IN THIS ISSUE

IMAGE: COMPUTERS & TECHNOLOGY IN A MODERN AIRCRAFT

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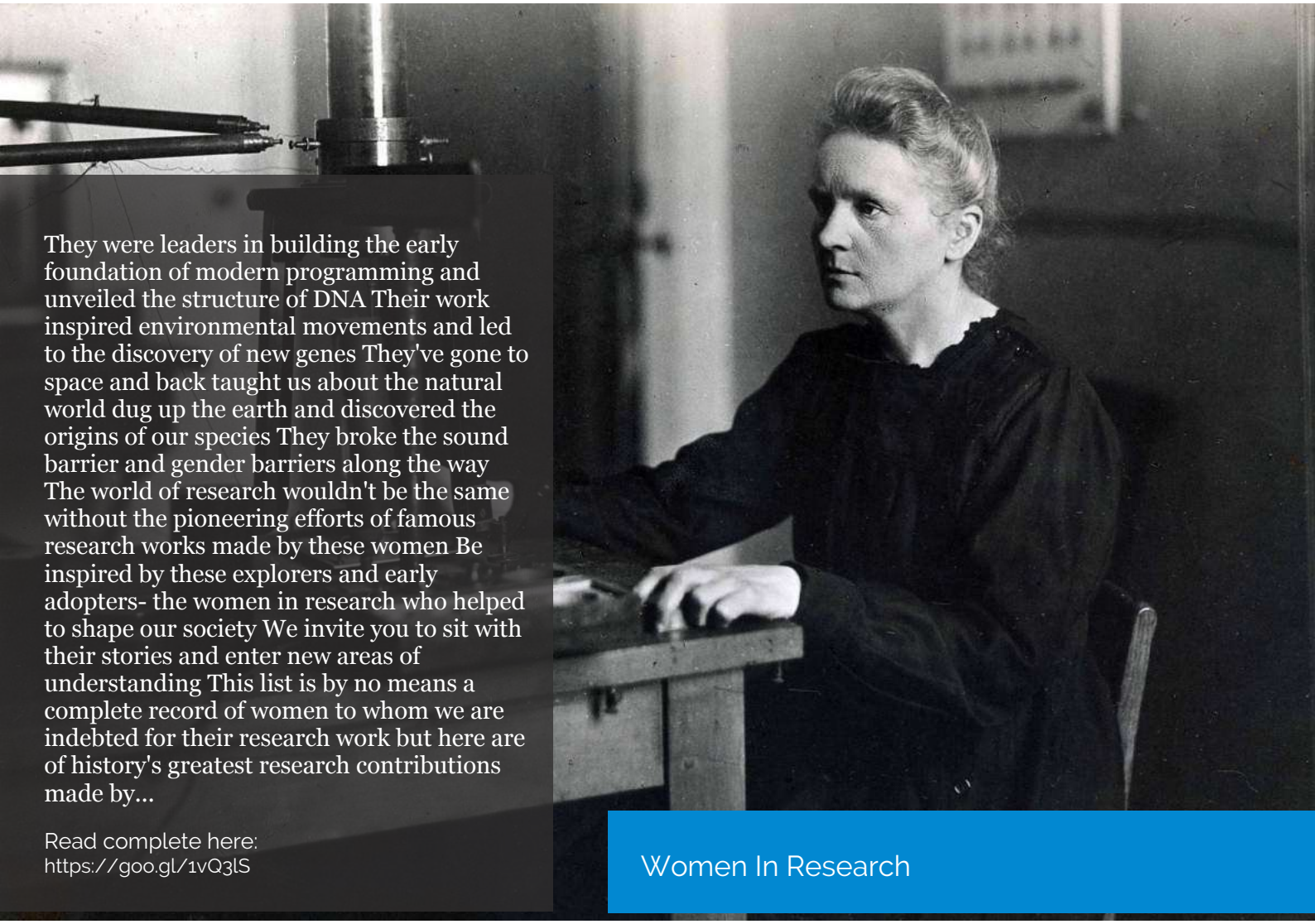

They were leaders in building the early foundation of modern programming and unveiled the structure of DNA Their work inspired environmental movements and led to the discovery of new genes They've gone to space and back taught us about the natural world dug up the earth and discovered the origins of our species They broke the sound barrier and gender barriers along the way The world of research wouldn't be the same without the pioneering efforts of famous research works made by these women Be inspired by these explorers and early adopters- the women in research who helped to shape our society We invite you to sit with their stories and enter new areas of understanding This list is by no means a complete record of women to whom we are indebted for their research work but here are of history's greatest research contributions made by...

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A Blockchain Technology to Secure Electronic Health Records in Healthcare System

Shaikh Abdul Hannan

AlBaha University

ABSTRACT

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Author: Assistant Professor, Department of Computer Science and Information Technology, AlBaha University, AlBaha, Kingdom of Saudi Arabia.

I. INTRODUCTION

The SARS-CoV-2 virus, responsible for the greatest epidemic in millennia, has posed a serious threat to healthcare systems throughout the world. In addition to the immediate problems caused by the virus, the pandemic has revealed flaws in even the most modern healthcare systems, such as the inability to keep track of individuals with pre-existing diseases. Although industrialized nations like the United States were better equipped than others in responding to the epidemic, nearly one million Americans lost their lives as a result of the virus. Pre-pandemic research revealed flaws in the world's top healthcare systems, which impeded the most effective response to SARS-CoV-2. While wealthy countries' healthcare systems have their flaws, those in underdeveloped or underprivileged areas, such as India, are far more at risk. Long-term needs for hospital facilities, support personnel, and manpower are created by this sort of viral pandemic, all of which are often in limited supply in developing nations [1]. For us to meet this challenge, we'll need to manage our resources efficiently.

The potential effect of SARS-CoV-2 on the Indian Subcontinent, and India in particular, has been recognized ever since the breakout of the virus [2]. Big data is the capability to manage a huge volume of disparate data, at the right speed, and within the right time frame to allow real-time analysis and reaction. Big data is an evolving term that describes any amount of structured, semi-structured and unstructured data that has the potential to be mined for information [3].

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II. LITERATURE SURVEY

With a population of close to 1.4 billion, India is one of the most populous countries on Earth. Before the epidemic, India's healthcare system already had significant challenges that were wreaking havoc on the country. Major public health issues include HIV/AIDS, malaria, and TB. As the income gap widens between the affluent and poor, another key worry is the availability and cost of decent healthcare.

This problem has been exacerbated by statewide lockdowns. Recent studies have shown that the immediate effects of the lockdown would be a decrease in healthcare availability and an adverse effect on the population's physical and mental health and social well-being.

The widespread use of handwritten prescriptions especially in rural areas without computer systems and the almost complete lack of integration between healthcare and insurance systems are just a few of the widespread problems that have arisen as a result of the fragmented nature of the healthcare industry's information, communication, and tracking infrastructure [4].

Poor healthcare professional accountability is exacerbated by inadequate facilities, further straining doctor-patient ties. Paper records are more prone to human errors, such as illegibility or the loss of the physical object, which may lead to delays in treatment and perhaps preventable deaths.

Prescriptions and insurance coverage data are just two examples of the kinds of critical information that healthcare and insurance providers may share with pharmacies to expedite the delivery of pharmaceuticals to patients. It is difficult to achieve large-scale coordinated performance using paper-based information, but this is made possible by integrated healthcare system synchronization, which allows for patient-oriented monitoring capabilities and refill requests.

Any healthcare system that lacks the modern infrastructure essential to facilitating effective communication between healthcare practitioners, insurance providers, and patients would benefit greatly from implementing an Electronic Health Record (EHR) system. The influence of EHR will grow as the worldwide effort to disseminate and administer the Coronavirus vaccination continues [5].

Electronic health record systems will be crucial in managing the massive amounts of information sharing and monitoring that will be necessary to accomplish this massive task.[6].

2.1 Healthcare Records Security Breaches

Between 2009 and 2020, the HHS Office for Civil Rights received 3,705 allegations of healthcare data breaches involving 500 or more records. 268,189,693 healthcare records have been lost, stolen, leaked, or unlawfully released. 81.72 percent of the US population. In 2018, one breach involving 500 or more records was recorded each day. The rate doubled by 2020. In 2020, 1.76 breaches occurred daily. Figure 1 shows 500+ Healthcare Data breaches from 2009 to 2020.

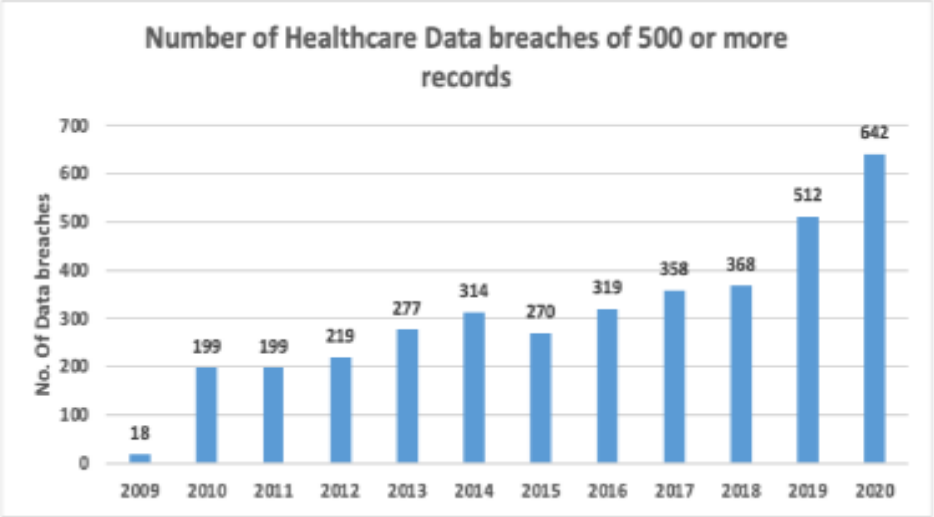

Figure 1: 500+ Healthcare Data Breaches Spanning 2009-2020

As our digital infrastructure develops, privacy concerns rise. Due to the sensitivity of healthcare information, a system breach might endanger a patient's identity and the providers' reputation. Statistically, scammers value patient data.

2.2 Electronic Health Record (HER) Benefits

Electronic Health Record (EHR) is a computerized compilation of medical information and other data that can be readily shared. EHR has numerous promises, including lowering morbidity and mortality, enhancing continuity of care, boosting efficiency, and minimizing adverse medication reactions. Electronic health records (EHR) provide real-time data that can be accessed and shared securely [7].

Transmitting information swiftly helps healthcare personnel to effectively support patients based on their individual medical requirements while dealing with the unpredictable Coronavirus, which disproportionately affects persons with underlying health concerns. EHR enabled patients and providers with major advances [8].

Figure 2: Typical Features of an Ideal EHR System

EHRs have been used in industrialized countries for over 50 years. Since the early 2000s, more U.S. doctors have joined HER incentive schemes. The dramatic increase of EHR utilization during this era is not surprising given EHR competitive benefits and the government's drive to strengthen EHR usage in healthcare IT infrastructure. The loss of life during the Coronavirus pandemic would have been substantially greater without EHR technologies to support healthcare services [9]. Even in industrialized countries, the need to enhance healthcare is evident. Before the epidemic, EHR implementation faced difficult hurdles.

People may complicate EHR systems; skepticism and disillusionment with technology are common, and EHR systems are no exception. Older medical workers and patients may resist change, particularly new technology. Minor EHR system glitches might demotivate hesitant participants. When we consider challenges new users may encounter while completing crucial jobs, including external communications, the situation becomes frustrating. Developed nations have several EHR service providers for offices, hospitals, clinics, and pharmacies. Without a proper referral, healthcare providers may overlook vital patient medical history information. Introducing a new workflow may be stressful for all workers, regardless of tech familiarity. HER systems must be adapted to user needs [10]. It's impractical to assume ideal efficiency in the early phases of EHR deployment, although training may boost user competency.

2.3 Blockchain Technology: From Centralized to Decentralized System

Blockchain technology generates a transparent, immutable, append-only record of network transactions. Digitally signed and broadcast transactions are organized and timestamp into blocks. A Block contains hashed and encoded valid transactions in a Merkle tree. The preceding block's hash is included. The Blockchain's Genesis Block may be found using the previous hash. The blockchain seeks maximal length. Changing one block's hash makes the next block invalid and reduces the blockchain's size. Due to the blockchain's purpose of maintaining the longest chain possible, it is immutable [11].

Each blockchain member has Public and Private keys. Public key is users shared identification. Only the user knows the private key. Digital signatures deterministically verify a message's origin and content. The 15 user signs the message using his private key, and others may verify it with his public key. Blockchain adds a new block using the consensus process. Consensus protocols distribute requests across nodes so each runs the identical sequence on its service instance. Popular consensus protocols include PoW and PoS. Digitalized technology has widely changed today's world. Depending upon this technology, starting from the day-to-day workings to the financial transactions, all can be controlled through the fingertip. By following the same fashion, the transition of the stock market is directly switching to the online platform and hence, the rate of the randomized investment rate in the stock is getting higher[12] .

2.4 Permissionless or Public Blockchain

Anyone may submit and confirm transactions on a permissionless blockchain. Transactions may be submitted by anybody who can pay fees. Anyone may be a validator by verifying transactions. This must be available to anybody who practices reasonably. Everyone who submits properly signed transactions to the network should expect it to execute them without fear of a group or firms banning them [13]. Blockchain technology is currently generating a lot of buzz among banks, businesses, and government agencies. Nearly every day, new initiatives and various collaboration agreements on Blockchain applications are announced in the economic press. This includes projects run by governments and central banks as well as banks and private enterprises [14].

2.5 Permissioned or private Blockchain

Permissioned or private Blockchains don't allow open involvement in submitting or verifying transactions, thus participants can't trust the network to withstand censorship. This means not all participants have a realistic assurance that their transactions won't be discriminated against.

Permissioned blockchain uses a membership structure to admit users. In permissioned Blockchains [15], nodes verify transactions using the originator's credentials. Permissioned blockchain technology's architectural design assures privacy and security. The Sybil Attack, 51% attack, and blockchain endpoint vulnerability affect public or permissionless Blockchains. We exclusively explore permissioned blockchain because we believe it can handle sensitive healthcare data [16].

2.6 Electronic Health Record (EHR) Is a Social Need

An electronic health record (EHR) is a collection of electronically controlled health information that many users may access. A patient's record traditionally documented their medical care. Smart care services urge doctors to consider the full patient, including wellness, sickness, and rehabilitation [17].

The main important risks and critical issues in a conventional healthcare system include a single point of failure, data modification, high chances of different malicious cyber attacks, centralized authority, high data management, keeping storage as well as cost, and databases that are not transparent. To address these issues, researchers have proposed numerous blockchain-based solutions.[18]

The record must include health and illness information from multiple doctors in different locations. Data should be kept so that hospitals, pharmacies, insurance companies, and academics may get different views. EHR systems offer clinical reminders and alerts, information assets for healthcare decision support, and aggregate data analysis for care administration and research. To extract clinical information from a paper medical record, the reader must edit data mentally or on paper. EHR systems give computer-based capabilities to organize, analyze, and respond to data [19].

III. RESEARCH METHODOLOGIES

Health concerns that are common in India were the focus of the research. Below is a key point of the main healthcare concerns:

- The absence of a comprehensive end-to-end electronic health record (EHR) system interlinking among separate, stand-alone hospital record systems, as well as the lack of just-in-time record updating
- Because of the prevalence of handwritten prescriptions, an abundance of fake medications have entered the market.
- Unauthorized hospital administrators may access and change patients' information stored in insecure hospital databases, and caregivers aren't held accountable for any harm that may result.
- A lack of a secure, immutable, auditable, and traceable health infrastructure system

The potential of an electronic health record system built on the Blockchain to resolve these problems is also highlighted. This study suggests a Blockchain-based HER system that can reliably identify users by their national ID, allows users access to and control over their health records, prevents malicious data manipulation, and can be easily scaled. As a result of the synergy, massive data like CT scans and X-ray reports may be kept in the cloud for easy access. A patient-centric electronic health record (EHR) system will need unique identifiers in order to accurately identify patients. When it comes to government-issued IDs like Aadhar and PAN, there is presently no comprehensive EHR system (Permanent Account Number).

It is also essential that the proposed system include unique identifiers such as national IDs for patients to ensure accurate identification. Users need to be able to exercise control over their health information, such as authorizing updates, and this can only be achieved with secure identification.

Blockchain's cutting-edge safety features prevent unauthorized changes to medical records. With the suggested scalable system, previous paper-based medical records may be migrated into the new system while also benefiting from useful features such as a mobile app-based interface for translating paper prescriptions to text using Natural Language Processing (NLP) algorithms. Therefore, the purpose of this thesis is to suggest a patient-centered EHR design that can communicate with other, separate healthcare systems and parse out information from paper prescriptions. The issues addressed by the suggested architecture are as follows:

- Health records should be readily available at the point of service and updated in real time to help medical professionals make more educated choices.
- Paper prescriptions are a common source of human mistake, but digitizing them and incorporating them into an existing system has many benefits.
- Data manipulation is impossible with secure, immutable, auditable, and traceable health infrastructure solutions.
- Integrated Health Record (EHR) Systems and Local Hospitals
- A patient-centered framework that protects sensitive information and gives individuals control over their own health records.

