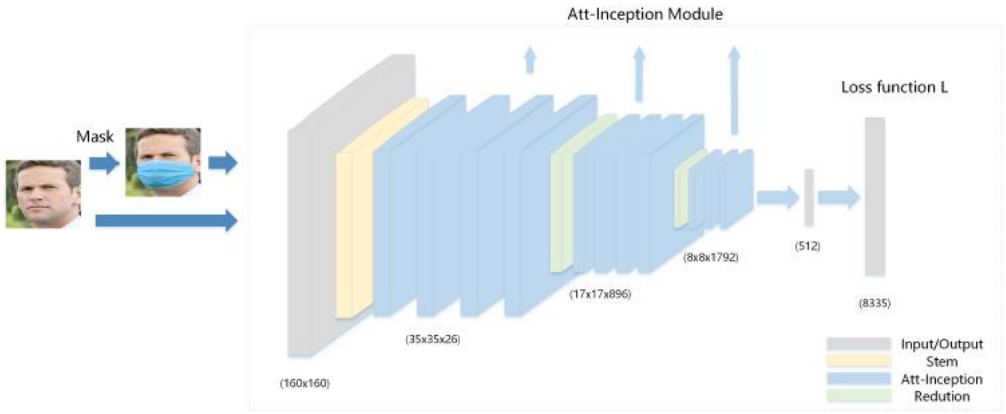


Figure 69: MFCosface network structure diagram (Deng et al., 2021)

5. Face recognition application recommended: LUNA, Betaface, BioID, Cognitec, DeepVision AI, Face++, FaceFirst, Kairos, SenseTime, Sky Biometry, Trueface.ai and others(Ramya Mohanakrishnan, 2021).

4.3.2.3 Systems integration flow

1- Installation of the hardware components, operating systems and applications as highlighted previously in section 4.3.2.1.1
2- Installation of HD stereo camera on the top of each metro gate.
3- Integrate the MTCNN, P-Net, R-Net, HOG, Mask coverage, CBAM and large margin cosine loss algorithms and classifiers based on MFCosface network structure.
4- Embed the algorithms and classifiers stated in the previous point into the face recognition application.
5- Install the face recognition application in the video analytics server located inside metro station.
6- Integrate video analytics server with the database server through middleware server API's.
7- Integrate metro gate barrier system with the face recognition application through middleware server API's.
8- Integrate database server with AFC server through middleware server API's.
9- Integrate ABT backend system with the database server through middleware server API's.

4.3.2.4 Transaction processing flow

1- Once passenger stands on the designated zone for facial recognition, stereo camera sensor detect passenger.
2- Facial recognition application begins image frame classification and face detection process based on MFCosface architecture while using " MTCNN, P-Net, R-Net, HOG, Mask coverage and CBAM" techniques.
3- Once face detection completed successfully, facial recognition application begins facial recognition process using large margin cosine loss algorithm.
4- If the face recognition frame pass, then:
    i. Facial recognition application matches the recognized face with biometric records stored in the database server.

ii. If the recognized face matches any record, then, blacklist validation check performed through blacklist file stored in the metro gate memory.

iii. If the blacklist file validation check pass, then metro gate is open and passenger can access, else failure error message display with a peep sound asking passenger to pay with their bank card or mobile phone in case of face recognition process failure or due to an account identified in the blacklist; thus, an alert message display asking passenger to visit ticket office operator for more support.

5- Follow the same steps mentioned in section 4.3.1.4 (from Point 6 to point 11).

❖ **Conditions**

A. Existing stereo camera should match the minimum requirements stated in section 4.3.2.1.1

B. Expected processing time till Metro gate open is 200-400 milliseconds.

C. Expected response for processing new image frame is 25 FPS.

The same conditions mentioned in section 4.3.1.4 “Condition” (from point F to point M) are applied.

Figure 70 present overall system architecture and transaction flow as described in section 4.3.2.3 and section 4.3.2.4