IV. RESULTS AND ANALYSIS

The study's goals were strictly adhered to throughout every step of the process, from framework execution through data collecting and analysis to system design. In this section, we also use benchmarks and other forms of evaluation to figure out how well the suggested architectural framework works. Hyperledger caliper is an instrument for measuring the efficiency of blockchain systems. This works with many different hyperledger frameworks. The performance of the system and its many metrics, including latency and throughput, may be tested and operated with the use of caliper.

System evaluation measures including latency, throughput, CPU utilization, memory, disc write/read, and network I/O are also checked and executed. The experiment was run with both read- and write-transaction modes, as well as with blocks of varied sizes and durations.

4.1 Experiment With Varying Transaction

Measurements with varying transaction: Write modes:

In simulation, we employed 3 firms with 3 peers each and 1 Orderer. The experiment uses 1000 writing transactions at 50, 100, 150, 200, and 250 per second. 1 Firm 1 Peer, 2 Firm 2 Peer, and 3 Firm 3 Peer are tested for transaction performance. Each round consists of 1000 transactions at different per-second speeds (tps).

Table 1 shows the time needed to perform transactions in the atypical network arrangement. 1 firm 1 peer's 5005th transaction takes 240 seconds. 2firm2peer completes 4509 transactions in 240 seconds, but 3 firm 3 peer completes just 4001.

Table 1: Total Completed Transactions for Three Configuration Models Over Four Minutes

Time in min ->	1	2	3	4
1 Firm 1 Peer	801	1909	3901	5005
2 Firm 2 Peer	701	1600	3500	4509
3 Firm 3 Peer	601	1452	3303	4001

Latency in a Blockchain network is the time between submitting a transaction and receiving network confirmation. Equation (1) measures blockchain write transaction delay.

$$W_l = (C_t * N_{th}) - S_t \quad \text{..... (1)}$$

Where W_l: Write transaction latency, C*t*: confirmation time, N*th*: Network threshold, S*t*: Submission Time.

Table 2 illustrates 1 Firm 1 Peer, 2 Firm 2 Peer, and 3 Firm 3 Peer average latency for varying transaction rates. It grows with the firms and peers. TPS grows proportionally to delay. 1 Firm 1 Peer has the lowest latency at 50TPS with 20.0098, whereas 2firm2peer and 3firm3peer have 35.009 and 46.1 correspondingly. Tables 1 and 2 show that delay increased with additional firms and peers.

Table 2: Variable Transaction Rates Affect Average Latency Measurements (50 Tps Through 250 Tps)

TPS->	50	100	150	200	250
1 Firm 1 Peer	20.0098	34.0098	40.09	50.08	55.09
2 Firm 2 Peer	35.009	44.0087	49.009	68.09	70.1
3 Firm 3 Peer	46.1	55.1	60.009	75.09	78.009

Table 3 shows throughput for different transaction rates and the number of transactions per minute for three network types. 1 Firm and 1 Peer had the lowest average latency, fastest throughput per transaction rate, and most jobs per minute. The 3 Firm and 3 Peer network architecture had the greatest average latency, lowest throughput per transaction rate, and completed the fewest jobs per minute. The 2 Firm/2 Peer network concepts were in between. 1 firm 1 peer throughput is 190; however it decreases with more firms and peers. Table 3 showed 182 for 2 firm 2 peer and 180 for 3 firm 3 peers.

Table 3: Variable Transaction Rate Throughput Readings (50 Tps Through 250 Tps)

TPS->	50	100	150	200	250
1 Firm 1 Peer	40	90	150	175	190
2 Firm 2 Peer	35	82	140	170	182
3 Firm 3 Peer	33	77	135	165	180

Write transaction throughput on a block chain network is given by:

$$W_t = (W_{ct} / T_{ts}) * N_{cn} \quad \text{..... (2)}$$

Where W_t: Write transaction throughput, W_{ct}: transaction committed on the entire network, T_{ts}: Total transaction time, N_{cn}: committed node.

Measurements with varying transaction- Read modes:
Five hyperledger caliper measurements were collected. The configuration file sets read mode to 50,100,150,200,250 tps. The delay for reading from a blockchain network may be calculated using equation (3).

$$R_l = R_t - S_t \ldots \quad \text{..... (3)}$$

Where

R_t: Read transaction latency, Rt: Response time, S_t = Submission time
Equation (4) measures read transaction throughput from a blockchain network.

$$R_t = R_o/T_t \quad \text{..... (4)}$$

Where R_t: Read transaction throughput, R_o: Total number of reading operations, T_t = total time in sec. Reading or querying is quicker than writing a transaction, as seen in tables 4 and 5.

Table 4: Read Average Delay for Different Transaction Rates

TPS->	50	100	150	200	250
1 Firm 1 Peer	2.02	3.01	3.0002	4.0008	5.129
2 Firm 2 Peer	6.0021	7.0032	8.0098	10.0087	11.021
3 Firm 3 Peer	7.0098	8.0087	10.0098	11.098	12.099

Table 2 shows that 3 firm 3 peer's maximum write latency was 78.009 seconds, while its greatest read latency was 12.099 seconds. Maximum read throughput for 1 firm 1 peer was 280, while write throughput was 180. The greatest read throughput with changing transaction rate was 240 for 3 firm 3 peer, compared to 180 for writes.

Table 5: Average Throughput with Varying Transaction Rate for Read

TPS->	50	100	150	200	250
1 Firm 1 Peer	80	150	200	250	280
2 Firm 2 Peer	60	130	180	230	250
3 Firm 3 Peer	50	110	170	220	240

Experiment with Varying block time

Measurements with varying block time: Write modes:

This experiment tries to assess network latency and throughput. Hyperledger caliper's EHR system block formation time was modified between 250ms and 2s with variable outcomes. To reduce 3 firm 3 peer transaction latency, optimization metrics were used. Caliper defaults to block time after rising endorse policy block creation time. Switching from 250ms to 2s reduces latency by 35-50%.

Minimum latency for 50 tps is 40s, down from 80s. Table 6 shows that 250 tps has 60s latency, down from 89s. Changing hyperledger's default network setup improves performance.

Table 6: Average Latency with Varying Block Time for Write

TPS->	50	100	150	200	250
250ms Block time	40.001	45.02	50.02	49.03	60.05
2s Block time	80.007	90.9	85.008	90.06	89.6

Table 7 depicts transaction throughput, which increases commit time and transaction success rate due to the network's variable block time policy. At 50 tps, throughput has grown 2.5-fold, from 20 to 49. Similarly, increasing block duration from 250 ms to 2s quadruples 250 tps throughput.

Table 7: Average Throughput with Varying Block Time for Write

TPS->	50	100	150	200	250
250ms Block time	20	25	22	25	15
2s Block time	50	70	55	60	65

Measurements with varying block time: Read modes

The read transaction mode reads transactions at a set interval. Modifying the network's endorsement policy and block time for transaction reading improves system speed. Variable block generation time optimizes blockchain for reading and querying transactions. Table 8 shows transaction rate and latency optimizations. Changing the policy and block time by 2s increases average delay by 9s. The default block time for 250 tps is 37s, however with the modified setup, it's 30s.

Table 8: Average Latency with Varying Block Time for Read

TPS->	50	100	150	200	250
250 ms Block time	20.09	25.02	30.03	31.01	38.1
2s Block time	9.1	14.2	20.1	25.1	30.4

Latency is inversely related to throughput; changing the block time and policy increases read throughput. Table 9 shows that 50 tps transaction throughput is 49 and 250 tps is 77. Read throughput has risen 1.3 times.

Table 9: Average Throughput with Varying Block Time for Read

TPS->	50	100	150	200	250
250ms Block time	50	55	55	60	57
2s Block time	70	72	78	80	76

Experiment with Varying block size

A blockchain's block size affects its performance. Changing block size improves performance. We analyzed 20 and 40-block sizes. Table 10 shows completed transactions for block sizes 20 and 40 over time. Table 10 shows those bigger blocks with a block size of 40 indicate more completed transactions, meaning a negligibly greater number of transactions per second. Our second experiment measured delay and block size as tps changed. We're using 50, 100, 150, 200, or 250 transactions per second. The assessment uses 20-by-40-blocks. Table 11 shows those 20-byte blocks have 50% less latency than 40-byte blocks. Reducing block size will reduce network latency, which may improve performance.

Table 10: Number of Completed Transactions with Varying Block Size

Time->	00:15	00:30	00:45	01:00	01:15	01:30	01:45	02:00
Block Size:40	70	100	150	225	250	400	600	725
Block Size:20	60	90	140	210	245	390	590	710

Table 11: Average Latency with varying Block size

TPS->	50	100	150	200	250
Block Size:40	80	90	85	90	89
Block Size:20	40	45	50	49	60

Transaction per second for an individual node

Transactions per second measures transaction volume (TPS). It may be approximated based on the number of test transactions and then recalculated.

Transactions per Second of $peer_u$ can be calculated by the following equation (5)

$$TPS_u = \frac{Count(T_x\ in(t_i,t_j))}{t_j - t_i}\ (txs/s) \quad \text{..... (5)}$$

Where Tx: Number of transactions, t_i, t_j are initial and final time, respectively Average TPS of N peers, we can take the calculated by:

CPU utilization

CPU use is another key metric. It's the most essential OS number during tweaking. Almost all operating systems display user and system CPU use. These supplementary stats help determine CPU activity.

Caliper estimates CPU use, RAM, incoming/outgoing traffic, and disc read/write. Table 12 shows four rounds of transactions into our hypothetical blockchain network with a 1000-transaction ledger.

Table 12 shows CPU use by network model. The network models' CPU utilization varied with transaction rates.

Table 12: Four Experiments' Resource Use

Round-1						
Type	Name	CPU (avg.)	Memory (avg)	Traffic in	Traffic out	Disc write
Docker	peer0.firm1.example.com	36.6	284.5MB	10.4MB	4.5MB	4.2MB
Docker	peer0.firm2.example.com	28.4	280.0MB	10.5M	5.6MB	4.2MB
Docker	peer0.firm3.example.com	25.1	275.5MB	12.5MB	9.8MB	4.2MB
Docker	Orderer.example.com	19.34	50.0MB	2.5MB	1.2MB	1.2MB
Round-2						
Type	Name	CPU(avg.)	Memory(avg.)	Traffic In	Traffic Out	Disc Write
Docker	peer0.firm1.example.com	38.8	274.5MB	19.4MB	9.5MB	9.2MB
Docker	peer0.firm2.example.com	29.5	270.5MB	15.5M	15.6MB	9.25MB
Docker	peer0.firm3.example.com	26.19	262.5MB	15.5MB	19.8MB	10.25MB
Docker	Orderer.example.com	20.4	51.0MB	4.5MB	1.25MB	2.2MB

Round-3						
Type	Name	CPU(avg.)	Memory(avg.)	Traffic In	Traffic Out	Disc Write
Docker	peer0.firm1.example.com	45.9	272.0MB	20.4MB	10.5MB	10.2MB
Docker	peer0.firm2.example.com	29.79	268.5MB	20.5M	17.8MB	11.7MB
Docker	peer0.firm3.example.com	26.6	260.5MB	22.5MB	21.8MB	14.5MB
Docker	Orderer.example.com	20.9	51.5MB	4.5MB	1.9MB	2.2MB
Round-4						
Type	Name	CPU(avg.)	Memory(avg.)	Traffic In	Traffic Out	Disc Write
Docker	peer0.firm1.example.com	47.3	282.0MB	21.4MB	11.5MB	11.25MB
Docker	peer0.firm2.example.com	30.8	270.5MB	21.5MB	18.8MB	11.7MB
Docker	peer0.firm3.example.com	27.5	262.5MB	25.5MB	22.8MB	14.5MB
Docker	Orderer.example.com	21.1	55.5MB	5.5MB	2.9MB	3.2MB

Peer1.firm1.example.com had the greatest CPU use at 200 transactions per second, while peer0.firm1.example.com had the lowest at 100.

Table 13: Average CPU Use (%) for the Network Model After 3 Rounds

TPS->	50	100	150	200	250
peer0.firm1.example.com	40	32	33	38	40
peer1.firm1.example.com	35	40	39	45	42
peer2.firm1.example.com	33	35	36	40	44
orderer.example.com	18	20	19	21	22

Table 13 is a network heatmap. Simulations reveal a large data volume transmission between peers since caliper generates and approves transactions. No traffic means green diagonals. The orderer distributes blocks to all peers, causing Firm 1's Peer 0 to get 8.25MB and send 1.3MB.

V. RESULT AND DISCUSSION ABOUT EXPERIMENTAL ANALYSIS

- The simulation phase used a network model with three companies and three peers. As the number of firms, block size, and block duration rose, throughput and latency were assessed.
- Adding more firms and peers increases network latency. Read/query latency is lower than write latency.
- Increasing block time decreases latency, boosting network efficiency and throughput. When write block duration is raised from 250 ms to 2s, 250 tps throughput improves by 4x.
- Block size 20 is 50% faster than block size 40, improving network performance.
- Since the network model's CPU utilization has remained steady over time, a drop in block size and an increase in block time will lead to a considerable decrease in network latency, boosting network performance.

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VI. CONCLUSION

Blockchain is vital in today's healthcare systems. It may lead to automated data collection and verification procedures, accurate and aggregated data from varied sources, and a lesser risk of cyberattacks. Distributed data, redundancy, and failure tolerance are also possible. Blockchain might be an alternative to documenting transactions and sending data via a trusted third party. Blockchain may ease transparency and security concerns, such as third-party trust, at every level of a transaction, eliminating intermediaries or third parties. This book addresses contemporary healthcare business challenges, focusing on the Indian subcontinent. We propose system architecture and methodology for permission EHR that communicates with local freestanding EHR systems, checks users against national citizen databases like UIDAI, and collects data from handwritten prescriptions. The suggested framework's performance findings are impressive and might transform EHR systems throughout the Indian subcontinent.

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Demystifying Text Generation Approaches

Lichi Upadhyay, M. I. Hasan & P. S. Patel

ABSTRACT

Natural Language Processing (NLP) is a subfield of Artificial Intelligence that is focused on enabling computers to understand and process human languages, to get computers closer to a human level understanding of language. The main emphasis in the task of text generation is to generate semantically and syntactically sound, coherent and meaning full text. At a high level.

The techniques has been to train end to end neural network models consisting of an encoder model to produce a hidden representation of text, followed by a decoder model to generate the target. For the task of text generation, various techniques and models are used.

Various algorithms which are used to generate text are discussed in the following subsections. In the field of Text Generation, researcher's main focus is on Hidden Markov Model(HMM) and Long Short Term Memory (LSTM) units which are used to generate sequential text. This paper also discusses limitations of Hidden Markov Model as well as richness of Long Short Term Memory units.

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Natural Language Processing (NLP) is a subfield of Artificial Intelligence that is focused on enabling computers to understand and process human languages, to get computers closer to a human level understanding of language. The main emphasis in the task of text generation is to generate semantically and syntactically sound, coherent and meaning full text. At a high level.

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Keywords: natural language processing, HMM, RNN, ANN, LSTM.

Author α σ ρ: Department of Computer Engineering, BVM Engineering College, Gujarat, India.

I. INTRODUCTION

Natural Language Processing (NLP) is a subfield of Artificial Intelligence that is focused on enabling computers to understand and process human languages, to get computers closer to a human level understanding of language. Humans have been writing things down for thousands of years. Over that time, our brains have gained tremendous amount of data and experience in understanding natural language. [9] The goal of NLP is to accomplish human like language processing. It is a theoretically motivated range of computational techniques. There are various applications such as Machine translation, Speech synthesis, Automatic summarization, word processing, Text Prediction, Dialogue systems, Named Entity Recognization, Story understanding, Language teaching and assistive computing.

The steps for generating text is divided in to four phases. First is dataset collection, second one is cleaning of that dataset, third one is loading of cleaned text and the final one is generating text.

In 2016, Artificial Intelligence has generated movie script "Sun spring" created by Ross Goodwin and also directed by Oscar Sharp. It was written by program called Jetson which is called Benjamin. Benjamin's other films are "Zone out" and "This wild." In addition, A new chapter of famous series "Harry Potter" by J. K. Rowling had been published by Botnik studios titled as "Harry Potter and the Portrait of What Looked Like a Large Pile of Ash."

There are many songs which are generated by Artificial Intelligence such as "Daddy's car" and "Break free". The other experiment is Wikipedia text generation. The poems can also be generated by Artificial Intelligence. In Chinese literature, poems have been generated by AI. The connectionist models are used to model the aspects of human perceptions such as, cognition and behavior, learning process under such behaviors and storage and information retrieval from memory. The Neural Networks, which are a sub part of connectionist models, are nothing but a model that mimics how human brain works. We will discuss how these neural networks are useful for generating text.

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II. RELATED WORK

Alex Graves (2014) [1] emphasized on demonstrating that LSTM can use it's memory to generate complex, realistic sequences containing long range structure. In this paper, Alex Graves has taken an approach for generating sequence is for text. He had also shown that how recurrent neural networks can be used to generate complex sequences with long range structure, simply by predicting one data point at a time. In this paper, he had shown that how Recurrent Neural Networks can be trained for sequence generation by processing real data sequences one step at a time, and predicting what comes next. Here predictions are assumed probabilistic and it is also assumed that sequences can be generated from a trained network by iteratively sampling from the network's output and then feeding in the sample as input at the next step. It has been stated in paper that in practice, standard Recurrent Neural Networks are not able to store information about past inputs for very long.The word level Recurrent Neural Network performed better than character level network but that gap appeared close when regularizations are used.

Lipton et al. (2015) [2] has given a review about recurrent neural networks regarding how they learn sequences. The Recurrent Neural Networks are connectionist models. The connectionist models are used to model the aspects of human perception, cognition and behavior, learning process under such behaviors and storage and their retrieval of information from memory.

The neural networks are powerful learning models that give the state-of-the-art results in a wide range of supervised and unsupervised machine learning tasks. But standard neural networks are having limitations, too. In that, there is no dependency between the concurrent states or layers. So when data is related through time or space, these network models are not useful. The examples of such data are frames from video, audio snippets, words pulled from sentences.

Thus, Recurrent Neural Network's requirement came in to picture. Because they are connected through time, all the data that is related through time can be modeled. The recurrent neural network is depicted in figure(1).

Zhengdong et al. (2014) [3] has proposed two convolutional neural networks models for matching two sentences, by adapting the convolutional strategy in vision and speech. The proposed models not only depicts the hierarchical structures (structure of sentences in which phrases are nested in phrases) of sentences with their layer-by-layer composition and pooling, but also can capture the rich matching patterns at different levels. A successful sentence-matching algorithm needs to capture the whole structure including the internal structures of sentences and also rich patterns in their interactions.

Kalchbrenner(2014) et al, have described convolutional architecture dubbed the Dynamic Convolutional Neural Network for semantic modeling of sentences. The network uses Dynamic K-max pooling, a global pooling operation over a linear sequences. The main aim of this paper is to analyze and represent thesemantic content of a sentence for a purpose of classification or generation.

Manurang et al. (2012) [4]has implemented system, McGonagall which uses genetic algorithm to construct text. In this paper, the main goal of authors is to generate texts which are syntactically well formed, meet certain pre specified patterns of metre and convey some meaning. They have proved that if some constraints on metre were relaxed, then their experiments can generate relatively meaningful text. The poetry generation involves many aspects of languages so automatic generation of such poetic text is challenging. They have set some restricted definition of poetry as a text that embodies meaningfulness, grammaticality and poeticness.

Malmi et al. (2016) [5]focus on generating rap lyrics They have given model which is based on two machine learning techniques: 1). The RankSVM algorithm 2).Deep neural Network model with a novel structure. They have taken dataset containing over half a million lines from lyrics of 104 different rap artists, and then new

lyrics are constructed line by line. They have described typical rap lyrics, different rhyme types that are often used. They have considered parameters: 1). Rhyming 2). Song Structure 3).

Automatic Rhyme Detection. They have divided next line prediction problem in to three groups that are rhyming, structural similarity and semantic similarity. They have generated tool called Deepbeat.org which generates rap lyrics by giving a key word as input.

Wei et al. (2018) [6]have tried to generate Classical Chinese poetry, which often incorporates expressive folk influences filtered through the minds of Chinese poets, which consistently has been held in extremely high regard in china. In this paper, they have proposed a Poet based Poetry generation method which generates poems by controlling not only content selection but also poetic style factor. They have done studies that improves the content quality issues of poetic generation system. PoetPG framework takes the content of current line and poet's name as input and then generates a poem in the following two stages: Poetic Style Model, Poem generation.

III. METHODOLOGY

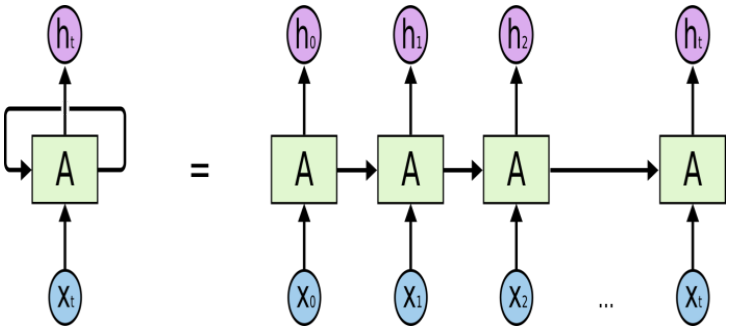
When any writer or poet determines to write about any particular topic, he/she has to gather abundant knowledge about that topic. That knowledge will work as raw material for building a new block. So, from that raw material he/she will be able to write new things about that topic, which will be proprietary. This process of generating new text will be same for the computer as of humans. Text Generation is a part of Natural Language Generation. The Neural Networks are used to model these facilities in the computers.

The connectionist models are used to model the aspects of human perceptions such as, cognition and behavior, learning process under such behaviors and storage and information retrieval from memory .The Neural Networks , which are a sub part of connectionist models, are nothing but a model that mimics how human brain works.

Basically, in a supervised learning ANN (Artificial Neural Network) plays an important role. If we compare it to the human brain, then we can assume that ANN works as temporal lobe, CNN (Convolutional Neural Network) works as a occipital lobe and RNN(Recurrent Neural Network.) works as a frontal lobe of the brain.

The ANNs are very powerful tool to learn machine perception tasks and gives various state-of-the-art results in a wide range of supervised and unsupervised machine learning tasks. But the standard neural networks have a major shortcoming i.e. the current output is independent of previous output. Which is not advantageous to our definition. Humans have context about things, so he/she can get the meaning of new things. When we are reading text book of any subject, if we have understood previous paragraph, then and then only we are able to understand the current paragraph. So we can reach to the conclusion that our current output is dependent on the previous one. So for our definition, RNNs are very helpful which address this issue. In these, networks have many loops which allow information to remain in it.

Basically, in these networks, neurons are connecting to themselves through time. So that they have memory which is short-term, but they can remember what was just happened in the previous neuron or layer. Which helps our definition to generate the sequences? The representation of RNN is as following.



(a) Representation of RNN

LSTMs (Long Short Term Memory units), which are called memory cells of RNN which work as memory units of RNN and also overcome the limitation of traditional Artificial Neural Network. The other techniques used to generate text are Markov chain, Recursive neural networks, Long Short Term Memory ,etc. [10] We will see LSTMs and HMM in depth in following subsection of the paper.

LSTMs:

The Long Short Term Memory unit is a memory unit of Recurrent Neural Network as discussed above. The traditional recurrent neural network is having a shortcoming of vanishing gradient, which is overcome by Long Short Term Memory.

The LSTM captures long range dependencies that means it can remember what has happened just previously. These LSTMs can implemented in various ways such as word level and character level. It observes sequence and then gives output according to input. The standard representation of LSTM is as shown below.

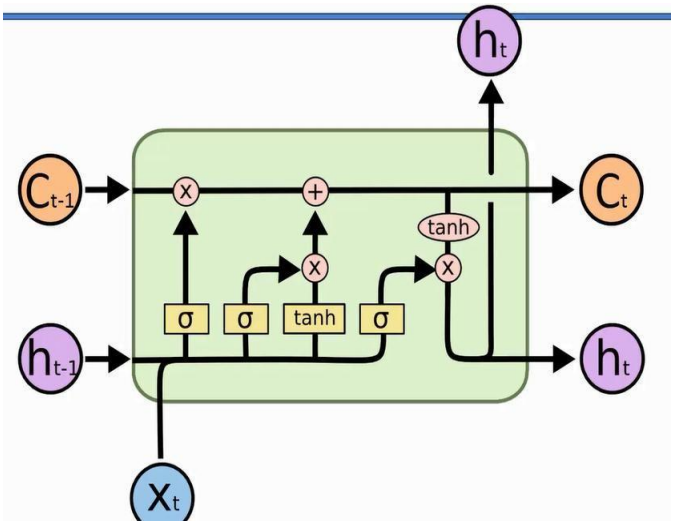


Fig. 2: LSTM[8]

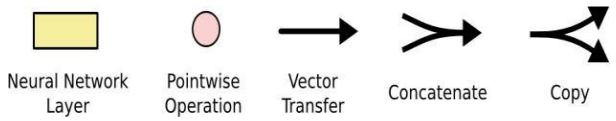


Fig. 3: LSTM notations[8]

Hidden Markov Model

The Markov chains are also capable of showing time dependencies. the data which are related through time (e.g. sequences) can be modeled through Markov models. The Hidden Markov Model is a finite set of transition states, each of which is associated with a probability distribution. These transitions among states are

governed by a set of probability called transition probability. According to associated probability distribution, the observations can be generated. It is called hidden markov model because only outcome is visible to external world, not the internal state transitions are visible. But when the set of possible hidden states grows large, HMM are infeasible. In addition , HMM cannot captures long range dependencies that means HMM cannot remember what has just happened previously.

IV. RESULTS AND DISCUSSION

The Hidden Markov model can model time dependent data. But it cannot capture long range dependencies. As we have to generate text, it can be in form of sentences also. And the sentence can be long. So, these Hidden Markov Model are not useful for generating text. The other model is LSTM. It can be implemented as word level and character level. in character level LSTM , it will observe sequence of characters, and according to that, it will give output. We can generate songs, poems, rap lyrics, etc by giving it's dataset as input.

V. CONCLUSION AND FUTURE SCOPE

from going through various methods used in various papers, we can conclude that, there are different methods available for modelling sequence of words for making sentence. It has been found from the survey that Long Short Term Memory(LSTMs) are best suited for generating text. These Long Short Term Memory units are of the Recurrent Neural Network. The Recurrent Neural Networks are not used for generating meaningful. Long Short Term Memory unit can remember what was just happened in previous layer. The traditional Recurrent Neural Network is having a problem called vanishing gradient, in which weights become smaller and smaller while the network is back propagating weights for training purpose. When these weights are small, and then we forward it in to the network and then we back propagate these weights back in to network for training purpose, then those small weights becomes smaller. This problem is known as vanishing gradient. Thus traditional Recurrent Neural Network faces problem of vanishing gradient. The Long Short Term Memory units of Recurrent Neural Network mitigate this problem of vanishing gradient. So they are having memory. We can use Long Short Term Memory for generating text.,which is best suited for generating text.

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The Conceivability of Consciousness-Kirk's and Chalmers's Zombie Thought Experiments

Dr. C. P. Hertogh

ABSTRACT

In this paper we will discuss Zombie TE (thought experiments)* from (e.g.) Robert Kirk and David Chalmers. On rhetorical analyses there appear three possible fallacies, popular science fallacy, objectivist fallacy and straw man which are restorable to some extent.

On surface analyses of Kirk's Zombie Replica we discover one more TE, Zulliver, an alternate of Brain-in-a-Vat (BIV). On deep analysis as by Kirk himself in Stanford Encyclopedia of Philosophy it is a Conceivability Argument that could be considered basic to TE in consciousness studies. Because of complexity and modal structure of Conceivability Argument we discuss a nonmodal, non-TE example as inverted spectrum (ST1) that appears acceptable to skeptics as W.V. Quine.

Keywords: thought experiment, antifallacy, zombie, conceivability argument, anti- materialism modal argument, qualia, pain ≠ C fibers firing, divine creation, modal semantics, substitution thesis, inverted spectrum, phantom pain. Robert Kirk, David Chalmers, Saul Kripke, Roy Sorensen, WVO Quine, Daniel Dennett.

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Dr. C. P. Hertogh

Zombie o, zombie (zombie o, zombie) Zombie o, zombie (zombie o, zombie)

Zombie no go go, unless you tell 'em to go (zombie) Zombie no go stop, unless you tell 'em to stop (zombie) Zombie no go turn, unless you tell 'em to turn (zombie) Zombie no go think, unless you tell 'em to think (zombie)

....

(from Fela Kuti and Africa '70 (1977). *Zombie* Lyrics)

(note o)

ABSTRACT

In this paper we will discuss Zombie TE (thought experiments) from (e.g.) Robert Kirk and David Chalmers. On rhetorical analyses there appear three possible fallacies, popular science fallacy, objectivist fallacy and straw man which are restorable to some extent.*

On surface analyses of Kirk's Zombie Replica we discover one more TE, Zulliver, an alternate of Brain-in-a-Vat (BIV). On deep analysis as by Kirk himself in Stanford Encyclopedia of Philosophy it is a Conceivability Argument that could be considered basic to TE in consciousness studies. Because of complexity and modal structure of Conceivability Argument we discuss a nonmodal, non-TE example as inverted spectrum (ST1) that appears acceptable to skeptics as W.V. Quine.

Chalmers proposes his global Zombie World TE as an argument from failure of logical supervenience of the mental on the physical.

Chalmers's Anti-materialism Modal Argument (AMMA) appears on deep analyses with help of modal logic an ontological modus tollens falsifying materialism.

As nonmodal alternate argument (ST2) we next discuss Saul Kripke's Pain ≠ (□) C fibers Firing.

It is itself not a TE but as according to Chalmers most essentially based on related Divine Creation TE by Kripke, which Kripke interpretation has received less attention than merited.

Lastly, we discuss a non-TE example of phantom pain as mentioned by Kripke (a/o) which appears acceptable to Daniel Dennett who even accepts René Descartes's metaphorical explanation of the bell-pull, although Dennett maintains it is only an example of a relatively 'thin hallucination.'

*We end the paper with some suggestions of further research as based upon Chalmers's catalogue of conscious experiences.**

Keywords: thought experiment, antifallacy, zombie, conceivability argument, anti-materialism modal argument, qualia, pain ≠ C fibers firing, divine creation, modal semantics, substitution thesis, inverted spectrum, phantom pain. Robert Kirk, David Chalmers, Saul Kripke, Roy Sorensen, WVO Quine, Daniel Dennett.

Zombies Robert Kirk, David Chalmers

I don't have the prejudices many have today, I don't believe in a naturalist world view. I don't base my thinking on prejudices or a world view and do not believe in materialism. (Saul Kripke in Saugstad 2001)

I. RHETORICAL ANALYSES--THREE (ANTI) FALLACIES

As many more TE, *Zombies* have equivocated with many sources, myths, stories etc. from

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popular culture, not at least with recent horror movies, which have added violent properties which turned them into flesh or brain eating monsters. *Zombies* may now function as a connotation trigger like Nagel's *Bat* ('What It Is Like to Be a Bat' 1974) which also has some horror aspects.

First step of our rhetorical analyses will not be a close analysis of the *Zombie* texts but a short intercultural research into the concept of zombie and the many mysterious notions and rather less-known phenomena it is related to as voodoo (or vodou), syncretism, satanism, ghosts and the undead.

Voodoo

The word stems from more than just one voodoo religion, African, Haitian and West Indian and it is also linked to Tibetan folklore where they are called rolangs risen up (ro) corpses (lang).

Webster's says Louisiana Creole or Haitian Creole *zonbi*, of Bantu origin; akin to Kimbundu *nzúmbe* ghost, dating from circa 1871. Most of these cultures share common features of zombie concept as a will-less, speech-less or psychotic person under control of a scorserer (bokor) drugged, poisoned or hypnotized whose actions are powered by the bokor instead of by itself, often performing evil, malicious deeds to individuals and society, that is enemies, opposers of the commissioner.

The Undead

In western folklore and popular culture zombies are only one category of the undead particularly reanimated corpses bereft of consciousness and self-awareness. An undead can be both a zombie and a vampire according to *Webster's 11th*. The word undead is not coined but anyway popularized by Bram Stoker's 1897 novel Dracula.

It has important precursors in Edgar Allen Poe's horror and Mary Shelley's 1818 Frankenstein. Just like Frankenstein modern-day scientists, philosophers and psychologists are still looking for the principle of life conducting bizarre—in sense of immoral—Es and TEs.

Next to corporeal species of the undead there are the better known incorporeal undead, e.g. (maleficent) ghosts and demons. The 19th century fictions go back again on (hi)stories of myths from bacchants and keres (tenebrae) to demons, skeletons and mummies (Europe), from Sheherazade *Thousand and One Nights* (e.g. Dawood 1954, 1957) to modern-day Disney versions of Alladin's Lamp (Arabia), from ancestor ghosts and spirits as guǐ (鬼) to jiangshi (僵尸) and nowadays movies as 2005 *The Maid* (e.g. Tong 2005) about e.g. the Ghost Month (鬼月) (China).

Hollywood Zombies

Romero's 1968 *Night of The Living Dead* redefines the concept of zombie from people controlled by a voodoo bokor to a story about a hypothetical zombie apocalypse, a mass homicide by a virtual army of unidentified killers, as we watch hundreds of those things that appear to be in a kind of trance, move over the fields slowly like rather humanoid automata or robots cannibalizing their victims, possibly caused by a mutation brought about by radiation from an exploded satellite the rather racist radio and TV commentaries tell a group of people closed in in a farmhouse to protect themselves from the zombies that are all around. The unverydead come back to life and are killing human victims.