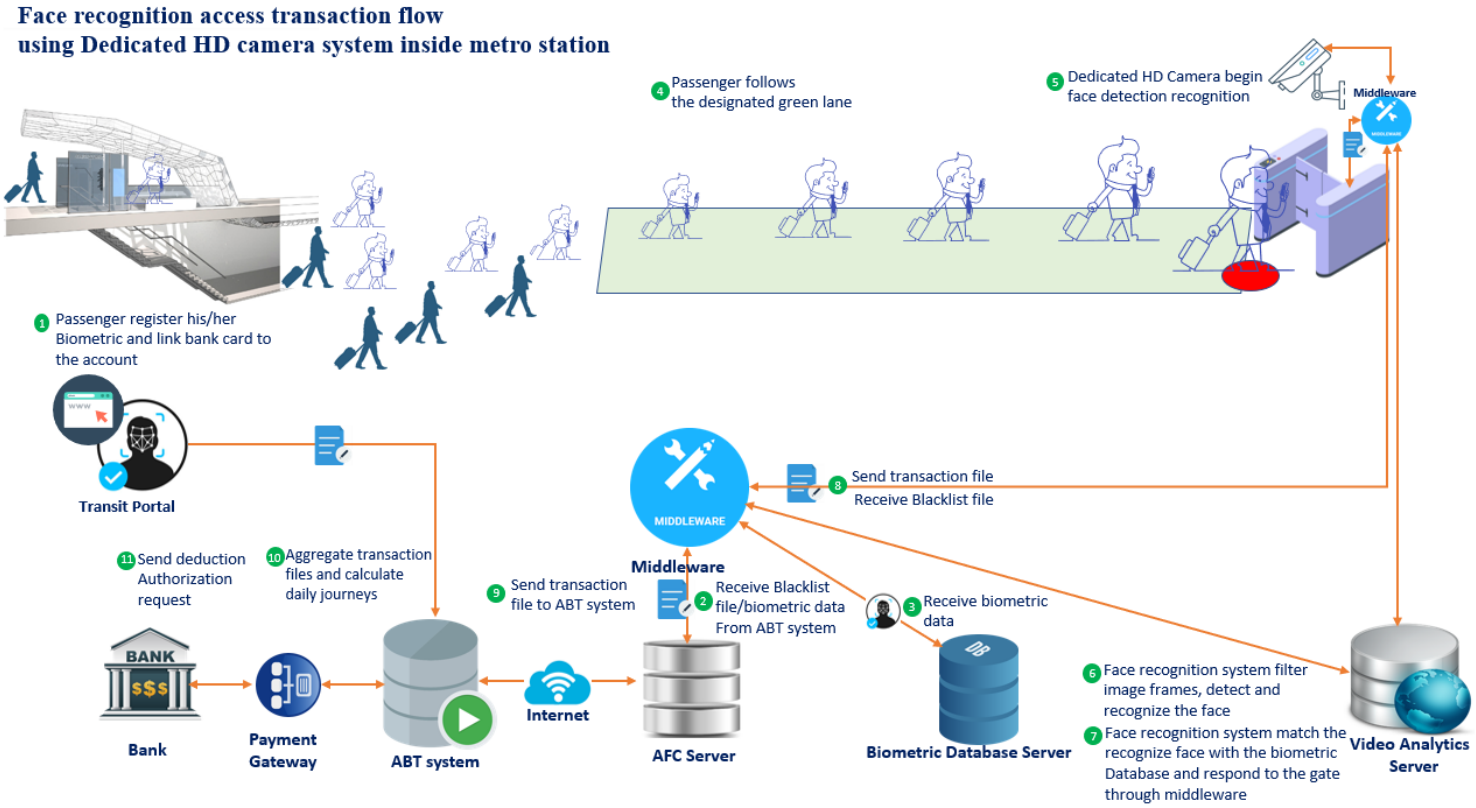


Figure 70: Second solution transaction

4.3.3 Solutions comparison

Following table 14 present a brief comparison between first and second solution proposed in the framework.

	Description	First Solution	Second solution
1	Camera system used	CCTV camera's	Dedicated HD stereo camera
2	Main Face recognition algorithms used	PCA	Cosine
	Algorithm selection rationale	Best for surveillance systems as per the literature	Best for masked-faces recognition as per the literature
3	Detection speed	40 FPS	25 FPS
4	Recognition speed	1114 milliseconds	180-200 milliseconds
5	Time required to open Metro gate	1114-1400 milliseconds	200-400 milliseconds
6	Implementation Cost	Low	High
7	Implementation complexity	Low	Low
8	Accuracy	98%-99.2%	99.3%-100%

Table 14: Comparison between the proposed solutions

4.3.4 Proposed criteria to evaluate the framework onsite

- Expected facial recognition accuracy rate and processing speed claimed in the solution verses onsite.
- Expected percentage of failures verses actual one.
- Expected fraud transactions verses actual one.

- Expected number of duplicate or incorrect recognized faces verses actual one.
- Actual customer satisfaction rate verses literature survey outcomes

4.4 Chapter four summery

Frist solution proposed which is built based on utilizing the existing surveillance cameras to offer face recognition service consider less costly in nature due to the fact that such system is already in operations and the only additions required is adding the face recognition system; however, major challenge of this system is the latency of the facial recognition process, especially during peaks hours; thus, first solution can be categorized as an effective cost-based solution.

Second solution proposed which is built based on installing a dedicated full HD stereo camera system for face recognition consider more costly than surveillance camera system due to the needs of installing a new camera hardware on top of each metro gate in additions to the existing surveillance camera system; however, the expected performance and efficiency from this solution especially with masked an mased faces is significant; therefore, it creates a high value for the transit operators to consider and invest in such solution; thus, second solution can be categorized as efficient performance-based solution.

5 Chapter Five: Conclusion

This chapter present a summery and conclusion of this dissertation and it briefly answers the dissertation questions; in addition, it addresses the theoretical contribution, practical implication, future work and limitations of this dissertation.

5.1 Answers to dissertation questions

Following are the summarized answers of each dissertation question based on the systematic literature review and data analytics outcomes which results to propose the framework carried out in the previous chapter:

RQ (1): What are the most popular real-time face detection and recognition techniques and its key challenges?

The most popular and common real-time face detection techniques noticed in the studies are: local Binary Pattern descriptor, Haar-Like descriptor, Ada-Boost, Cascade classifiers, Affine Transformation, Histogram Equalization, R-FCN, KFE, KNN, INN, Multi-order Statistical descriptors, Grammatical Evolution, ordered weighted average, Viola Jones, Tiny Face detector, Fast Face Detector and gaussian filter; in addition, the most popular and common real-time face recognition techniques are: Cosine, Eigenfaces, Sface, Cosine, F-CNN, YOLOv3 and MFcoface; however, the most popular facial recognition techniques used in the surveillance camera systems are the PCA and KNN; furthermore, the most common face recognition applications used are: MATLAB, OpenCV and Softmax. It's worth to mention that the most common methods, techniques and algorithms used the convolutional neural network architecture as a base to propose new method or improve an existing method.

Furthermore, the most common challenges aimed to address across all studies are: image illumination, low resolution, variation across pose, lighting, occlusion and body movement; in addition, masked face challenge which becomes more popular due to the recent Covid-19 pandemic and the essential need for the public to wear a mask.

RQ (2): Which are the most recommended face detection and recognition algorithms might be applicable to implement in real-life complex environment (Metro)?

First method named: MFcoface is the most recommended face detection and recognition algorithm to implement in real-life complex environment due to several factors: Experiment strength, experts' recommendation, sufficient dataset coverage, most common descriptors and classifiers are used to build the method, detect and recognize the masked and unmasked faces with 99.3% claimed accuracy.

Second method which consist of a group of algorithms named: PCA/LBP/AB/HR method is the most recommended face detection and recognition algorithms to implement in real-life complex environment due to several factors: the same techniques and algorithms are commonly used in several studies on the surveillance systems, experiment strength, experts' recommendation and sufficient dataset coverage with 99% claimed accuracy in 1114 milliseconds acceptable processing speed.

RQ (3): What are the passengers and transit expert's feedback on enabling face recognition as new payment mean to access and ride metro?

Online survey result indicates 69% as overall passenger satisfaction with the existing transport card/tickets; thus, it creates a need to identify the gaps and offer an alternative payment option to improve the travel experience; moreover, 84% of the respondents expecting more connivance and better travel experience if the face recognition payment option offered to access metro gate.

Experts overall result indicates that enabling face recognition as new payment option to access metro is possible and recommended; moreover, experts recommend the commercially named account based ticketing system "BPC" Automated Fare Collection | BPC |, (2020), to be utilize due to its efficiency to manage financial transaction and its global certifications,; finally, experts recommend the large margin cosine loss algorithm, principal components analysis and multi-order statistical descriptor algorithms to utilize in the complex environment.