In the end the only survivor, an African-American man (Ben played by Duane Jones) in those days potentially controversially casted as the hero of the story, is killed by a gun shot of police who behave like slave hunters. Romero made many sequels as 1978 *Dawn of the Dead* and 1985 *Day of the Dead* and nowadays zombies are commonly familiar and thus lost most of their initial horror effects.

Considered a cult classic it is said to be critical of American society (patriarchal nuclear family as e.g. a daughter kills and eats her mother), horrors of Vietnam era (showing bloody slaughters, newsreels telling about search-and-destroy operations) and domestic racism (murder of Ben would have reminded murders on MLK and Malcolm X). Possibly it also connotes a secularized version of Resurrection of the Body

without Soul though they have a (re)animated soul in physical sense.

Nigerian musician Fela Kuti calls one of his tracks Zombi therein likening authorities as police and military to these will-less creatures, sort of human automata without any consciousness or conscience that kill on purpose—and that subsequently raided Fela's home, killing his mother. (note 1)

Philosophical Zombies (P Zombies, P Zeds)

Next to the popular zombies, Wikipedia distinguishes philosophical zombies, p zombies or p zeds.

Stanford Encyclopedia of Philosophy defines Zombies

Zombies in philosophy are imaginary creatures used to illuminate problems about consciousness and its relation to the physical world. Unlike those in films or witchcraft, they are exactly like us in all physical respects but without conscious experiences: by definition there is 'nothing it is like' to be a zombie. Yet zombies behave just like us, and some even spend a lot of time discussing consciousness.

The *SEP* entry was written by Robert Kirk in 2011, updated in 2019. Kirk developed his *Zombie* TE in his 1974 paper ' Zombies versus Materialists'.

In the 90s it was revived by David Chalmers in his 1996 *The Conscious Mind*. It is often thought to be preceded by e.g. Saul Kripke's proof that we are all intuitive dualists. We will first discuss Kirk's *Zombie (Replica)* TE, next Chalmers's *Zombie (World)* TE as used in his ground-breaking *AMMA* (*Anti-materialism Modal Argument*) and lastly—as after e.g. Chalmers 1996--relate it to Kripke's *Pain ≠ C fibers Firing* which argument has no reference to anything as *Zombies*.

Dennett 1995 distinguishes between *Zombies* and *Zimbos* the latter having higher order reflective informational states as beliefsz about beliefsz, but Chalmers considers the distinction irrelevant as according to him "...my zombies and Dennett's zimbos are exactly the same thing." (Chalmers in private email from 2000, Dennett did not reply to Chalmers's statement which contradicts Dennet's 1995 quote).

1.1 Popular Science (Anti) Fallacy

Like (e.g.) Nagel's *Bat*, analyses of *Zombies* are blurring popular and scientific contexts. Although there is now a philosophical *P Zombie* and philosophico-scientific definition, Chalmers populates his *Zombie* internet page with Hollywood zombies and the philosophical concept of zombie—not its imaginability as one does not need to perform a dreadful personification after the *P Zed* definition as (possibly) different from Nagel's *Bat*—is still parasitic on popular concept of how one can imagine bodies without consciousness.

We will call this seeming fallacy the popular science fallacy which is restorable by meticulous elaboration for which many philosophers however seem to be missing adequate time or literary skills. Examples of convincing TE in literature as Bram Stoker's 1897 *Dracula* show it is possible to portray personifications in literature and Jean Paul Sartre, 1964 Laureate of Nobel Prize in Literature, shows the same for philosophical experiences as in his 1938 *La nausée* (*Nausea*). (note 2)

Furthermore, when performing such a personification there appears an ambiguity between imaginer and imagined character which we also point out in Einstein's *CABOL* (*Chasing a Beam of Light*), an instance of kabuki antifallacy in Sorensen's words. Additionally we refer to Denis Diderot's 1830 *Paradoxe sur le comédien* e.g. on issues as if an actor really feels who/what he plays or merely imitates these feelings, and more theater analyses. (note 3)

Like Nagel escapes from the seeming fallacy by rejecting the *Bat* personification from a restricted empathy point of view, Chalmers—and already his precursor Kirk—evades the problem by explicitly stating the *Zombie* TE as a modal argument—it is about the possibility of *Zombies*—thereby evading discussions on actual existence of *Zombies* as well. For this reason we will focus on modal logical analyses of their *Zombie* arguments

though both Kirk and Chalmers mention nonmodal analogues.

As modal possibility arguments the *Zombie* TE *seem* to be directed against radical materialist accounts of the mind that attribute necessary truth to statements as 'man is nothing but a physical object', although Kirk argues 'that it is logically implied by *any* view of man which remains true to the rationale of materialism.' (Kirk 1974 : 135) (note 4)

1.2 Objectivist/Fact-Value (Anti) Fallacy

Consciousness and philosophy of mind discussions are confused by many senses of consciousness and mind, the former also meaning conscience (indeed possibly Dennett's higher order *Zombies*, *Zimbos*), the latter having overlapping senses with I, self, brain, soul, heart, spirit etc. Body – mind dualism originates as rationale to account for morals, ethics and the Afterlife (e.g. immortal soul, moral heart and spirit, sense of self for moral reasons). Also, Descartes's dualism had these connotations.

This fact remains unmentioned in nowadays philosophy of mind and consciousness studies, and philosophers and cognitive scientists hardly ever supplement their texts with e.g. explanations of moral, ethical consciousness (pace e.g. Nagel).

We will call it the objectivist or fact-value fallacy that is also committed by Kirk and Chalmers and more nowadays epistemological dualists. Possible explanation is utilitarianism in ethics but still, if so, it has to be stated in so many words. And the fact-value distinction does not hold in the area of consciousness as strong as in e.g. physics.

Anyway, the moral implications that ring that strong in the popular *Zombie* stories are missing in the philosophical texts though they are often suggested.

Question remains, what does the *Zombie* discussion contribute to previous man-machine, automaton, *Doppelgänger*, human clone, duplicate (without consciousness—e.g. Campbell's *Imitation Man*), monsters created by science (e.g. Mary Shelley's *Frankenstein* and its many movie remakes) discussions?

One of the meanings of *Zombie* is automaton and the philosophical *Zombie* (*P Zed*) definition adds nothing to a machine, automaton definition of man or a human replica TE, Descartes res extensa without res cogitans, as possible connotations of *Zombie* are abstracted from in *P Zed*. Why Chalmers hasnot dubbed his TE e.g. *(Human) Replica* as after Robert Kirk's *Zombie Replica* TE or Keith Campbell's *Imitation Man* TE, whom Chalmers refers to both on introduction of his *Zombie* TE in *The Conscious Mind*? (note 5)

We may only guess the choice for *Zombie* instead of e.g. *Imitation Man* is rhetorically motivated and it fits in with rather general rhetoric nature of use of TE in philosophy. As a Dinosaur cartoon on Chalmers's web site (wherein *P Zombie*s are also called *Mental Zombies*) says, 'You must admit that it makes the whole debate a lot more interesting.'

Scientifically speaking the delusive moral overtones are not fallacious and on analyses *P Zombies* are antifallacies, but morally speaking the deception is fallacious, although we couldnot say this just because of the prevalent fact-value dichotomy in contemporary philosophy and science (see also sections on moral biases in ...).

Nevertheless, it may distort PF (prima facie) conceivability of *Zombie* TE.

1.3 Straw Man (Anti) Fallacy

Lastly, both Kirk and Chalmers may commit fallacy of straw man, that is, they represent arguments of functionalists, physicalists, materialists, behaviorists stronger, more extreme and more radical than they are and their modal conceivability/possibility arguments only refute necessary functionalism etc.

Most functionalists etc., however, don't hold on to the strongest type of materialism all their life. And linguistic behaviorist Quine, whose skepticism about meaning did not find many supporters, does not doubt subjective experiences, but rather their relevance to communication and their explanatory use; Quine

does admit that introspection is indispensable heuristically as a source of insights that can lead to new theories. (Quine, Block 1994 Section 1)

Kirk's and Chalmers's modal arguments are valid but *seem* to refute only necessary materialism and their conceivability arguments *seem* to defend only failure of the weakest form of supervenience of the mental on the physical, logical supervenience, not natural supervenience. (note 4) Chalmers does not defend natural possibility of *P Zeds* neither *Qualia*.

On the other hand, if Kirk and Chalmers and particularly Kirk don't want to direct their *Zombie* arguments against necessary materialism only (but e.g. against any kind of materialism), this (anti)fallacy does not hold to a high extent.

Furthermore, as according to 2013 email correspondence Robert Kirk has soon after changed his views as by Kirk 1979, 'From Physical Explicability to Full- Blooded Materialism', and he now rejects the *Zombie* TE (e.g. Kirk 2005) and considers himself materialist, although a materialist who does not deny occurrence of conscious subjects and the mental, but rather tries to explain them from a materialist point of view.

II. ROBERT KIRK'S *ZOMBIE (REPLICA) TE*

Robert Kirk is still most known for his 70s *Zombie* argument. In recent 2011/2019 contribution on *Zombies* to *Stanford Encyclopedia of Philosophy* Kirk himself proposes a deep analysis of it. We however will start with surface analysis of Kirk's 1974 paper.

2.2 Surface Analyses (Zombie Replica, Zulliver)

Kirk introduces his *Zombie* TE towards the end of part I of 1974 paper as a counter to his so-called Entailment Thesis--

> Every non-relational description which applies to a given man at a given time is entailed by the conjunction of all the purely physical non-relational descriptions which apply to him at that time. (Kirk 1974 : 139)

The Entailment Thesis would be false if and only if there were a man who 'would be *more* than that,' a *Zombie Replica*

> What would undoubtedly be nothing but a physical object, and that in a transparently clear sense, is a physical replica of the man to which there applied *only* the physical descriptions and whatever they entailed—something we may conveniently dub a 'Zombie replica'. (Kirk 1974 : 141)

Like Putnam's *Twin Earth* Kirk's modal TE seems to be devised to fill a logical or explanatory gap–

> (I shall assume for the sake of simplicity that if Zombie replicas are logically possible, the descriptions which fail to apply to them are descriptions of sensations. Obviously such descriptions are likely candidates, if any are; and my argument is unaffected by the exact nature of the class of descriptions in question.) (Kirk 1974 : 141-142)

Chalmers calls it phenomenal feel (etc.), Kripke mentions example of pain.

It is a modal argument as actual existence of *Zombie Replicas* 'does not matter'--

> The point is that if such things are merely possibly, it is false that we are mere physical objects. We would add 'necessarily' between 'are' and 'mere'. Such a race of Zombies would indeed have been 'nothing but physical objects.'

The replica concept appears to be possibly inspired by Descartes--

> ... Thus if Descartes' view of the nature of man were correct, an exact physical replica of a given man would not necessarily be an exact replica of that man—unless by natural necessity a soul were automatically assigned to it. ....

As nonmodal alternates Kirk mentions a paralyzed man (Kirk 1974 : 145), dreamless sleep, sleep- walking and sleep-talking (148-9). However, as in email correspondence in 2013 Kirk does not confirm these are examples of evidence of consciousness--

> No, I don't think they are *evidence* of consciousness. The point is that it is highly counterintuitive to suggest that the paralysed man *doesn't* have conscious experiences .... The point of the cases of dreamless sleep, sleepwalking and sleeptalking, on the other hand, is that we have evidence that such cases occur. (email dd. February 18, 2013)

Dreamless sleep account is reminiscent of Zhuangzi (庄子, 4th C BCE Warring States Period) dreaming Zhuangzi is a butterfly, although Kirk stresses the victim is considered to be able to describe gaps in his experience whereas Zhuangzi and the butterfly are not. (note 6)

Next, Kirk develops a related *Zulliver* TE, an alternate of Descartes *Evil Demon*, nowadays known as *Brain-In-a-Vat* (*BIV*)--

Consider Gulliver in Liliput. ... He had encountered a race of beings even tinier than the Lilliputians, and technologically more advanced than ourselves. A team of their scientists (the 'Brain Team') had invaded his head ... The Brain Team had thus taken over those functions of Gulliver's brain which governed his behaviour. ... I will refer to this entity as 'Zulliver.'

Zombie Replica and *Zulliver* TE are directed as 'decisive counter-examples' against particular materialist accounts or suggestions as analytical behaviorism (p. 144) and causal or functional analyses of mental states as Armstrong's, Lewis's and Putnam's and alleged Identity Thesis (p. 142, 145).

2.2 Deep Analyses--Conceivability Argument

The *Zombie* debate is quite argumentative of nature because of its technical restriction to *P Zombies* as, in fact, arguments and there are hardly any digressions into literary or story analyses just because of the restrictive definition.

The *Zombie* TE argument is a conceivability argument for possibility of *Zombies* and it can be summarized after Kirk 2019 as modus ponens [1]
P1 (Major) Whatever is conceivable is possible. P2 (Minor) Zombies are conceivable. -
C (onclusion) Therefore zombies are possible.

Next it can be analyzed as modus ponens instantiation--[2]
Suppose

Cx : x is Conceivable
Px : x is Possible
z : zombie(s)
Cx --> Px
Cz
- - - - - - - - -
Pz

The argument is valid but both premises are disputable and apparently--as there are many discussions on them--no evident necessary truths but only probabilistic opinions.

It is an example of universal instantiation, but universal here only refers to nature of inference of instantiation, not to truth value of major premise.

So, according to definition by Aristotle it is an enthymeme as after syllogistic model of modus ponens (p --> q, p, so q).

This *Zombie* TE argument has been preceded by Saul Kripke's modal arguments against type-type identity materialism (pain ≠ (□) C-fibre firing, heat ≠ (□) molecular motion) in Kripke's 1970 Princeton lectures *Naming and Necessity* (Kripke 1972, 1980) who, however, does not use words like *Zombie* or *Zombie World*. (Papineau 2008—see note 7)

III. DAVID CHALMERS'S ZOMBIE (WORLD) TE AND ANTI-MATERIALISM MODAL ARGUMENT (AMMA)

Chalmers introduces his *AMMA* (*Anti-materialism Modal Argument*) in chapter 4 on Naturalistic Dualism of 1996 *The Conscious Mind*. We will start with chapter 3, in which Chalmers develops his *Zombie World* TE, a case from global supervenience, instead of Kirk's individual *Zombie Replica*.

3.1 Surface Analyses (TE Argument from Failure of Logical Supervenience)

Chalmers develops his *Zombie World* as one out of five arguments against reductive explanation of

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consciousness as that everything in the world can be explained in physical terms.

Again, the vocabulary is highly technical–

> The most obvious way (although not the only way) to investigate the logical supervenience of consciousness is to consider the logical possibility of a *zombie*: someone or something physically identical to me (or to any other conscious being), but lacking conscious experiences altogether. At the global level, we can consider the logical possibility of a *zombie world*: a world physically identical to ours, but in which there are no conscious experiences at all. In such a world, everybody is a zombie. (Chalmers 1996 : 94)

Chalmers states his case against reductive explanation in terms of logical supervenience--

> we need to show that consciousness is not logically supervenient on the physical.

The notion of supervenience was first introduced into the philosophy of mind by Donald Davidson (1970)

> [M]ental characteristics are in some sense dependent, or supervenient, on physical characteristics. Such supervenience might be taken to mean that there cannot be two events alike in all physical respects but differing in some mental respect, or that an object cannot alter in some mental respect without altering in some physical respect. (Davidson 1970 : 98) (note 8)

Next, Zombie World reminisces of (one of) Putnam's Twin Earth(s) when Chalmers continues--

> So let us consider my zombie twin. This creature is molecule for molecule identical to me, and identical in all the low-level properties postulated by a completed physics, but he lacks conscious experience entirely.

Later on using Nagel's vocabulary

> .... It is just that none of this functioning will be accompanied by any real conscious experience. There will be no phenomenal feel. There is nothing it is like to be a zombie. (Chalmers 1996 : 95).

Again, we may conclude that TE nature and popular connotations may have contributed to fame of the *Zombie* argument as applied in Chalmers's *AMMA*. Chalmers has elaborated his views on to 1998 Princeton lectures *Mind and Modality* as supported by (metaphysics of) two-dimensionality (e.g. primary and secondary intension instead of Frege's sense and reference).

In 2002 as part of his contribution to Gendler's and Hawthorne's *Conceivability and Possibility* Chalmers develops a TE theory that we discuss in part on natural sciences in ... , applying it to Einstein's *CABOL* (*Chasing a Beam of Light*). In a 2010 explanation to *AMMA*, 'The Two-dimensional Argument against Materialism', Chalmers adds a formalization to *AMMA* and analogously to Kripke's *Pain ≠ C fibers Firing* argument—please, see notes 11 and 14--as well as some non-TE examples, nonmodal analogues of a zombie or 'invert, who has an experience that differs slightly from the corresponding experience of the corresponding individual in our (physically identical) world'--

> It suffices if we can conceive of a being whose conscious experience is for just a moment slightly different from that of an actual physical duplicate's: perhaps they experience a slightly different shade at a point in the background of their visual field. Any problems that are specific to zombies then will not apply.

3.2 Inverted Spectrum (ST1)

The *Qualia* debate is difficult to access and assess because of many ambiguities and emotions lurking in the vocabulary. *Qualia* are defined as both (1) sort of universals or abstracts (fitting in with mysterious conceptions from Plato's forms and Aristotle's essences to Wittgenstein's beetle/thing-in-a- box) and (b) sense experiences (colors etc. but also pain) as different from the source it may have in an object (and discussion features on whether it is about brain, physical, (neuro)physiological, neural states or a mental, phenomenal etc. states). The debate is beset by emotions with terms as the slightly deprecatory 'qualophiles' versus supposedly die-hard

necessarily necessary materialists of various sorts and types.

When looking for non-TE, non-modal alternate qualia we may find more convincing examples in the field of pain experiences—e.g. phantom pain mentioned by e.g. Saul Kripke, phenomenal pain without physical cause—than in the field of colors—where inverted spectrum of qualia donot refer to obvious examples of red-green color blindness but to a TE from John Locke about an intrapersonal case of inverted qualia viz. waking up and experiencing that the world has inverted its colors, Block's *Inverted Earth*, or meeting one's *Inverted Twin* (interpersonal case of Chalmers) often again emotionally explained by sci-fi actions of 'evil neurosurgeons' and 'second switcheroos' (Dennett 1991, similar to Kirk's *Zulliver* TE). The problem has changed from whether inverted spectrum like red-green color blindness is logically or naturally possible—and science has proved the latter, it is not only possible it is an actual defect of the retinal cones quite often genetically determined—to debating a situation wherein two or more people are sharing vocabularies but 'systematically' differ on sense impressions or experiences, qualia e.g. A says red and sees red but B says red and sees green—in their minds.

Of course, medical tests can reveal who is color-blind and who has common vision and experiments (e. g. visual field inversion experiments with goggles mentioned in Dennett 1991 : 393) have demonstrated that humans adapt extremely quick to modifications of their visual field.

W. V. Quine is taking a conservative logical-positivist stance--'the extent to which that [*Inverted Qualia* TE] make sense is still a puzzle to me' in 1994 video conversation with Ned Block as according to Quine it is 'irrelevant to linguistic side of assessing communication' when there are only stimuli and words without any fixed or fixable ideas and Quine guesses mental states can be explained by neuroscience--'it's going to be mechanistic, physiological'. Philosophers of mind and cognitive scientists, of course, struggle with it from a cognitive, psychological or phenomenological point of view as with possibility of Cartesian substance dualism, property dualism etc. (versus materialist Identity Theory) and nowadays the latter quite obvious perspective seems evaded for modal logical phrasings as failure of reductive physical account of consciousness when the mental does not logically supervene on the physical (Chalmers 1996).

However, on nonmodal non-TE examples there seems some consensus possible as in Section 3 of aforementioned video conversation with Ned Block, Quine admits that inverted spectrum example is a 'meaningful claim' that is 'rescuing something of the mentalistic realm and gives it some respectability.' (note 9)

We conclude that qualia in the sense of sense experiences may exist independent from properties of the objects as from nonmodal, non-TE medical evidence of (e.g.) red-green color blindness that can be examined by medical tests as the quite known so-called ishihara color test plate used by optometrists all around the globe, a circle with red and green dots where the latter have the shape of a number.

Nonphysical or nonphysically caused qualia like pain which may not belong to sense impressions proper--perhaps it are reflexes or biological defense mechanisms—are considered to be proven by phenomena as phantom pain—an example by Saul Kripke to illustrate *Pain ≠ (□) C fibers Firing*; perhaps it is memory of pain but humans apparently can't discern between real, actual, momentary pain and memory of it.

Since Quine seems convinced by the inverted spectrum analogue we can apply ST1 (Substitution Thesis 1)*—the *Inverted Qualia TE* can be replaced by *(real) experiments*, in fact, established medical tests for inverted qualia.

Because of the many intricacies as discussed by Chalmers and Block and particularly because of the explicitly modal statement of logical possibility of *Zombies* TE as well as *Qualia* TE, we think modal analyses of the problem aren't overdone and in next section we will propose a modal logical analysis of Chalmers's *AMMA* by applying Kripke's frame or PWS semantics.

The issue is in need of more research but it may take us far beyond the philosophical literature on TE. We miss in the philosophical literature more examples of qualia (beyond the usual ones of colors and pain) and references to up-to-date research that does not necessarily need to be fundamental neuroscience but can start from everyday experiences as a visit to an optometrist.

The *Qualia* TE treatment could benefit from results of applied science and technology as medicine instead of speculations about possible future of neuroscience (Quine, Dennett) or objective phenomenology (Nagel), a little more 'scientific journalism' that Quine usually advises. (note 10)

Possible disadvantage of this approach is question whether we can explain the usual from the unusual, whether we can give an adequate account of color vision by considering medical research about defects. We may doubt Freud's theories because he explained the psychological from the psychopathological.

We guess these doubts may hold for western sciences and their methodology as a whole (see Section on cultural, scientific, moral biases in part III of ...). Nevertheless, we have answered some philosophical issue about natural possibility by showing evidence from actual medical practice and, thus, we have at the same time answered issues about logical possibility for if something is naturally possible it is therefore also logically possible as logical possibility is broader and encompasses natural possibility—not the other way around.

3.3 Deep Analyses—Ontological Modus Tollens (AMMA)

In Chapter 4 of Chalmers 1996 on naturalistic dualism David Chalmers states an argument against materialism as an *ontological* consequence of (e.g.) logical possibility of *Zombies* (Chalmers 1996 : 123)--[3]

1. In our world, there are conscious experiences.
2. There is a logically possible world physically identical to ours, in which the positive facts about consciousness in our world do not hold.
3. Therefore, facts about consciousness are further facts about our world, over and above the physical facts.
4. So materialism is false.
5. Refers to what Chalmers defines as a zombie world.

Disputable premise seems 1, on which physicalists probably won't agree (note 11), that is exactly the transcendental presupposition the *Zombie* TE argument appears to be about as in debates between physicalists and nonphysicalists. How to scientifically, logically and empirically prove conscious experience in our world, evidence we could expect 1 to be based upon.

Applying modal semantics like Kripke's frame semantics by assuming {W, R, |=} i.e. a set of (possible) worlds (w_1, w_2, w_3 ..., w_x, w_y, w_z etc., e.g. w_1 actual world), an accessibility relation R and a satisfaction relation |=, where quantification over *all* worlds, Aw , signifies *necessar(il)y* (cf. □ box operator) and quantification over *some* worlds, ∃w, signifies *possible/y* (cf. ◇ diamond operator).

Suppose [4]

CSx	x has/is having Conscious(ness)
(experiences) Px	x is/has (only) Physical (features)
∃	extistential quantifier
A	universal quantifier
/\	conjunction
-	negation

then as after structure of modus tollens
∃wx | = Ax (Px /\ - CSx) (2) i.e. *Zombie (World)* TE

w1 | = ∃x (Px /\ CSx) (1) i.e. in our world (Planet Earth) there are conscious experiences

- -

-Awx | = Ax (Px /\ - CSx) (4) i.e. so materialism is false (note 12)
On analysis statement 1 is a presupposition that can be left out as a major and reintroduced as a minor to 2 as possibly together with 3 which is not necessary for the final argument.
Statement 3 can be formalized like this

w1 | = Ax (CSx → Px /\ CSx) (3) i.e. in our world facts about consciousness are further facts about the (physical) world [5]

It seems logically redundant to falsify materialism but it is exactly Chalmers's positive statement of irreducibility thesis of consciousness in our world and in *AMMA* it functions as a sub-premise to sustain 1.

Furthermore, 3 is inferred from 1 and 2 ([t]herefore in 3).

Again both *Zombie* TE and *AMMA*('s use of *Zombie* TE) aren't scientific syllogisms with necessarily true or false premises and conclusion but rhetorical syllogisms--enthymemes--with possible, probable premises and conclusion as (e.g.) opinions.

Considered as a (psycho)physical theory, however, we could ask for more (note 13) and in Coherence as a psychophysical law at the end of the first step towards a nonreductive theory of consciousness in chapter 6 Chalmers reveals 'the overall epistemological framework'

[6]

> This is the same sort of reasoning that goes on in formulating physical theories .... In all these cases, the underlying assumption is that the world is a simple and reasonable place. Failing such an assumption, anything goes. With such an assumption, things fall into place. (Chalmers 1996 : 246)

Coherence as between conscious experience and cognitive structure, between phenomenology and psychology of the mind, between consciousness and awareness is '[t]he most promising way to get started in developing a theory of consciousness' (Chalmers 1996 : 218).

In our TE Matrix terminology *Zombie World* TE is the basic or elementary TE in restricted sense, [TE]RS—which structure is similar to Kirk's local *Zombie* TE and *Conceivability Argument—AMMA* or, in fact, formula [4] is TE in broad sense, [TE]BS –and [5] and [6] are supporting premises of the TE in extended sense, [TE]EX revealing [6] as epistemological principle, that functions as justificatory underpinning or backing.* On closer discussion of Chalmers's theory of consciousness more different and more extended formalizations are possible e.g. involving coherence principles etc.

For dualists [TE]BS is MT (modus tollens) for the major (1) is (necessary) true. Since materialists doubt the major the logical strength of the syllogism is mitigated to enthymematic probability and the major is only an opinion.

Radical necessary materialists will deny the major and for them *AMMA* is only formally valid since at least one of the premises, major (1), is necessarily false.

3.4 Kripke's Pain ≠ C fibers Firing Argument (ST2) (note 14)*

Chalmers discusses two more arguments for dualism, Frank Jackson's 1982 *Mary's Room* (or *Color Scientist Mary*) and Kripke's *Pain ≠ C fibers Firing*.

In part of Kripke's 1971, 1972, 1980 philosophy of mind argument Chalmers recognizes a related *Zombie* argument from supervenience in Kripke's contention that God had to do more work--after creating brain states, he next had to create mental states corresponding to phenomenal feelings as pain. Because it is only hinted at in the secondary literature we will quote Kripke's *Divine Creation* TE here in length in as far as it relates to pain and C fibers (note 15)--

> Suppose we imagine God creating the world. ...
>
> What about the case of the stimulation of C-fibers? To create this phenomenon, it would seem that God need only create beings with C-fibers capable of the appropriate type of physical stimulation; whether the beings are conscious or not is irrelevant here. It would seem, though, that to make the C-fiber stimulation correspond to pain, or be felt as pain, *God must do something in addition to* the mere creation of the C-fiber stimulation; he must let the creatures feel the C-fiber stimulation as pain, and not as a tickle, or as warmth, or as nothing, as apparently would also have been within His powers. (Kripke 1980 : 153-4, italics added)

On Chalmers interpretation this passage in Kripke supports 'an argument from the failure of logical supervenience' (Chalmers 1996 : 149)--

> This leaves the argument from the possibility of instantiating physical states without the corresponding phenomenal states—essentially an argument from the possibility of zombies. Curiously, this is the part of Kripke's argument that has received the least critical attention, with most commentators focusing on the possibility of disembodiment.
>
> The possibility of instantiating the relevant physical states without pain, Kripke argues (pp. 153-154), shows that even after God created all the physical stuff going on when one has a pain—perhaps a brain with C-fibers firing—*he had to do more work* in order that those firings be felt as pain. This is enough to establish that materialism is false (David Chalmers 1996 : 148)

Kripke himself uses the *Divine Creation* TE to conclude that the relation between brain states and mental states seems to be contingent and, so, the Identity Thesis is not correct.

On Chalmers interpretation this passage in Kripke supports a supervenience argument as opposed to an identity argument, so, Chalmers twists Kripke's Anti(or Non)Identity Thesis argument into an Anti(Non)Supervenience Thesis--

> It is crucial that the argument as I have put it does not turn on questions of *identity* but on *supervenience*. The form of the argument is not, "One can imagine physical state *P* without consciousness, therefore consciousness is not physical state *P*." The form of the argument is rather, "One can imagine all the physical facts holding without the facts about consciousness holding, so the physical facts do not exhaust all the facts." (Chalmers 1996 : 131)

However, the last paragraph of *Naming and Necessity* may point in same supervenience direction phrased as 'ontological dependent' like *AMMA* is stated as an ontological argument--

> Materialism, I think, must hold that a physical description of the world is a *complete* description of it, that any mental facts are 'ontologically dependent' on physical facts in the straightforward sense of following from them by necessity. No identity theorist seems

> to me to have made a convincing argument against the intuitive view that this is not the case .... (Kripke 1980 : 155)

Now we seem back again at Kirk's Entailment Thesis. The TE from God's creation of the world having to do more work seems unnecessarily metaphysical, although, of course, it brings in an additional teleological aspect as the TE reminds (teleological) proof for God's existence from design in nature, which however could be considered even more metaphysical and it remains undiscussed.

Dennett confesses himself to be 'a sort of "telefunctionalist"' though explained with reference to evolutionary natural selection instead of *Divine Creation* (TE) and proofs for God's existence. (note 16)

3.5 Phantom Pain (ST1)

In Section 3.2 together with non-TE, nonmodal alternates of *Qualia* TE we have already discussed Kripke's non-TE, non-modal analogue of phantom pain as to prove mental states independent from brain states.

Dennett 1991 traces the example back to Descartes's discussion of phantom limbs of amputees and seems to agree on Descartes analogy of the bell-pull while admitting existence of the phenomenon but as relatively weak ('thin hallucinations') and explains it as false information from the brain–

> Phantom-limb hallucinations, while remarkably vivid, are—by our terminology—relatively weak; they consist of *un*organized pains and itches, all in our sensory modality. Amputees don't see or hear or (so far as I know) smell their phantom feet. So something like Descartes's account *could* be the right way to explain phantom limbs, setting aside for the time being the notorious mysteries about how the physical brain could interact with the nonphysical conscious mind. But we can see that even the purely mechanical part of Descartes's story must be wrong as an account of relatively strong hallucinations; there is no way the brain as illusionist could store and manipulate enough false information to fool an inquiring mind. (Dennett 1991 : 9)

Although Dennett does not know how to explain it, he can't deny the natural occurrence of the phenomenon nor possible truth of Descartes's explanation, so, phantom pain seems indeed a successful example of a non-TE, nonmodal natural phenomenon of conscious of phenomenal feel that is acceptable to both proponents and opponents of mentalism or any sort of dualism.

So, we can apply ST1* and substitute modal TE as *Zombies* and *Qualia* by a nonsensory conscious example as pain, particularly phantom pain as when one won't accept natural or possible existence of *Qualia* or *Zombies*. Again, like the example of color blindness it is a quite known phenomenon that does not need any advanced neuroscientific explanation. But again, it is an unusual example from medicine that can't escape possibly disputable second nature of western science to explain the common from the uncommon, health from disease etc. which could be considered part of bias from negative thinking.

Chalmers lists pain in his catalogue of conscious experiences as a paradigm example, adds that 'pains form a very distinctive class of qualitative experiences' that 'can seem even more subjective than most sensory experiences' and points out 'a great variety of pain experiences from shooting pains and fierce burns through sharp pricks to dull aches.' (Chalmers 1996 : 9).

We expect that inclusion of more scientific research into not just variety of color sensations and pains, but particularly of many more categories of sense impressions (as auditory, tactile, olfactory, taste, hot/cold experiences next to visual senses) and conscious experiences (like bodily sensations, mental imagery, conscious thought, emotions, sense of self) may surely advance philosophical investigations in this field.

To Chalmers's list we want to add intuition since it is often mentioned as cause, source, or psychological faculty of TE as may be clear from alternate, but usually deprecatory considered, names as 'intuition pump,' while, conversely, established theories as Identity Theory in philosophy of mind are attacked on grounds of being counter intuitive.

Notes

*Terminological abbreviations from our TE theory (see ...e.g. Sup. D Glossary) used in this paper TE thought experiment(s) - passim

ST1 Substitution Thesis (ST) No. 1/Transformation Rule (TR) No. 1
holding that a TE can be substituted by an experiment or experience as indicated by thought experimenter in TE text or elsewhere or as indicated in secondary literature. See Sections 3.2, 3.5

ST2 Substitution Thesis (ST) No. 2/Transformation Rule (TR) No. 2
holding that a (modal) TE can be substituted by a nonmodal example, alternate or analogue as in accordance with intention of thought experimenter, purport of TE text or possibly indicated elsewhere or in secondary literature.

See Section 3.4

[TE] RS TE in restricted sense - see Section 3.3, one but last paragraph [TE] BS TE in broad sense – see Section 3.3, one but last paragraph [TE]EX TE in extended sense – see Section 3.3, one but last paragraph RTE religious thought experiment – see note 15

note 0- motto derived from lyrics to Fela Kuti and Africa 70 (1977). *Zombie* as derived from e.g. https://songmeanings.com/songs/view/3530822107858712085/ (retrieved June 24, 2022)

e.g. performed by *Seun Kuti and The Egypt 80* in LA 2011 http://www.youtube.com/watch?

v=X8SHLF3rKZ0&feature=related (retrieved June 24, 2022).