RQ (4): What is the recommended end to end architecture framework that provides the best outcomes to be utilize in a real-life environment?

The framework recommends two solutions as per the following:

1. First solution: Integration between the existing surveillance camera systems, account-based ticketing" BPC" and the group of recommended algorithms and classifiers "PCA/LBP/AB/HR". this solution consider a cost-effective and fast-to-implement solution; however, the processing speed might be consider a challenge during the peaks hours.
2. Second solution: Installation of a dedicated HD face recognition stereo camera system then integrate it with the recommended account-based ticketing" BPC" and "MFcoface" face recognition method. this solution consider an efficient performance-based solution.

5.2 Theoretical contribution

This dissertation contributes to the relevant literature and transit operators from different angles. First, the comprehensive systematic literature review strengthens our knowledge of the most common state-of-art real-time face detection and recognition techniques and its potential use, in addition to the challenges and limitations of each claimed method. Second, the outcomes of the online survey and expert questionnaire aimed to advances the transit operators understanding of the gaps and challenges associated to the current payment options; for instance, transport card and metro ticket. Third, the proposed solutions mitigate the stated challenges observed in the online survey outcomes.

5.3 Practical implication

The solutions which are built based on the literature and experts' outcomes have strong possibilities to enable it as pilot inside metro station. The proposed framework contains a detailed functional and non-functional specifications of the solutions including a proposed transaction diagrams which all together are considered significant assets for better decision making to offer the service. Finally, the proposed framework aims to provide a broader impact on the relevant industries and in specific to the complex and crowded environment.

5.4 Limitations

The primary limitations of this dissertation impact the second and third chapter. Firstly, very few researchers explicitly elaborate on the integration between fare collection system and face recognition system; moreover, most of the recommended use of any claimed facial recognition method mentioned in the literature was generic and not specific to transit industry. Secondly, the respondents of the online survey were not surly known of their usage of public transport; however, the assumption was built based on the sample criteria and the results of the data analyses; in addition, the sample size was not sufficient enough to strengthen the claim; furthermore, the size of the selected facial recognition companies and its experts' representative was not sufficient enough to build the proposed framework. Finally, the proposed framework was not tested in the real-life environment to prof the claim.

5.5 Future work

The proposed solutions included in the conceptual framework required to test it in the field to prof the argued outcomes; therefore, field testing have been left for future work.

6 References

Al-Emran, M., Mezhuyev, V., Kamaludin, A. and Shaalan, K. (2018) “The impact of knowledge management processes on information systems: A systematic review.” *International Journal of Information Management*.

Automated Fare Collection | BPC | (2020) Banking payments context. [Online] [Accessed on November 26th, 2021] https://www.bpcbt.com/smartvista-solutions/automated-fare-collection/.

Awais, M., Iqbal, M. J., Ahmad, I., Alassafi, M. O., Alghamdi, R., Basheri, M. and Waqas, M. (2019) “Real-time surveillance through face recognition using HOG and feedforward neural networks.” *IEEE Access*, 7.

Brumercikova, E., Bukova, B. and Nedeliakova, E. (2020) “A proposal for the account-based ticketing application in passenger transport in the Slovak Republic: A case study.” *Sustainability (Switzerland)*, 12(12).

Celin, M. A., Fathima Farzana, K. and Jude, L. (2017) “Fare Calculation System Using Face Recognition.” *International Journal of Computer Science Trends and Technology*, 7.

Chen, W., Huang, H., Peng, S., Zhou, C. and Zhang, C. (2021) “YOLO-face: a real-time face detector.” *Visual Computer*, 37(4).

Chira-Chavala, T. and Coifman, B. (2019) “Effects of Smart Cards on Transit Operators:” *https://doi.org/10.1177/0361198196152100112*. SAGE PublicationsSage CA: Los Angeles, CA, 1521(1) pp. 84–90.

Costa, V., Fontes, T., Borges, J. L. and Dias, T. G. (2019) “Prediction of Journey Destination for Travelers of Urban Public Transport: A Comparison Model Study.” *In Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*.

Deng, H., Feng, Z., Qian, G., Lv, X., Li, H. and Li, G. (2021) “MFCosface: A Masked-Face Recognition Algorithm Based on Large Margin Cosine Loss.” *Applied Sciences 2021, Vol. 11, Page 7310*. Multidisciplinary Digital Publishing Institute, 11(16) p. 7310.

Deng, J., Guo, J., Xue, N. and Zafeiriou, S. (2019) “ArcFace: Additive angular margin loss for deep face recognition.” *In Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition*.

Elhamshary, M., Youssef, M., Uchiyama, A., Yamaguchi, H. and Higashino, T. (2018) “CrowdMeter: Congestion Level Estimation in Railway Stations Using Smartphones.” *In 2018 IEEE International Conference on Pervasive Computing and Communications, PerCom 2018*.

EMVCo (2021) EMVCo. [Online] [Accessed on November 26th, 2021] https://www.emvco.com/about/overview/.

Goyal, K., Agarwal, K. and Kumar, R. (2017) “Face detection and tracking: Using OpenCV.” *In Proceedings of the International Conference on Electronics, Communication and Aerospace Technology, ICECA 2017*.

Gupta, S., Gupta, N., Ghosh, S., Singh, M., Nagpal, S., Vatsa, M. and Singh, R. (2019) “FaceSurv: A Benchmark video dataset for face detection and recognition across spectra and resolutions.” *In*

Proceedings - 14th IEEE International Conference on Automatic Face and Gesture Recognition, FG 2019.

Handte, M., Iqbal, M. U., Wagner, S., Apolinarski, W., Marrón, P. J., Navarro, E. M. M., Martinez, S., Barthelemy, S. I. and Fernández, M. G. (2014) "Crowd density estimation for public transport vehicles." *In CEUR Workshop Proceedings*.

Huang, J., Shang, Y. and Chen, H. (2019) "Improved Viola-Jones face detection algorithm based on HoloLens." *Eurasip Journal on Image and Video Processing*, 2019(1).

Jabareen, Y. (2009) "Building a Conceptual Framework: Philosophy, Definitions, and Procedure." *International Journal of Qualitative Methods*, 8(4).

Kavalionak, H., Gennaro, C., Amato, G., Vairo, C., Perciante, C., Meghini, C. and Falchi, F. (2019) "Distributed Video Surveillance Using Smart Cameras." *Journal of Grid Computing*, 17(1).

Kitchenham, B. (2007) "Guidelines for performing systematic literature reviews in software engineering." *Technical report, Ver. 2.3 EBSE Technical Report. EBSE*.

Kumar Sarkar, P. and Jain, A. K. (2017) "DEFINING AND ASSESSING CONGESTION INSIDE METRO TRAINS AND AT STATION: CASE STUDY OF DELHI METRO, INDIA." *International Journal for Traffic and Transport Engineering*, 7(1) pp. 93–107.

Lee, H., Park, S. H., Yoo, J. H., Jung, S. H. and Huh, J. H. (2020) "Face recognition at a distance for a stand-alone access control system." *Sensors (Switzerland)*, 20(3).

Mahmood, A., Uzair, M. and Al-Maadeed, S. (2018) "Multi-Order Statistical Descriptors for Real-Time Face Recognition and Object Classification." *IEEE Access*, 6.

Malach, T. and Pomenkova, J. (2020) "Optimal face templates: the next step in surveillance face recognition." *Pattern Analysis and Applications*, 23(2).

Marciniak, T., Chmielewska, A., Weychan, R., Parzych, M. and Dabrowski, A. (2015) "Influence of low resolution of images on reliability of face detection and recognition." *Multimedia Tools and Applications*, 74(12).

Milioti, C., Panoutsopoulos, A., Kepaptsoglou, K. and Tyrinopoulos, Y. (2020) "Key drivers of fare evasion in a metro system: Evidence from Athens, Greece." *Case Studies on Transport Policy*. Elsevier, 8(3) pp. 778–783.

Mundial, I. Q., Ul Hassan, M. S., Tiwana, M. I., Qureshi, W. S. and Alanazi, E. (2020) "Towards facial recognition problem in COVID-19 pandemic." *In 2020 4th International Conference on Electrical, Telecommunication and Computer Engineering, ELTICOM 2020 - Proceedings*.

National Institute of Standards and Technology | NIST (n.d.). [Online] [Accessed on November 26th, 2021] https://www.nist.gov/.

Nguyen-Meidine, L. T., Granger, E., Kiran, M. and Blais-Morin, L. A. (2018) "A comparison of CNN-based face and head detectors for real-time video surveillance applications." *In Proceedings of the 7th International Conference on Image Processing Theory, Tools and Applications, IPTA 2017*.

Oracle (2020) *OCI Vision*. Artificial Intelligence. [Online] [Accessed on November 26th, 2021] https://www.oracle.com/artificial-intelligence/vision/.

Ouyang, D., Zhang, Y. and Shao, J. (2019) “Video-based person re-identification via spatio-temporal attentional and two-stream fusion convolutional networks.” *Pattern Recognition Letters*, 117.

Prasanna, M. and Reddy, G. (2017) “Development of real time face recognition system using openCV.” *International Research Journal of Engineering and Technology*, 4(12).

Qi, X., Liu, C. and Schuckers, S. (2018) “CNN based key frame extraction for face in video recognition.” *In 2018 IEEE 4th International Conference on Identity, Security, and Behavior Analysis, ISBA 2018*.

Ramos, L. and Morales, B. (2020) “SwiftFace: Real-Time Face Detection.” *IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE*, (1) September.

Ramya Mohanakrishnan (2021) *Facial Recognition Software*. Identity & Access Management. [Online] [Accessed on November 26th, 2021] https://www.toolbox.com/it-security/identity-access-management/articles/facial-recognition-software/.

Rivero-Hernández, J., Morales-González, A., Denis, L. G. and Méndez-Vázquez, H. (2021) “Ordered Weighted Aggregation Networks for Video Face Recognition.” *Pattern Recognition Letters*, 146.

Sun, X., Wu, P. and Hoi, S. C. H. (2018) “Face detection using deep learning: An improved faster RCNN approach.” *Neurocomputing*, 299.

Tang, P., Wang, C., Wang, X., Liu, W., Zeng, W. and Wang, J. (2020) “Object Detection in Videos by High Quality Object Linking.” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 42(5).

Tuncer, T., Dogan, S., Abdar, M. and Pławiak, P. (2020) “A novel facial image recognition method based on perceptual hash using quintet triple binary pattern.” *Multimedia Tools and Applications*, 79(39–40).

Veerajay, G., Ramiah, S. and Vasudavan, H. (2019) “Biometric bus ticketing system in mauritius.” *International Journal of Scientific and Technology Research*, 8(12).

Vijaya Kumar, D. T. T. and Mahammad Shafi, R. (2021) “Analysis and fast feature selection technique for real-time face detection materials using modified region optimized convolutional neural network.” *Materials Today: Proceedings*.

Wang, J., Yuan, Y., Li, B., Yu, G., Jian, S., Wang, J., Yuan, Y., Li, B., Yu, G. and Jian, S. (2018) “SFace: An Efficient Network for Face Detection in Large Scale Variations.” *arXiv*, April, p. arXiv:1804.06559.

Yuan, M., Nikouei, S. Y., Fitwi, A., Chen, Y. and Dong, Y. (2020) “Minor Privacy Protection through Real-time Video Processing at the Edge.” *In Proceedings - International Conference on Computer Communications and Networks, ICCCN*.

Zafar, U., Ghafoor, M., Zia, T., Ahmed, G., Latif, A., Malik, K. R. and Sharif, A. M. (2019) “Face recognition with Bayesian convolutional networks for robust surveillance systems.” *Eurasip Journal on Image and Video Processing*, 2019(1).

Zahedi, M., Shahin, M. and Ali Babar, M. (2016) “A systematic review of knowledge sharing challenges and practices in global software development.” *International Journal of Information Management*, 36(6).

Zamer, K. Z. (2018) “Account Based Ticketing: The Benefits and Drivers for Transit Operators.” *Journal of Transportation Technologies*, 08(04).

Zhang, S., Zhu, X., Lei, Z., Shi, H., Wang, X. and Li, S. Z. (2018) “FaceBoxes: A CPU real-time face detector with high accuracy.” *In IEEE International Joint Conference on Biometrics, IJCB 2017*.

Zhang, X., Gonnot, T. and Saniie, J. (2017) “Real-Time Face Detection and Recognition in Complex Background.” *Journal of Signal and Information Processing*, 08(02).