From *Wikipedia* on Fela Kuti (1938-1997 Nigerian musician and composer)

In 1977, Kuti and Africa 70 released the album *Zombie*, which heavily criticized Nigerian soldiers, and used the zombie metaphor to describe the Nigerian military's methods. The album was a massive success and infuriated the government, who raided the Kalakuta Republic [communal compound that housed Kuti's family, band members, and recording studio] with 1,000 soldiers.... (http://en.wikipedia.org/wiki/Fela_Kuti (retrieved June 24, 2022)

note 1- The concept of zombie may seem to have political connotations.

Michael Jackson's best-selling 1982 album *Thriller* and single 'Thriller' seem to allude to Caucasians as zombies, and later track 'DS', from album *HIStory*, to a Caucasian police chief as a 'cold man'.

note 2- However, Sartre did not accept the Nobel Award--

> ... on 23 October, *Le Figaro* published a statement by Sartre explaining his refusal. He said he did not wish to be "transformed" by such an award, and did not want to take sides in an East vs. West cultural struggle ....(*Wikipedia* retrieved June 24, 2022)

From Sartre's letter to Nobel Academy--

> *Mes raisons objectives sont les suivantes:* Le seul combat actuellement possible sur le front de la culture est celui pour la coexistence pacifique des deux cultures, celles de l'est et celle de l'ouest. [...] Mes sympathies vont indéniablement au socialisme et à ce qu'on appelle le bloc de l'est, mais je suis né et j'ai été élevé dans une famille bourgeoise. [...] J'espère cependant bien entendu que "le meilleur gagne", c'est à dire le socialisme. (http://vietsciences.free.fr/nobel/litterature/sartre.htm e.g. retrieved June 24, 2022)

note 3- Tamar Gendler has published on related psychological topics as alief/belief.

note 4- In email comments to this paper Robert Kirk emphasized-

> Although some materialists think materialism is necessarily true, most do not. It is perfectly consistent to maintain that it is only contingent that our world is exclusively

material (physical). (For discussion, see my book *The Conceptual Link from Physical to Mental* (2013).) Contrast something different: *materialists must maintain that:*

(A) IF materialism is true, then if P is the totality of purely physical truths about the world and Q is some actual truth about conscious experience, THEN it is absolutely necessary that if P, then Q.
Kirk and Chalmers's zombie arguments are intended to show that (A) is false. (Since I have long been a materialist, I argue in my Zombies and Consciousness (2005) and my (2013) that (A) is true.)

In our first interpretation and formalization we have chosen the safest interpretation and analyzed and symbolized *Zombie* TE as necessity refuters, one of the main categories of modal TE discussed in Sorensen 1992a and Cohnitz 2003. After receipt of comments by Robert Kirk we have italicized 'seem' in this place and more places in this paper.

note 5- We quote Chalmers's introduction of his *Zombie* TE in Section 3. In a note Chalmers refers to both Robert Kirk 1974 and Australian realist Keith Campbell 1970--

> Kirk (1974) provides a vivid description of a zombie, and even outlines a situation that might lead us to believe that someone in the actual world had turned into a zombie, by specifying appropriate intermediate cases. Campbell (1970) similarly discusses an 'imitation man' that is physically identical to a normal person, but that lacks experience entirely. (Chalmers 1996 : 369)

Kirk's description of a zombie is not very vivid in possible sense that he refers to popular zombies or describes them. Kirk adds in a note to his statement

> Such a race of Zombies would indeed have been 'nothing but physical objects.'

a reference to British biologist Thomas H. Huxley for the idea of *Zombies*

> G.F. Stout, in *Mind and Matter* (Cambridge, 1931), pp. 138-139, describes this possibility as an objection to materialism, though in connexion with the causation of events. The idea of Zombies is of course an old one. See, e.g. T.H. Huxley, 'On the Hypothesis that Animals are Automata, and its history', in his *Methods and Results* (London, 1894)

Only in Kirk's 2011-2019 *SEP* definition there is a negative reference to zombies in films and witchcraft and Chalmers distinguishes both Haitian and Hollywood zombies from *Philosophical Zombies* on his web site *Zombies on the Web* (http://consc.net/zombies.html retrieved June 24, 2022) but without much concern about morals (although he mentions Haitian zombies lack free will and Hollywood zombies are 'typically rather mean, and fond of human flesh'). As according to philosophical definitions of Kirk and Chalmers *P Zeds* are morally neutral as they have no particular moral properties, possibly because they are lacking consciousness and free will, nor seem their *Zombies* be driven by powers beyond their control.

The latter feature, however, is in Kirk's *Zulliver* TE in same 1974 text. This TE is rather vividly described as by a story on the Brain Team, but we doubt if Chalmers is confusing Kirk's *Zombie Replica* with Kirk's *Zulliver*, the latter reminding of Descartes *Evil Demon* TE and nowadays *Brain-In- a-Vat* TE introduced by Hilary Putnam in the first chapter of 1982 *Reason, Truth, and History* who attributes it to some arguments in Wittgenstein 1953 *Philosophical Investigations*.

Wikipedia traces BIV back to Plato's Cave, Hindu Maya Illusion and Zhuangzi's Butterfly TE.

We won't trace the references to zombies in philosophical literature further down as we have already traced the concept of zombie to (e.g.) voodoo. We only want to say that nonmoral names as *(Human) Replica* or *Imitation Man* suit the *P Zed* definition much better than *Zombie*.

note 6- Zhuangzi dreaming he's a butterfly 昔者莊周夢為胡蝶, 栩栩然胡蝶也, 自喻　　適適志志與與！！

不知周也。俄然覺, 則蘧蘧然周也。不知周之夢為胡蝶與, 胡蝶之夢為周與？周與胡蝶, 則必有分矣。此之謂物化。

(http://ctext.org/zhuangzi/adjustment-of-controversies #14 retrieved June 24, 2022)

Once Zhuangzi dreamt he was a butterfly, a butterfly flitting and fluttering around, happy with himself and doing as he pleased. He didn't know he was Zhuangzi. Suddenly he woke up and there he was, solid and unmistakable Zhuangzi. But he didn't know if he was Zhuangzi who had dreamt he was a butterfly, or a butterfly dreaming he was Zhuangzi. Between Zhuangzi and a butterfly there must be some distinction! This is called the Transformation of Things. (trans. Burton Watson 1968:49 e.g. after *Wikipedia* Zhuangzi entry)

note 7- -Papineau 2008, 2 Kripke's Argument—italics and bracketed reference added

> As I said, I want to use Kripke's anti-physicalist argument from the end of Naming and Necessity to show that we are all in the grip of a dualist intuition. Let me begin by reminding you how this argument goes.
>
> After some preliminaries, Kripke turns to type-type identities like pain = C-fibres firing (p 148) [Kripke 1980 : 148]. If such an identity obtains, then it obtains necessarily. Even so, claims like pain = C-fibres firing certainly seem contingent. There certainly seem to be metaphysically possible worlds in which C-fibres fire, yet there are no pains. (*'Zombie worlds' as we would call them now, though this is not Kripke's terminology*.)

note 8-- Davidson developed a TE himself in 1987 called *Swampman*, after comic book character Swamp Thing, a so-called humanoid/ plantcreature, invented by writer Len Wein and artist Berni Wrightson.

note 9- Quine, Block 1994: Section 3 which is referred to on Ned Block's homepage of online papers at inverted spectrum. Same development as from extreme, hardwired to moderate, softwired functionalism, physicalism, materialism etc. we can see in oeuvres of e.g. Putnam and Dennett. Block's

> TE, such as *Inverted Earth*, has raised discussions on representationalism or intentionalism according to which theory qualia are intentional contents or representational properties.

note 10- The example of ishihara color tests is ours but we guess Quine and Block could accept it as test that proves natural de facto existence of (e.g. red-green) color blindness. Speculations on future of neuroscience may not be that convincing as Quine contends that with any new discovery, breakthrough in the field of neuroscience we may still not know 'how we can link any kind of physical discovery with' e.g. sensations of green and red. To *Color Scientist Mary* TE of Australian philosopher Frank Jackson Quine replies that Mary has apparently 'acquired capacity to a new neural connection.'

note 11- In email comments to this paper Robert Kirk countered he cannot agree on it--

> Pretty well all materialists today agree we have conscious experiences (I - a materialist - certainly do). We take our main problem to be to explain how a merely physical system can be a conscious subject.

In Section 18.2 of ... we conclude to additional research into various shades of materialism, dualism etc. in nowadays philosophy of mind e.g. Kirk 2013 *The Conceptual Link from Physical to Mental,* as it seems hard to us that materialists can acknowledge consciousness and the mental and still go on considering themselves materialists.

note 12- In email conversation David Chalmers refers to his 2010 'The Two-dimensional Argument against Materialism' for a formalization update of his 1996 *AMMA* under the heading of *Conceivability Argument*.

> To bridge the epistemic and modal domains, the framework of two-dimensional semantics can play a central role. I have used this framework in earlier work (Chalmers 1996) to mount an argument against materialism. Here, I want to revisit the argument, laying it out in a more explicit and careful form In what follows I will concentrate mostly on the conceivability argument. I think that very similar considerations apply to the other arguments mentioned above, however. In the

final section of the paper, I show how this analysis might yield a unified treatment of a number of anti-materialist arguments.

1 The Conceivability Argument-

The most straightforward form of the conceivability argument against materialism runs as follows.

1. P&~Q is conceivable
2. If P&~Q is conceivable, P&~Q is metaphysically possible
3. If P&~Q is metaphysically possible, materialism is false.
4. Materialism is false.

Where P is 'the conjunction of all microphysical truths about the universe, specifying the fundamental features of every fundamental microphysical entity in the language of microphysics'; Q is 'an arbitrary phenomenal truth: perhaps the truth that someone is phenomenally conscious, or perhaps the truth that a certain individual (that is, an individual satisfying a certain description) instantiates a certain phenomenal property'; and P&-Q is 'the statement that everything is microphysically as in our world, but no-one is phenomenally conscious, ' so it says that 'the world is a zombie world', or 'the statement that everything is microphysically as in our world, but that it is not the case that the individual in question instantiates the relevant phenomenal property' in which case 'it will suffice ... that the world is a *zombie world*, or simply that the individual in question is a zombie in a physically identical world
....'

Inference from (3) to (4) only holds on a strong thesis of necessary materialism.

Our modal formula applying possible worlds semantics expresses directly what Chalmers adds in comments to his formalization--

The third premise is relatively uncontroversial. It is widely accepted that materialism has modal commitments. Some philosophers question whether materialism is equivalent to a modal thesis, but almost all accept that materialism at least entails a modal thesis. Here one can invoke Kripke's metaphor: if it is possible that there is a world physically identical to our world but phenomenally different, then after God fixed the physical facts about our world, he had to do more work to fix the phenomenal facts.

note 13- TE from natural sciences can often be completed as an argument by revealing epistemological principles. Analogously, Chalmers proposes some principles of coherence to support his theory of consciousness.

note 14- In Section 11 towards the end of the 2010 paper Chalmers discusses four 'other anti-materialist arguments', Kripke's *Pain ≠ C fibers Firing* at the end, proposing formalizations similar to his *AMMA* alternate of the *Conceivability Argument*.

... Kripke's modal argument
The anti-materialist argument that is most closely related to the two-dimensional argument is Kripke's modal argument against the identity theory. Kripke's argument can put as follows. Let 'p' stand for pain and 'c' be a term for C fiber firing. Then

1. 'p=c' is apparently contingent.
2. If 'p=c' is apparently contingent, then there is a world with a being in an epistemic situation that is qualitatively identical to mine in which a corresponding statement is false.
3. If there is a world with a being in an epistemic situation that is qualitatively identical to mine in which a statement corresponding to 'p=c' is false, then there is a world at which 'p=c' is false.
4. If there is a world at which 'p=c' is false, then 'p=c' is false
5. 'p=c' is false.

Inference from (4) to (5) is only valid if it is about necessary equivalence of p and c (p≡c) saying Aw |= p=c , or □ p=c (when □ is box operator for necessary/ily). It again demonstrates the straw man antifallacy.

note 15- What we call *Divine Creation* TE is in the last pages of 1980 *Naming and Necessity* and referred in Chalmers 1996.

The *Divine Creation* TE has two parts, first, example of heat and molecular motion, second,

example of pain and C fibers firing. The latter part is quoted in the text, here we quote the first part and show how it alludes to *Genesis*--

> Perhaps the same point can be made vivid without such specific reference to the technical apparatus in these lectures. Suppose we imagine God creating the world; what does he need to do to make the identity of heat and molecular motion obtain? Here it would seem that all He needs to do is to create the heat, that is the molecular motion itself. If the air molecules on this earth are sufficiently agitated, if there is a burning fire, then the earth will be hot even if there are no observers to see it. God created light (and thus created streams of photons, according to present scientific doctrine) before He created human and animal observers; and the same presumably holds for heat. How then does it appear to us that the identity of molecular motion with heat is a substantive scientific fact, that the mere creation of molecular motion still leaves God with the additional task of making molecular motion into heat? This feeling is indeed illusory, but what *is* a substantive task for the Deity is the task of making molecular motion felt as heat. To do this he must create some sentient beings to insure that the molecular motion produces the sensation *S* in them. Only after he has done this will there be beings who can learn that the sentence 'Heat is the motion of molecules' expresses an *a posteriori* truth in precisely the same way that we do. (Kripke 1980: 153—underline added)

Kripke's idea of *God must do something in addition to* can be understood theologically from *Genesis* 1 in Old Testament that God first created heat and molecular motion (on the first and possibly fourth day, Gen 1, 3, 'Then God said: Let there be light, and there was light', and 1, 14 e.g.

'Then God said: Let there be lights in the dome of the sky, to separate day from night ...' telling about creation of sun and moon) and only after man (on the sixth day, Gen 1, 24, 'Then God said: Let the earth bring forth every kind of living creature ...' and 26, 'Then God said: Let us make human beings in our image, after our likeness'). On the sixth day God does not only create man but as Kripke says (also) some sentient beings.

God's subsequent additional task of having to do more work, having to do something in addition, creating first the physical world (as light) and only after man (and animals etc.) literally refers to the chronology of the seven days of Divine Creation in *Genesis* 1. Because of very likely allusions to *Genesis*, most obviously 'God created light' and possibly 'he must create some sentient beings,' that is a creation in separate consequent phases, it is in fact a TE referring to religious discourse, what we call RTE, religious thought experiment.

(Yiftach Fehige calls same type of TE 'TE of revealed theology' e.g. Fehige 2009.) In our account a RTE is verified supernaturally (as after Józef Bochenski's 1965 supernatural verification vs. scientific natural verification) by an intervention of the Deity or supernatural agent as a Angel, Saint etc. In *Genesis* it is a very strong sort of supernatural verification by the Divinity without any intermediary agents, which is acknowledged by at least three world religions, Judaism, Christianity and Islam as similar passages occur in Torah, Bible and Quran.

According to us creationism and evolutionary theory do not exclude each other but, in fact, complement each other to some extent as both assume a development in subsequent phases. The crucial allusion to the Bible as different from reference to evolutionary theory is Kripke's 'God created light.' However, the (R)TE is not introduced by a RTE indicator (as 'Ergo, domine, qui das fidei intellectum, da mihi, ut quantum scis expedire intelligam, quia es sicut credimus, et hoc es quod credimus' in Anselm's Ontological Argument, *Proslogion* II) but by a complex higher-order TE indicator phrase as 'Suppose we imagine God creating the world,' which religious believers could consider an insult (faculty of imagination instead of belief in truth) and which would also not fully suit secularists (who deny both God and creationism). Kripke's reference to divine creation instead of evolutionism can be explained from desire for a vivid example without

any specific technical apparatus as expressed in introductory line of TE and we assume scientific theorizing of evolutionism could also diminish vividness of the example.

note 16- E.g. Dennett 1991 : 460

> Am I, then, a functionalist? Yes and no. ... I am a sort of "teleofunctionalist," of course, perhaps the original teleofunctionalist (in *Content and Consciousness*), but as I have all along made clear, and emphasize here in the discussion of evolution, and of qualia, I don't make the mistake of trying to define all salient mental differences in terms of biological *functions*. That would be to misread Darwin badly.

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ABSTRACT

The Aging variation1 poses an interesting challenge for the task of automatic face recognition. Most face recognition studies that have addressed this problem focused on age estimation or aging simulation. Designing an appropriate feature representation and an effective matching framework for age invariant face recognition remains an open problem.

In this research study, a novel age-invariant face recognition framework that is built based on two face biometric traits is proposed. The first trait is a set of anthropometric measurements acquired from the lip-nose complex. Lip-nose complex measurements have been known in several physiological studies to be discriminative among different ethnicities and among different genders within the same ethnicity.

Keywords: anthropometric measurements, craniofacial growth, FG-NET, lip-nose complex, MORPH.

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Amal S. O. Ali[α], Sarat C. Dass[σ], Aamir S. Malik[ρ], Azrina Aziz[CO] & Vijanth S. Asirvadam[¥]

ABSTRACT

The Aging variation[1] poses an interesting challenge for the task of automatic face recognition. Most face recognition studies that have addressed this problem focused on age estimation or aging simulation. Designing an appropriate feature representation and an effective matching framework for age invariant face recognition remains an open problem.