Appendix 1: (Table 5: Data Coding- Summery of the selected study's)

S#	Problem/Objective	Approach/Key points	Results/Finding	Dataset/Evaluation	Recommendations
S1	Improve the automated face detection on the surveillance system to reduce security threats	A proposal to use combined methods named: histogram of oriented gradients [HOG] and Feedforward Neural Networks [FNN] to increase system accuracy with less computational requirements A comparison with 14 methods has been conducted during comprehensive experiment	Recognition rate: • ChokePoint: 99% • AT&T: 99 % • Proposed real time dataset: 99.8% Accuracy: • Proposed real time dataset: 96.8% • ChokePoint : 88% • AT&T: 96 %	**Dataset:** • ChokePoint • AT&T • Proposed real time dataset **Evaluation:** • Recognition rate • Accuracy	The proposed method argues its efficiency and improvement due to the significant accuracy and recognition rate outcomes claimed in the experiment.
S2	Enhance the discriminative power of feature for the DCNN algorithm by proposing new method for better accuracy and performance	Propose a Additive Angular Margin Loss(AAML) algorithm to get a highly discriminative features, accuracy and performance for face recognition in a comparison with 12 methods has which been conducted during comprehensive experiment.	Verification performance % of the ArcFace on LFW dataset: 99.83% & 98.02% on YTF dataset. Overall average accuracy: 0.99% Speed: 25ms.	**Datasets used:** • CASIA : 0.5M image/video • VGGFace2: 3.3M image/video • MS1MV2: 5.8M image/video • MS1M-DeepGlint-Face: 3.9M image/video • Asian-DeepGlint: 2.83M • LFW : 13.23K image/video • CFP-FP : 7K image/video • AgeDB-30: 16K image/video • YTF: 3.2K image/video • MegaFace 1M (G) image/video • IJB-B 76.8K image/video • IJB-C 148.8K image/video • Trillion-Pairs 1.58M (G) image/video • iQIYI-VID 172,835 image/video **Evaluation: :** • Accuracy • Precision Rate • Recognition rate • Speed	The proposed method claimed to be the best to utilize as the state-of-the-art algorithm for face detection and recognition based on the fact that it demonstrates through a comprehensive experiment with a large-scale datasets type and sizes used to prof the results and strength the claim.
S3	Improvement on "the highly discriminative face feature" in the current CNN's methods "softmax loss, angular softmax" in particular to the inter-class variance in order to mitigate the lacks of power of discrimination	Propose a new algorithm named: large margin cosine loss(LMCL) to improve inter-class variance and increase face recognition accuracy by verifying the effectiveness of the proposed method. Comparison with 6 methods has been conducted during comprehensive experiment.	CosFace Accuracy: 99.73%	**Datasets:** • MegaFace Challenge: I Million images • YouTube Faces: 3,425 videos • (YTF) Labeled Face: 13,233 face images from **Evaluation**: • Accuracy • Verification	The proposed algorithm argued its effectiveness based on the geometrical and theoretical interpretation.

S4	Improvement of the processing time & accuracy required for face recognition in video.	Propose a new method named: key-frame extraction (KFE) engine integrated with a Graphic Processing Unit for acceleration. A comparison with 5 methods has been conducted during comprehensive experiment	AUC = 0.943 Face detection and processing time of one face frame: 0.019 s Overall processing time: 11.05 Seconds.	**Dataset:** ChokePoint – 4800 images **Evolution:** • Accuracy • Processing Performance	The claimed method suggest to use it in real world surveillance camera system due to the efficiency and effectiveness claimed in the accuracy and processing speed.
S5	Improvement on the dimensionality feature of the descriptor and the noisy image captured from video.	Propose an algorithm named: multi-order statistical descriptors (MOSD) which is built based on kernel & multiple linear discriminant analysis, and compare the accuracy of the algorithm with 11 different methods based on 6 famous datasets throughout an experiment.	Accuracy results based on each dataset: • Honda/UCSD : 100% • CMU-Mobo : 97.64 % • MGBC : 93.33 % • Youtube : 77.19 % • ETH-80 : 80 % • Cambridge: 89.64 % Execution times (in seconds) MLDA: • Training time =11.52 • Testing Time = 0.05 KLDA: • Training time =5.28 • Testing Time = 0.04	**Datasets:** • Honda/UCSD: 59 Videos • CMU-Mobo: 96 Videos • MGBC: Portal Realtime images • Youtube: 1910 Videos • ETH-80 : 8 categories-10 objects • Cambridge: 900 videos **Evaluation:** • Recognition rate • Accurcy • Execution times (in seconds)	Claimed algorithm recommends to use it on real time video recognition based on the argued effeminacy in the processing time which is 107 fasters than 11 compared methods without impacting the accuracy level.
S6	Object detection from real time videos is more challenging than from static image due to image quality factor.	Propose a method: • Cuboid proposal network[SPN] • Short tubelet Detection[STD&L] • Short tubelet linking. Experimental analysis targeting 9 methods and 30 classes of video data.	Improved Results by 8.8% for fast moving objects.	**Dataset:** ImageNet VID dataset (5354 videos 300 average frames) **Evaluation:** MAP	method claimed its improvements of 8.8% in comparison with other methods to detect fast moving objects from video.
S7	Propose an algorithm to provide high accuracy face recognition of children's faces.	The proposed algorithm named: MiPRE, which is built based on multi stages of the DNN architecture and compared with 4 different algorithms to claim the result.	Accuracy: 92.1%	**Dataset:** 20,000 images (10,000 child's & 10,000 Adult) **Evaluation:** Accuracy	The proposed method claimed it's a novel lightweight minor privacy protection scheme for the children to identify child faces and de-identify it before it uploaded to the internet to protect child's privacy.
S8	The issue of large-scale variations in high resolution images observed, and a propose method claimed to improve this issue.	The proposed algorithm named: Sface, is built based on the integration of the anchor based and anchor-free methods to resolve the large-scale variation issues in the face images. A comparison with 6 methods has been conducted during comprehensive experiment	Accuracy: 80% Precision recall curve: 65.4% Processing speed of 80fps for 1080p images: 12.46 milliseconds.	**Dataset:** 4K-Face - 32,203 images which includes 393,703 annotated faces **Evaluation:** • Precision recall • Accuracy • Processing speed	The proposed method claimed its state-of-the-art method to reduce large scale image variation and face recognition processing speed of the high-resolution images detected from video.
S9	The huge feature set of the current R-CNN leads to inefficiency of real time face recognition; therefore, an Improvement claimed to the current R-CNN architecture through	The proposed algorithm named: Grammatical Evolution (GE) which is built based on the Region Fully Conventional Neural Network (R-FCN)	Accuracy: 99.1% Precision-recall: 0.972	**Dataset:** The WIDER face : 32,203 images with 393,703 annotated face Benchmark (FDDB): ,845 images with 5,171 annotated faces	The proposed enhancement of the current R-CNN method claimed its Significant decrease of the R-FCN's GPU computation cost and increase the accuracy of the face detections in real time video.

<table>
<tr><td></td><td>proposing an enhanced algorithm to be utilize in the real-world face recognitions scenarios</td><td></td><td></td><td>Evaluation:
Precision-recall
Accuracy</td><td></td></tr>
<tr><td>S10</td><td>Variation in the appearance of people faces, complexity of the image background and obstruction process consider the main key challenges of the real time face recognition techniques.</td><td>Comprehensive comparison proposed of the single pass CNN(SP-CNN) architectures through an experiment proposed based on the most challenging and complex datasets to identify the optimum architecture to be utilize for face and head detection
Main criteria of this comparison is built based on the accuracy and its complexity.</td><td>Result of the comparison based on the FDDB dataset:<table><tr><th>Method</th><th>AUC</th><th>Time/s</th><th>GPU</th></tr><tr><td>VJ & VJ-CRF</td><td>0.66</td><td>5.6</td><td>2.8</td></tr><tr><td>HeadHunter & DPM</td><td>0.77</td><td>5.0</td><td>2.0</td></tr><tr><td>SSD</td><td>0.77</td><td>45.8</td><td>0.7</td></tr><tr><td>Faster R-CNN</td><td>0.92</td><td>223.9</td><td>2.1</td></tr><tr><td>R-FCN</td><td>0.93</td><td>132.1</td><td>2.4</td></tr><tr><td>R-FCN 101</td><td>0.92</td><td>186.6</td><td>3.1</td></tr><tr><td>PVANET</td><td>0.91</td><td>40.1</td><td>2.6</td></tr><tr><td>Local-RCNN</td><td>0.78</td><td>1206</td><td>2.1</td></tr></table></td><td>Dataset:
FDDB data : 5,171 faces
Casablanca data
Evaluation:
AUC
Processing Time
Memory consumption (GB)</td><td>It’s claimed that the SSD and PVANET architectures consider the best algorithms to utilize in real time face recognition from the surveillance camera’s based on low-resolution images.</td></tr>
<tr><td>S11</td><td>A lost occurs in a set of a landmark points in 2d images; for instance, , ignorance of the pose or movement of the visible boundaries which cause to insufficient face recognition accuracy.</td><td>The proposed approach named: A 3D Spatial Transformer Network. Works based on extracting reliable alignment points across large poses of the image. The novel key in this approach is the extraction technique of the 3D images from the 2D images.
A comparison with 6 methods has been conducted during comprehensive experiment</td><td>Normalized Mean Error (%) of face alignment results to 4.49 based on (68 pts)</td><td>Dataset
Wild (AFLW) : 25,000 faces annotated with 21 landmarks
AFLW2000-3D: 2000 images with 68 points
Evaluation:
Normalized Mean Error (%) of face alignment results
Alignment accuracy</td><td>the proposed approach claimed higher accuracy and consistency to the landmark points of the image which are better than the 2D and 3D CNN methods</td></tr>
<tr><td>S12</td><td>Significant increase of bus riders creates a pressure on the bus ticketing system and long queues to obtain the ticket.</td><td>A proposed approach targeting public transport riders to recognize their faces as an authorization mechanism to travel in the bus and bus fare will be deducted from their account. Using Principal Component Analysis (PCA) algorithm – statistical method integrated with front end system named: Biometric Bus Ticketing system. This approach supported by the survey outcomes which obtained from 50 customer aiming to get feedbacks on the current service and appetite to enhance implementation of the current system</td><td>System design of an end-to-end integration between PCA face recognition algorithm and biometric bus ticketing system. to offer this service to use as an experiment/PILOT then to the production environment.</td><td>Sample Survey size: 50 people.
Rapid Application development agile approach.</td><td>The offered solution (BBTS) argued its significant impact on the current ticketing system and its reliability and security to be utilize in as new service for Mauritius public bus ticketing system.</td></tr>
<tr><td>S13</td><td>Most of the existing Surveillance cameras doesn’t have the full capability to perform an accurate face recognition which create a challenge for the companies to</td><td>The proposed model aims to minimize the face recognition operational load on the existing surveillance camera which use the (PCA) algorithm to decrease the load on the servers by using</td><td>Weighted KNN
Accuracy: 0.81
Speed: 450 milliseconds</td><td>Dataset:
Yale Database B - 350 images
Evaluation:
Accuracy: 0.81
Speed</td><td>The proposal claimed 50% load reduction and no quality impact on the surveillance service.</td></tr>
</table>