In this research study, a novel age-invariant face recognition framework that is built based on two face biometric traits is proposed. The first trait is a set of anthropometric measurements acquired from the lip-nose complex.

Lip-nose complex measurements have been known in several physiological studies to be discriminative among different ethnicities and among different genders within the same ethnicity.

The second trait is based on extracting features of the periocular region using two robust descriptors, namely local binary patterns rotation invariant descriptor (LBPV) and GIST descriptors. The periocular area is considered as the most discriminative face area and is known to preserve its stability with aging. The two biometric face traits were combined at the feature level after being normalized separately using the Z-score rule and projected into a principle component analysis (PCA) subspace.

Eight algorithms were derived as part of the proposed framework for performing age invariant face verification and identification.

Furthermore, the proposed framework was used to produce demographic information, namely: age group, gender, and ethnicity from aging faces.

Experimental results show that the proposed framework reported an EER of 6.51% over the MORPH album 2 database (compared to 16.49% reported by Mahalingam et al), which is the largest public face aging database and 7.22% over the FG-NET database (compared to 24.08% reported by Mahalingam et al).

The proposed framework achieved an identification accuracy of more than 95% (compared to 66.40% reported by Park et al) over the MORPH album 2 database, which is the largest public face aging database and 93% over the FG-NET database (compared to 38.10% reported by Geng et al).

[1]This paragraph of the first footnote will contain the date on which you submitted your paper for review. It will also contain support information, including sponsor and financial support acknowledgment. For example, "This work was supported in part by the U.S. Department of Commerce under Grant BS123456".

The next few paragraphs should contain the authors' current affiliations, including current address and e-mail. For example, F. A. Author is with the National Institute of Standards and Technology, Boulder, CO 80305 USA (e-mail: author@ boulder.nist.gov).

S. B. Author, Jr., was with Rice University, Houston, TX 77005 USA. He is now with the Department of Physics, Colorado State University, Fort Collins, CO 80523 USA (e-mail: author@lamar.colostate.edu).

T. C. Author is with the Electrical Engineering Department, University of Colorado, Boulder, CO 80309 USA, on leave from the National Research Institute for Metals, Tsukuba, Japan (e-mail: author@nrim.go.jp).

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Index Terms: anthropometric measurements, craniofacial growth, FG-NET, lip-nose complex, MORPH.

I. INTRODUCTION

Human perception studies reveal that attributes derived from one's appearance, such as one's emotional state, attractiveness, perceived age, etc. tends to significantly influence interpersonal behavior [1].

Hence, for many decades, human faces have been closely studied in computer vision and psychophysics with the objective of characterizing the many factors that induce appearance variations and subsequently unearthing information pertaining to an individual from his/her varying facial appearances. Facial aging is known as a complex process that varies with both the shape and the texture of the facial area. Shape variations include craniofacial, whereas texture variations include skin coloration, lines and/or wrinkles. Shape and texture are both considered as the common facial aging patterns. Since the aging process occurs throughout different ages, it can be classified into the above-mentioned aging patterns. As a result, an age-invariant facial recognition method should account for these aging patterns [2].

The applications of age-invariant facial recognition are lost children investigations, human-computer interaction, and passport photo verification. These applications possess two basic attributes: 1) significant age difference between probe and gallery photos (photos acquired during enrollment and also authentication phases), and 2) failure to acquire the person's facial photo in order to update the template [3].

Furthermore, real-world conditions continue to be challenging, mainly due to the great amount of changes in the process of acquiring faces. For example, criminal offense inspections and society safety organizations must frequently fit a probe photo with registered photos in a database, which may depict significant differences in facial characteristics due to the presence of different age groups. The effects of aging on the performance of facial recognition systems have not been thoroughly studied. Thus, there is a need to develop facial recognition algorithms, which are generally invariant towards aging [4].

Forensic scientists proved that human face aging strongly depends on ethnicity and gender [5].

Although human faces have the same general manner in aging, each ethnic and gender group has distinct characteristics. Therefore, it is insufficient to assume that similar faces age in similar ways for each and every individual.

Several physiological studies [6] [7] [8] have proved that the arithmetic range of the lip-nose complex measurements is different for different ethnicities, and thus can be adopted for ethnicity classification. The same studies have also proven that such measurements have a different arithmetic range of different genders within the same ethnicity. Moreover, some of the studies [7] [8] concluded that there is a possibility that the growth rate for such measurements is unique for each individual. Inspired by the aforementioned physiological facts, the lip-nose complex measurements were used as the first facial trait in the proposed system.

The Periocular region has the densest and the most complex biomedical features on the human face, e.g. contour, eyelids, eyeball, eyebrow, etc., which could all vary in shape, size and color.

Biologically and genetically speaking, more complex structure means more "coding processing" occurs with fetal development, and therefore more proteins and genes are involved in the determination of appearance. Moreover, the Periocular region goes through little changes over time because the shape and location of the eyes remain largely unchanged [9]. As it is stable across ages and has strong discriminative power, using the Periocular region for age invariant face recognition is rational and wise. In the proposed model, texture features extracted from the Periocular region are used as the second facial biometric trait.

The remainder of this paper is organized as follows: Section 2 surveys previous research

efforts related to age-invariant face recognition and the Morphometry of the Lip-Nose Complex. The proposed system is discussed in details in Section 3. Section 4 is dedicated to the experiments and results. The conclusion and future work are presented in Section 5.

II. RELATED WORK

When Face recognition across age has not been explored much in the past in spite of its importance in real-world applications. A detailed survey of the effects of aging on face verification tasks can be found in [1, 2]. Earlier approaches [3, 4] perform recognition by transforming one image to have the same age as the other, or by transforming both the images to reduce the aging effects. Table I summarizes a number of age-invariant face recognition studies.

Chellapa et al. [3, 5] proposed a craniofacial growth model that characterized the shape variations in human faces across age variations.

The authors observed that the growth parameter k for different face features across age can be adapted in the model to characterize the face growth. Ramanthan and Chellapa [4] also proposed a two-step approach for modeling aging in adults, which comprised of a shape and texture variation model. The formulation of shape variations is performed by constructing physical models which characterizes the functionalities of the face muscles.

Table 1: Published Age-Invariant Face Recognition Studies

Reference	Approach /Method	Description of the Proposed System
Ramanathan et al.[5]	Generative/ Mathematical Modelling.	Shape (Craniofacial) growth modelling up to age 18.
Geng et al. [7]	Non-generative/ Subspace method.	Learn aging pattern on concatenated PCA coefficients of shape and texture across a series of ages.
Park et al.[6]	Generative/ 3D modelling.	Learn aging pattern based on PCA coefficients in separate 3D shape and texture spaces from the given 2D database.
Ling et al.[8], [9]	Non-generative/ Feature-based method.	GOP+SVM
Mahalingam et al. [11]	Non-generative/Featu re-based method.	HLBP + AdaBoost classifier.

Park et al. [6] designed an aging simulation technique that learns the aging patterns of shape and the texture based on PCA coefficients. A 3D morphable model is used to model the aging variations from a set of 2D face images. To model the aging variations from two-dimensional images, a morphable model that is three dimensional is employed. The prototype technique is applied to the 3D face data. Although the prototype technique is able to extract average patterns, many details crucial for age perception such as wrinkles and pigments are neglected. Park et al. fitted their 3D morphable model to a set of face images by fitting an active appearance model (AAM) and extracting a 3D model from the AAM.

Aging is performed by calculating a set of weights between an input face and exemplar faces in the

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same age group. These weights are then used to build an aged face as the weighted sum of the resulting faces at the anticipated age. After the appearance is predicted, they used commercial face recognition software to evaluate the recognition performance and observed that aging prediction model improves the performance of face recognition algorithms. The shortcomings in three-dimensional face recognition include the significant size of the three-dimensional models which usually demands high computation cost in matching, as well as the expensive price of three-dimensional imaging sensors. Building a model for craniofacial growth and another one for modelling texture variations with the possibility of the need to transform the 2D models to the 3D space increases the computational complexity and consequently the total processing time.

Geng et al. [7] learned a subspace of aging pattern based on the assumption that similar faces age in similar ways. Their face representation is composed of face texture and the 2D shape represented by the coordinates of the feature points as in the active appearance models.

The aging pattern is developed which is defined as the sequence of face images sorted in time order, by constructing a subspace. The aging pattern of the query image is determined by projecting it in the subspace. The position of the face image in aging pattern which is sorted in the time order indicates the age. The above method requires prior information like the actual age of the individual, the face feature points to model the aging pattern in the face images.

The shortcomings of the above mentioned approaches are that the information about the age of the probe image is required in order to perform the age transformation. This information is usually not available in real-world applications.

Also, the accuracy in age transformation relies on the accuracy of the aging model. Such inaccuracies may result in inappropriate age transformations causing instabilities to these approaches. Moreover, Construction of face models is difficult and sometimes they do not represent the aging process very well, especially when the training sample size is limited. Further, the face aging process is very complex and, consequently, in order to construct the aging model, strong parametric assumptions are needed, which are often unrealistic in real-world face recognition scenarios.

Discriminative approaches proposed in the past [8, 9] follow a non-generative approach to perform face recognition across age progression.

Ramanthan and Chellappa [5] proposed a discriminative approach for face verification across age progression. The authors adapted the probabilistic eigenspace framework and a Bayesian model to learn the differences between intra-personal pairs and extra-personal pairs. To avoid the challenges caused by illumination variations, they use the half face that has better illumination (termed as PointFive faces) and use the symmetry property of the face to construct a face image.

Ling et al. [9] also used a non-generative discriminative approach for face verification of age separated images. They propose a face representation called gradient orientation pyramid, in which a Gaussian pyramid is generated for each face image and the gradient orientation is computed for each pixel at all levels of the pyramid. SVM is then used to classify the image pairs as intra-personal or extra-personal.

Bereta et al. [10] compared seven local descriptors commonly used in face recognition, e.g. LBP and WLD, and classify images by calculating a distance between feature vectors containing local texture. The Gabor coded MBLBP feature combined with the Euclidean distance brings the best recognition accuracy. Bereta et al. conducted experiments using MB-LBP to check the robustness of the features against ageing using FGNET database and with MB-LBP and Euclidean distance as similarity metric obtained 70% recognition accuracy. They also evaluated MB-LBP method along with Gabor features using Euclidean and cosine distances as similarity measurements and achieved 76% and 75% recognition rates respectively.

Mahalingam et al. [11] proposed a hierarchical local binary pattern (HLBP) feature descriptor used for face representation across age.

The representation by HLBP across minimal age, illumination, and expression variations combined with its hierarchical computation provides a discriminative representation of the face image.

The proposed face descriptor is combined with an AdaBoost classification framework to model the face verification task as a two-class problem. HLBP for each image is constructed by computing the uniform LBP at every level of the image pyramid and concatenating them together to form the HLBP descriptor. A dense sampling using LBP local descriptors allows the extraction of discriminatory information such as the distribution of the edge direction in the face image which is an age invariant feature.

A non-generative discriminative approach for the task of face recognition of age separated images is proposed in this research study. The framework proposed in this research study differs from the above mentioned non-generative approaches in the face representation and the classification framework. A discriminative feature based face representation coupled with a classification framework is proposed. The proposed framework has been applied to two face aging databases, which include both internal and external variations in the face images.

III. THE PROPOSED SYSTEM

A block diagram of the proposed age invariant face recognition framework is illustrated in Fig. 1.

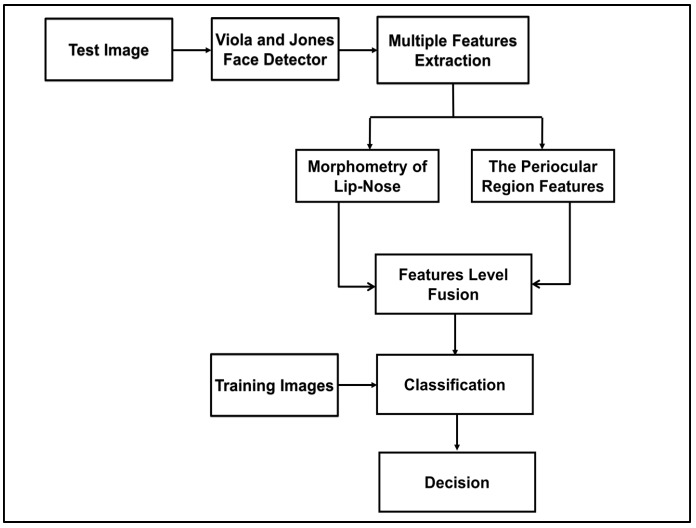


Fig. 1: Magnetization A Block Diagram of the Proposed Age Invariant Face Recognition Framework

Assume a framework where the test image may be derived from an image or a sequence of images containing human faces. The face area is detected using the real time implementation of the Viola and Jones face detector [109]. Such a detector is effective for real time applications. The training patterns of the Viola and Jones face and eye localizer are from a set of images with predefined coordinates (i.e., annotation). Based on these coordinates, the face feature vector of size 12x12 is extracted from the original face image using the landmark template (LMT) features [110]. The LMT features consist of multi-scale Gabor features (at 6 scales and 12 orientations) applied to 13 landmark facial points that are locally searched within the bounding box starting from the tracked state [111].

To detect a face in an input image, each of the possible sub-images is processed to see if it represents a face. The input images are preprocessed before inputting to the face detector.

A confidence score is produced by the face detector, indicating the system's confidence on this detection result. If the score is below some threshold, then no face is detected.

At the preprocessing stage, all face images in FG-NET and MORPH databases were properly

normalized and pre-processed. The pre-processing stage comprised of converting the color input images into 8-bit greyscale images and normalizing the face images photometrically by eliminating their means and scaling their pixels to unit variance [40]. Finally, pose correction was performed to non-frontal face images using the same method adopted by Kambhamettu et al. [41], which uses Active Appearance Model (AAM) technique as proposed by Cootes et al. [42]. A number of preprocessed sample images from the FGNET and MORPH databases are illustrated in Fig. 2 where the images in the top row are the original images and the images in the bottom row are the preprocessed images.

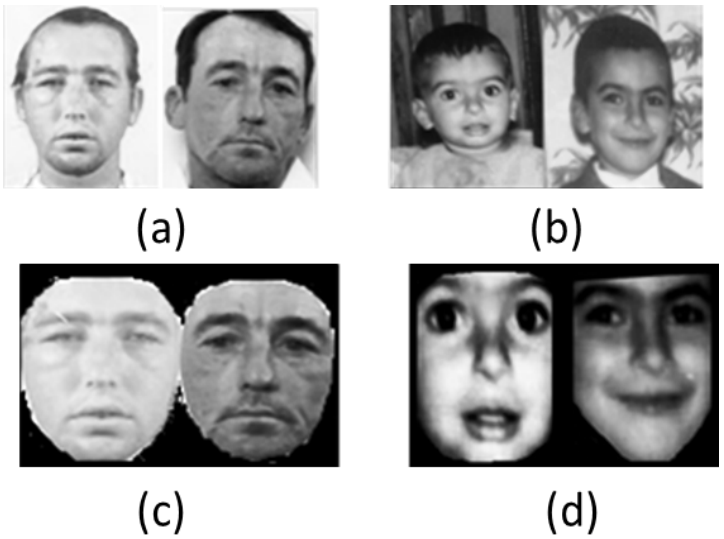


Fig. 2: Images Taken from the FG-NET and MORPH Databases in Panels (a) and (b) respectively Original Images are in the top row and Preprocessed Images are in the bottom row

In the proposed system, only 11 facial landmarks were considered and automatically localized using a facial landmark detector introduced recently by Zhou et al. [34], known as Exemplar-based Graph Matching (EGM). For the training stage, localizing the related landmarks was performed manually only for the MORPH database since the FGNET database was provided with annotations for a set of 68 landmarks, which included the 11 landmarks considered in the proposed system. For the MORPH database, about 1132 images were manually annotated and used for training the system. Fig. 3 illustrates examples of the automatic landmark localization using the EGM detector on sample image from the MORPH database.

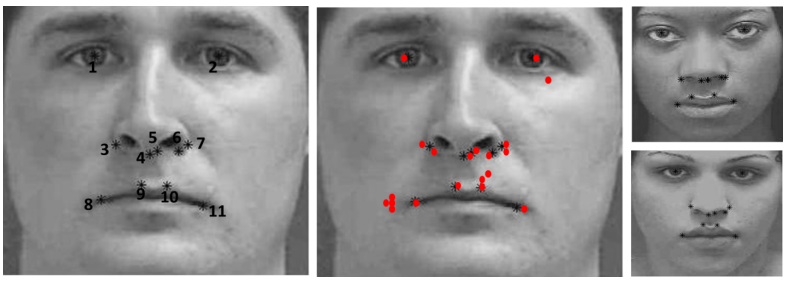


Fig. 3: Example of Response Map and Candidate Generations for a Face Image Collected from the MORPH Database. (a) A testing image labeled with 11 landmarks. (b) A 1/7 portion of all the candidates. The Black marks indicate the candidates that are transformed from exemplars, while red ones are the peaks of the response maps. (c) The top two exemplars found by the RANSAC step

Once the set of face landmarks is localized, a multilevel feature extraction is performed such that two set of face features are extracted from the test image and later fused. The first set of face features is a set of anthropometric measurements known as the lip-nose complex measurements.