	invest and upgrade their system and allocate a resource to maintain and operate the backend servers.	weighted KNN algorithm, after comparing its accuracy in a comparison with the INN algorithm.			
S14	Identify the best algorithm and application which can be used for the face detection and recognitions based on a comparison with the most famous ones in this field.	Comparison with different algorithms: Haar Cascades(HC), CamShift (CS) and finding via motion based on the utilization of these algorithms on MATLAB verses OpenCV applications. A comparison with 3 methods has been conducted during comprehensive experiment	Haar Cascades algorithm consider the most efficient in terms of performance, accuracy and time consumption in comparison with the other algorithms selected in this study.	**Dataset:** NA **Evaluation:** • Time consumption • Performance • Accuracy	A claim to use the Haar cascades algorithm in real life environment among other algorithms in this study, due to its efficiency, time consumption and accuracy; in addition, its argued to use the OpenCV application among MATLAB due to low expense cost and better outcomes.
S15	Objective of this study to propose new state of the art method aimed to utilize in a real time face recognition system using video cameras and mitigate the following problems: Facial Expression Change, Spectacle's presence or absence, illumination change, scaling factor, aging, Pose change, scarf or mask.	Propose a new application for real time face detection using Open source tool named: Open-face application which is built based on the Histogram of Oriented Gradients [HOG], Deep Neural Network [DNN] and Support Vector machine [SVM] algorithms.	Average accuracy among 15 training images: 70%	**Dataset:** • 128 images from extracted from Video **Evaluation:** • Accuracy	The study proposed to use Open-face application in real life environment; for instance, student attendance system.
S16	Lights and illumination challenge with real time face recognition consider significant for various famous methods. This study aims to address and resolve the resolution challenge.	Propose a novel framework named The local binary pattern (LBP)-AdaBoost to detect face and eyes with a support of modifying the Gabor-LBP histogram framework targeting to reduce the illumination challenges, based on employing the k-nearest neighbourhood classifier metric. A comparison with 7 different methods verses proposed method illustrated.	E-face Dataset accuracy 97.27% XM2VTS dataset accuracy 99.06% TAR: 91.5% FAR: 0.28% Processing speed: 5.26 frames/sec.	**DataSet:** • E-face: 55 subject/20 images for each • XM2VTS: 295 subjects/8 images for each **Evaluation:** • Accuracy • True acceptance rate (TAR) • False acceptance rate (FAR) • Processing speed	The study claimed its efficiency, accuracy and effectiveness among the most famous 7 real time face recognitions methods compared in the study. The study proved the proposed system through comprehensive experiment and based on 2 famous datasets. It's argued to utilize the proposed system in real life environment.
S17	Improve the efficacy of face recognition system based on improving the false positives results which results to an overall performance improvement of face recognition in the surveillance camera systems	Propose a model named: uncertainty, to improve the efficiency of the B-DCNNs algorithm which uses softmax application and aiming to improve the false positive results. A comparison with 4 different methods verses proposed method illustrated.	Accuracy for AT&T Dataset: 94.2% Accuracy for EKFD: 97.5% 3–4% of accuracy improved with the suggested model.	**DataSet:** • AT&T face: 780 images • EURECOM Kinect Face (EKFD) 780 images **Evaluation:** • Accuracy	Proposed method claims its improvement of the B-DCNN architecture; however, it doesn't recommend to utilize it the real-life environment.
S18	Failure to perform an optimum experiment while using existing available datasets for real time face recognition through surveillance camera. Main focus in this study on the resolutions and spectra	A proposal of a novel dataset named: FaceSurv dataset, claimed to perform state-of-the-art experiment based on defining the new dataset" FaceSurv "which targeting to improve image resolution and spectra. Experiment performed on the FaceSurv dataset and other existing dataset through applying	Tiny Face detector results consider the best: Precision: 0.96 Recall: 0.99	**Datasets:** • Face in Action • YouTube Face • ChokePoint • PaSC • SN-Flip • McGillFaces	The study argued a new dataset named: FaceSurv to facilitate an optimum real time face recognition experiment addressing resolutions and spectra challenges, which applied in different algorithms and commercial applications.

		different algorithms (Viola Jones,Tiny Face Detector, Fast Face Detector, Single Shot Scale- Invariant Face Detector) to conclude that the new dataset is sufficient enough to be utilized. For further research. A comparison with 4 different methods using the proposed dataset verses other datasets is illustrated.		• CrowdFaceDB • CSCRV • IJB-S • FaceSurv - 460 videos -252 subjects-460 videos – 142K faces (taken from 36ft and other distances) **Evalation:** • Precision: 0.96 • Recall: 0.99	
S19	Misuse of the smart card for payment in metro system, lengthy queues and frauds consider the main challenges of the current face collection system in Metro station which requires system improvement.	A proposal of an end-to-end framework to use face recognition technique as replacement of the smart cards to pay and travel with the Metro. OpenCV application proposed to process the Image through an integration with the PCA and KNN algorithms to detect and classify the faces and the AES algorithm complement the framework by adding scarcity layer to the claimed architecture. Main assumption of the proposal that users must register their faces, identity and have its active wallet account.	Proposed Framework claims high accuracy based on the selected cameras and easy to implement in real life environment	**Datasets:** PCA and KNN preference datasets. **Evalation:** • Accuracy • Scalability	The study claims novel framework of the fare collection system inside metro stations. The framework argues to replace the smart card payment with the face recognition payment, to eliminates smart card usage hazards.
S20	Due to Covid19 pandemic facemask essentials creates a challenge to the facial recognition and detection technology in several industrial use.	A proposal to utilize the supervised learning concept (SLC) along with the in-depth neural network, to improve the current facial recognition techniques in particular for the facemask segment.	Accuracy: 97% (masked faces)	**Datasets:** • VGGFACE2: 9500 classes-Each 330 images • LFW : 800 facemask images **Evalation:** • Evaluation: • Accuracy	Proposed method claims its state-of-the-art method to improve current facial recognition methods in terms of accuracy and security, and it suggest to be utilized in the real-world scenarios.
S21	Latency and slowness of the face detection method used in Microsoft HoloLens product.	A proposal to improve the Viola-Jones algorithm [VJ] used in the Microsoft Hololens product by depending on Haar-like rectangle.	12% face detection accuracy improvement claimed from the current algorithm. 4 times speed improvement claimed from the current algorithm.	**Datasets:** • Orl 400 images, • Yale 165 images • Ar, 2600 images • Stanford 400 images • Jaffe 213 images • cit face 450 images **Evaluation:** • Accuracy • Speed	The proposed method argued its efficiency to be utilize in public security, business engagement and social contact fields.

S22	Image based face detection methods are not accurate and efficient as video-based face detection methods in case of person reidentification.	A proposal of video-based person reidentification named (TSF-CNN), a comparison with 12 methods has been conducted during comprehensive experiment	Accuracy (Rank 5): • iLIDSVID : 90.7 % • PRID 2011: 96.7	**Datasets:** • iLIDSVID: 600 images • PRID 2011: 400 images **Evaluation:** • Accuracy	The proposed method claimed its best efficiency and accuracy, but it doesn't suggest to utilize it in the real-world scenarios.
S23	Accuracy and performance of the face recognition on surveillance systems are not much sufficient to depend on it.	A proposal of an algorithm named: higher quantile method aimed to improve the overall performance of face recognition in surveillance systems in terms of (time, accuracy and cost) and based on utilizing a low computational power while using the nearest neighbor classifier.	Accuracy: QIM: 0.8 QHM: 0.9	**Dataset:** • IFaViD (Only one dataset represents real surveillance system: 8731 images) **Evaluation:** • Accuracy • False acceptance rate	The proposed method (QIM and HQM) claims its 4-10% improvement and efficiency among other methods while using a low computational requirement.
S24	Objective of this study to encourage utilizing the average operator for aggregation instead of only relaying on the weighted mean operator for better outcomes.	A proposal of an aggregation scheme for video face recognition named: ordered weighted average (OWA) operators which consists of 2 proposed sub operators named: Ordered weighted aggregation network (OWANet) and Weighted OWANet (WOWANet). A comparison with 7 methods has been conducted during comprehensive experiment	AUC : • OWANet: 98.34 • WOWANet: 98.35 Accuracy: • OWANet: 95 . 86 • WOWANet: 96 . 00 Average aggregation time – milliseconds: • OWANet 4.68 • WOWANet 4.68	**Dataset:** • YouTube Faces : 3425 videos • COX Face: 1000 subjects • the IARPA Janus : 500 subjects **Evaluation** • Accuracy • Speed	The proposed scheme claimed its effectiveness and efficiency to utilize in real time video face recognition scenarios.
S25	High computational requirements noticed to obtain high speed and accurate real time face detection and recognition in real world scenario.	A proposal of face detector algorithm named: FaceBoxes which improved the speed and accuracy with lightweight computational requirements. The algorithm consists of Multiple Scale Convolutional Layers (MSCL) aims to handle faces of various scales and Rapidly Digested Convolutional Layers (RDCL) which aims to achieve real-time speed on the a normal CPU. A comparison with 5 methods has been conducted during comprehensive experiment	Accuracy: 96% Speed: 20 FPS & able to accelerate to 125 FPS	**Dataset:** • AFW • PASCAL face • FDDB 2,880 images of the WIDER FACE **Evaluation:** • Accuracy • Speed	The proposed method claims its state-of-the-art method in real time face recognition with lightweight computational requirements without impact on the accuracy and speed. It's argued to use this method in real world scenarios.
S26	Objective to present better solution for real time face detection in the most challenging and complex environments.	The proposed solution suggests to integrate different algorithms which uses signal processing methods for better outcomes such as: (Principal Component Analysis (PCA), Local Binary Pattern (LBP), cascade	Face detection true positive rate: 98.8% Accuracy (facial recognition): 99.2%	**Dataset:** • MIT CBCL: 2492 faces & 4548 non-face images **Evaluation:** • Accuracy	The propose method argues its efficient and effective utilization in real world scenario due to the high accuracy and performance observed in the experiment outcomes.

		classifier, Ada Boost(AB), Haar-like(HR) features). A comparison with 3 methods has been conducted during comprehensive experiment			
S27	Objective to improve the current faster RCNN architecture for real time face recognition.	A proposal to improve the current faster RCNN architecture for real time face recognition based on utilizing different features of the FDDB trained dataset through a claimed strategy; for instance, hard negative mining, calibration and concatenation. A comparison with 2 methods has been conducted during comprehensive experiment	Accuracy: 98%	**Dataset:** • FDDB: 5171 faces • WIDER FACE: 1281 faces **Evaluation:** • Accuracy	The proposed improvement claims its state-of-the-art method for real time face detection due to the significant performance observed from the experiment.
S28	Objective to identify the image resolution effect on face detection and recognition.	A discussion, analyses and proposed approach outlines to identify the reliability of real time face detection and recognition from low resolution images by using "eigenfaces" approach aiming for better accuracy and speed. A comparison with 3 methods has been conducted during comprehensive experiment	Minimum face height [pixels]: • Detection 21 • Recognition 21	**Dataset:** • Sheffield University 564 images • Yale Face: 5,760 images • MUCT: 3,755 images • FERET: 2,413 images **Evaluation:** • Image resolution requirement	The proposed approach argued its efficiency on the low-resolution images even with little training data.
S29	Improve image classification processing capability	A proposal of the face recognition method named: quintet triple binary pattern (QTBP) which is built based on perceptual hash to pre-process then extract image. A comparison with 10 methods has been conducted during comprehensive experiment	Classification accuracy: • AT&T, Face94 and CIE : 100 % • AR : 99.4% • LFW: 97.1%	**Dataset:** • AT&T • Face94 • CIE • AR • LFW **Evaluation:** • Accuracy	Proposed method argued that it's the best classification processing accuracy among the 10 compared methods in the experiment; moreover, it suggest to utilize it in the real-world environment.
S30	Small object detection and face variation is a challenge for YOLO method.	A proposal of an improved method named: YOLOv3 aim to improve face detection performance based on anchor boxes and regression loss technique a comparison with 14 methods has been conducted during comprehensive experiment	Recall: 0.693 Detection: 0.899 YOLO-face -darknet-53: 45 FPS YOLO-face -deeper darknet: 38 FPS	**Dataset:** • WIDER FACE: 393,703 faces • FDDB: 5171 faces **Evaluation:** • Recall • Detection • Speed	A claim that the improved method achieves higher performance and speed of detecting faces and small objects with a lightweight computation and flexibility to implement and integrate.
S31	Objective to find out a better speed detection of the faces to improve face recognition technology	A proposal of new method named: SwiftFace which is built based on YOLO algorithm and aims to improve the speed detection and accuracy feature based on the existing CNN face recognition architectures. A comparison with 3 CNN face recognition architectures has been conducted during the experiment	Speed: Process 16067 images in 470s (39.5 FPS) Accuracy: around 78.6%	**Dataset:** WIDERFACE 16067 images **Evaluation:** Processing speed in seconds Accuracy	It's claimed to utilize the proposed method in real-life access control scenario due to its argued processing speed in a lightweight computational requirement without compromising on the accuracy level.

S32	Facemask impact on face recognition accuracy	A proposal of a new method named; (MFCosface) which is built based on large margin cosine loss algorithm, which combines Resnet and the convolutional block attention module with the intention of increasing the focus in the uncovered areas of the face and detecting key facial features for these areas. A comparison with 5 CNN face recognition architectures has been conducted during the experiment	Accuracy: 99.33	**Dataset** LFW_m : 13,233 face images CF_m : 2500 faces VGGface2_m: 8335 identities MER2 : 269 faces RMFD: 90,000 unmasked-face images 85,000 pictures cleared and used **Evaluation**: Processing speed in seconds Accuracy	The proposed method claims its state-of-the-art method to be utilize in the real-world complex environment especially during Covid-19 pandemic where facemasks become a must and this method claims that it mitigate the associated facemask challenges of the face recognition technology