Since angular measurements and tangential measurements on faces cannot be estimated accurately using photogrammetry of face images, a set of linear projective measurements acquired from the nose-lip complex are taken into account. Thus, five lip-nose complex measurements are considered in the proposed framework as follows:

1. Vertical length of the lip: bottom of the columella up to the highest point of the Cupid's bow. This specific parameter was basically identified alongside the bottom of columella up to the tubercle.
2. Cupid's bow width (philtrum peak to peak): absolute breadth for oral cavity (commissural to commissural length).
3. Columella width: the portion between the nostrils.
4. Nose area width: Distance from one alar to another.
5. Total width of the mouth: Distance from one oral commissure to another.

Fig. 4 depicts the lip-nose complex measurements considered in the proposed framework.

For face recognition problems, the face measurements extracted from face images lose their absolute scales because face images can be easily enlarged. Since the absolute scale information is lost in the face images, a relative scale has to be adopted to normalize the face measurements [5]. Moreover, ratios of distance, area, and angles are usually measured to compensate for the varying size of images [14].

The distance between the centers of two eyes is usually not affected by expressions and thus is relatively stable. Hence, this distance is used in this work as the reference scale. After calculating the set of lip-nose complex measurements, they are scaled through dividing each of the measurements by the distance between the centers of two eyes. Fig. 5 illustrates the notations related to the coordinates of the face landmarks considered in the proposed framework.

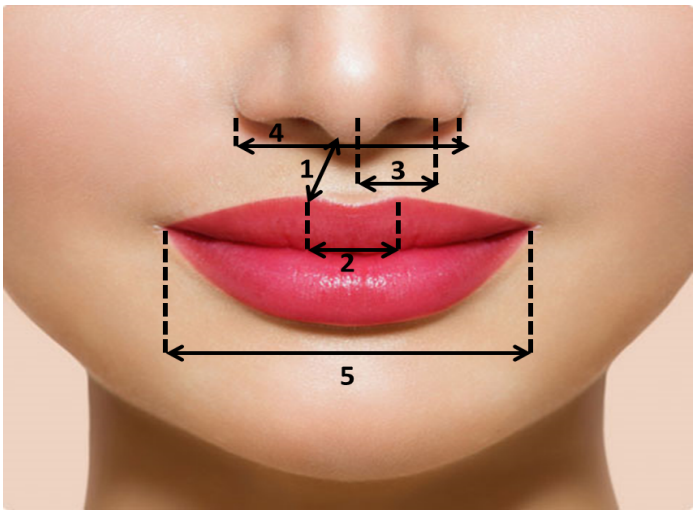


Fig. 4: The Lip-Nose Complex Measurements used in the Proposed Framework

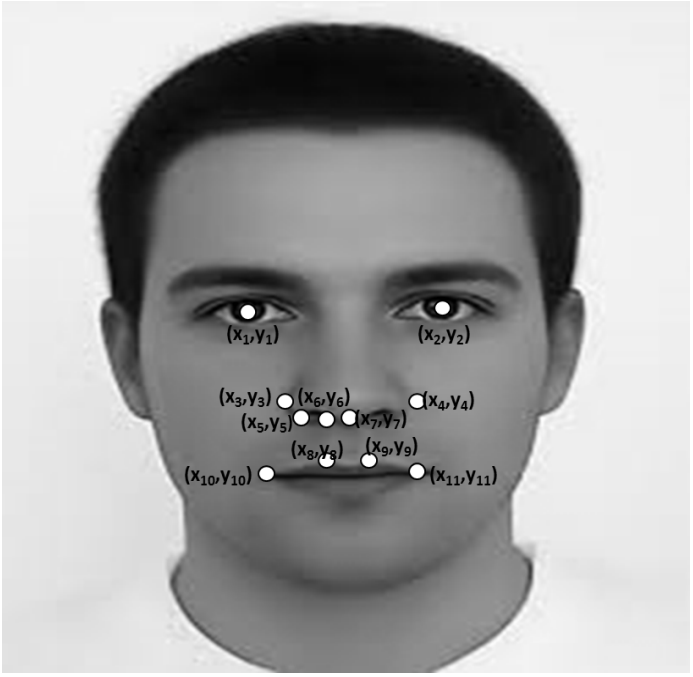


Fig. 5: Notation of the Face Landmarks Coordinates

After localizing the set of 11 face landmarks using the EGM detector as described previously, the coordinates of the points are then passed as inputs to a set of Euclidean distance mathematical equations presented by equations (1) through (6) to determine the lip-nose measurements for each sample face. A feature vector containing the geometric features (scaled lip-nose complex measurements) is created for each sample image, and a class incorporating all the geometric feature vectors related to the sample images, is created for each subject.

$$d_1 = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

$$d_2 = \frac{\sqrt{(x_3 - x_4)^2 + (y_3 - y_4)^2}}{d_1} \quad (2)$$

$$d_3 = \frac{\sqrt{(x_5 - x_6)^2 + (y_5 - y_6)^2}}{d_1} \quad (3)$$

$$d_4 = \frac{\sqrt{(x_7 - x_8)^2 + (y_7 - y_8)^2}}{d_1} \quad (4)$$

$$d_5 = \frac{\sqrt{(x_8 - x_9)^2 + (y_8 - y_9)^2}}{d_1} \quad (5)$$

$$d_6 = \frac{\sqrt{(x_{10} - x_{11})^2 + (y_{10} - y_{11})^2}}{d_1} \quad (6)$$

Where x_i and y_i $(i = 1 \ldots 11)$ are the horizontal and vertical coordinates of the face landmarks respectively. Also, d_1 is the distance between the centers of the eyes, d_2 is the nose total width, d_3 is the Columella width, d_4 is the vertical length of the lip, d_5 is the Cupid's bow width, and d_6 is the total width of the mouth. Since the FG-NET database consists of 82 subjects, a dataset of 82 classes is created as illustrated in Table II.

Table 2: The Lip-Nose Complex Measurements Extracted From One Subject's Samples in the Fg-Net Face Database

Samples	Features d1=0.2					Class (subject ID)
	Total nose width	Colum-ella width	Vertical length of the lip	Cupid's bow width	Total width of the mouth	
Age 0	3.15	0.75	1.65	1.15	3.3	1
Age 1	3.15	0.75	1.65	1.15	3.55	1
Age 2	3.3	0.75	1.65	1.25	3.85	1
Age 3	3.4	0.8	1.65	1.3	3.9	1
Age 4	3.45	0.9	1.7	1.35	4.15	1
Age 5	5.9	1.65	3	2.8	7	1
Age 6	6.1	1.75	3	2.85	7.9	1

The periocular region contains the most discriminating features that can vary across individuals, which makes it an effective soft biometric trait. Moreover, early anthropometric studies agreed that the periocular region is stable with aging. The proposed framework outperformed the LBP, Gabor, and a number of the-state-of-the-art age-invariant face recognition systems with a maximum verification accuracy of more than 95% for the MORPH album 2, which is the largest public face aging database.

The framework preserved the simplicity since it does not require building aging models or any pre-processing step prior to performing the recognition task. Such framework is promising for real time applications that require high performance in addition to low processing time.

The second face trait is a set features extracted from the periocular region using LBPVp,r and GIST descriptors. The periocular region is a small region in the neighborhood of the eye and includes the eyebrows (the definition of the periocular region provided here is specific to this work.). This region usually encompasses the eyelashes, eyelids, eyebrows, and the bordering skin region, depending on the size of the image used.

Using the periocular region has the following advantages: (a) the information regarding the shape of the eye and the surrounding skin texture could vary across individuals, which can be used as a soft biometric trait, (b) no additional sensor besides the iris camera was required to acquire the periocular data [15], and (c) periocular region is perceptually more stable across ages than the full face [16] (Early anthropometric studies agreed that the periocular region has stability across ages.).

Park et al. [17], [18] in their feasibility study, they concluded that the periocular region is best discriminated through the fusion of global and local descriptors. Based on their conclusions, this research work adopts an approach to combine the global and local features in order to obtain the benefits of both of these. The choice of the appropriate and complementary component features is vital for good performance. In view of this, the proposed method includes the Gist descriptor in order to obtain the global features.

The Gist descriptor aggregate image statistics of the responses of several filters combined with the input image. The advantage of the descriptor is that it is very compact and fast to compute. In the standard configuration, each image is represented by a 320-D vector per color band, resulting in a 960-D descriptor per image. The feature vector corresponds to the mean response to steerable filters at different scales and orientations.

Likewise, the LBP descriptor is able to efficiently extract the local details of face images, i.e. image edges, peaks, etc., even in the presence of noise. The LBP features are invariant to changes in lighting and scale. LBP has been recognized as computationally simple and efficient method which is invariant to monotonic gray scale transformation and illumination changes [19].

The idea of using LBP in face description is motivated by the fact that faces can be seen as a composition of micro-patterns which are well described by such operator.

As a variance of LBP, LBPV is robust because it exploits the complementary information of local contrast and spatial pattern. Both of the two descriptors (Gist and LBPV) are rich in information and computationally efficient.

Therefore, the designed method will comprise of the invariant characteristics of both the approaches, and it will be able to generate the optimal results against most of the variations (pose, expression and illumination) present in the periocular region images beside the variations introduced by the face aging. In the feature fusion model, Gist and LBPV features were extracted and normalized separately, and then, their feature vectors were simply concatenated and the singular values of the fused feature vector are projected to a PCA subspace for dimensionality reduction.

The periocular region is first extracted from the face test image using the ground truth eye centers for the faces. The ground truth eye centers of the faces were provided in FG-NET datasets, which acted as the centers of the periocular images to be cropped from the original face images. The size of the cropping region was calculated by the ratio of the distance between the eye centers. The periocular region images were then scaled down to a uniform size of 100x120 pixels. A number of preprocessed periocular regions that were extracted from the FGNET database are illustrated in Fig. 6. The sample periocular regions images were cropped from a set of images related to the same subject at different ages.

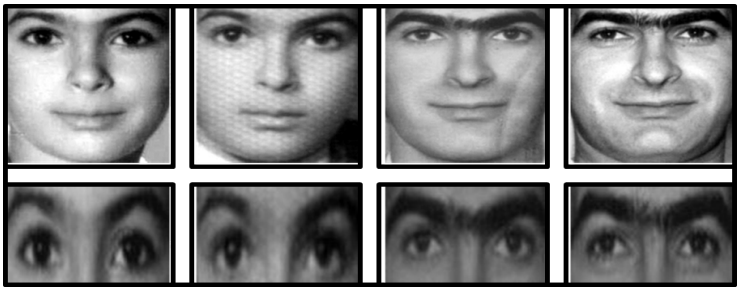


Fig. 6: Examples Periocular Regions from the FG-NET

As for the MORPH database, the eye centers of the faces were localized using the exemplar-based graph matching (EGM) landmarks detector [20]. Then, the cropping of the periocular region was performed in the same manner as the FG-NET database. Fig. 7 shows a number of sample images collected from the MORPH database of one subject at different ages and the preprocessed periocular regions that were extracted from the images. The first row shows the original images and the second row shows the preprocessed periocular regions.

Fig. 7: Examples Periocular Regions from the MORPH

The objective of using a global descriptor for periocular recognition is to obtain a basic and a subordinate level description of the perceptual dimensions. GIST descriptor [21] effectively encodes the scene images where the distance between a fixated point and the observer is large (greater than four meters) [21].

The gist descriptor is a vector of features G, where each individual feature G_k is computed in Equation (7) as follows:

$$G_k = \sum_{i,j} w_k(i,j) \times \left| I(i,j) \otimes h_k(i,j) \right|^2 \quad (7)$$

Where (i,j) are a pixel position, $\otimes$denotes image convolution, and $\times$ is a pixel-wise multiplication. The luminance channel of the input image is represented by $I(i,j)$. $h_k(i,j)$ is a filter from a bank of multi-scale-oriented Gabor filters (eight orientations and four scales), and $w_k(i,j)$ is a spatial window that will compute the average output energy of each filter at different image locations. The windows $w_k(i,j)$ divide the image into a grid of 4×4 non-overlapping windows. This results in a descriptor with a dimension of $4 \times 4 \times 8 \times 4 = 512$.

Here, a set of five perceptual dimensions, namely, naturalness, openness, roughness, expansion and ruggedness are used to give a low dimensional, holistic representation of the image.

- Degree of Naturalness: This spatial property describes the distribution of edges in the horizontal and vertical orientations. It describes the presence of artificial elements such as spectacles.
- Degree of Openness: The second major attribute describes the presence or lack of points of reference. An image with a higher percentage of periocular regions than sclera and iris region will have less points of reference or be more 'open'.
- Degree of Roughness: This perceptual attribute refers to the size of the largest prominent object in the image. It evaluates the common global attributes of the image.
- Degree of Expansion: This attribute describes the depth in the gradient of the space within the image.
- Degree of Ruggedness: This attribute gives the deviation from the horizontal by assessing the orientation of the contours of the image.

These perceptual properties are correlated with the second order statistics and spatial arrangement of structured components in the image [21]. They are easy to calculate and can be translated to a useful global descriptors of the periocular region. The GIST implementation in this research study receives a fixed size square periocular area image as input and produces a vector of dimension 512 as output.

The systems that use GIST descriptor, mostly resize the input image in a preprocessing stage, to produce a small square image. The width of the image is typically in the range from 32 to 128 pixels. Such approach is sufficient due to the low dimensionality of the descriptor, i.e., it does not represent the details of an image. In the proposed framework, an image size of 32×32 pixels is used. The periocular area images are all re-scaled to that size regardless of their aspect ratio.

A number of periocular area images which are related to the same subject (from the FG-NET database) at different ages are depicted in Fig. 8 along with visualization of their Gist descriptor features. The original periocular area images are illustrated in the top row and their Gist descriptor features are illustrated in the bottom row. Also, the age of the subject is illustrated for each image.

The periocular skin texture has been used for human identification in various ways. Jain et al. [22] detected micro-features such as moles, scars, or freckles and used them as soft biometric traits.

Others adopted a more general representation of the overall texture to facilitate recognition using popular texture measures such as the discrete cosine transformations (DCT) [23], the gradient orientation histograms (GOH), or the LBP [18],[24]. A variance of the LBP (LBPV) for extracting the overall texture of the periocular region is adopted to facilitate recognition in this research study. Basically, LBP is a fine-scale descriptor that captures small texture details.

As a variance of LBP, LBPV is robust because it exploits the complementary information of local contrast and spatial pattern. LBP variance (LBPV) was first introduced by Zhenhua Guo et al. [25] to characterize the local contrast information into one dimensional LBP histogram. It is simplified yet effective combined LBPs, as well as a method

of contrast distribution. LBPVp,r /VARp,r is robust because it exploits the complementary information of local contrast and spatial pattern.

LBPV/VAR descriptor exploits the supporting information for the local spatial pattern, as well as local contrast.

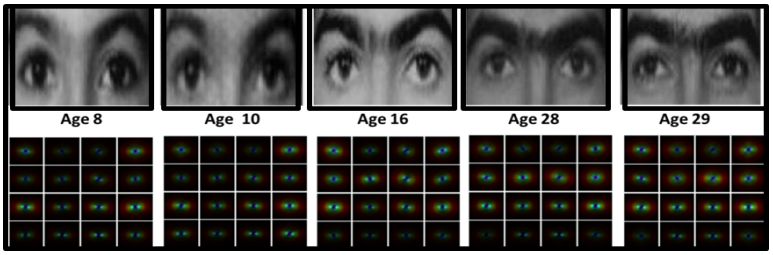


Fig. 8: A Number of some Periocular Region and their Gist Descriptor Features

The VAR possesses a continuous value, which needs to be quantized. That can be carried out first by computing feature distributions out of all training images to acquire an overall distribution.

Following that, a few threshold values are calculated to partition the overall distribution into N bins using an equal number of entries [26] to guarantee the maximum quantization resolution.

The threshold values are employed to quantize the VAR of the test images. There are three specific limitations to this quantization technique pointed out by [27]. The LBPV offers a way to handle these difficulties associated with the descriptor.

Typically, the information associated with the variance VAR will not be involved in the calculations of the histogram of the LBP. The histogram operation allocates identical weight to every LBP pattern independent of the LBPV of the local region. The LBPV is presented by Equations (8) and (9) as follows:

$$LBPV(K) = \sum_{i=1}^{n} \sum_{j=1}^{m} W(LBP(i,j),k),k \quad (8)$$

$$W(LBP(i,j),k) = \{VAR(i,j)\ LBP(i, \quad (9)$$

Where n and m are the dimensions of the texture image, (i, j) is the position of each pixel, K is the maximal LBP pattern value, and $W(LBP(i,j),k)$ is the adaptive weight to adjust the contribution of the LBP code. LBPV can be described as a simplified descriptor whose feature size is small in a way that it can be employed in several applications. Additionally, it is training free and does not require quantization. Fig. 9 depicts the Periocular region extracted from FG-NET database images of one subject at different ages and their LBPV transformations, where the first row shows the original Periocular region images and the second row shows their LBPV transformation.

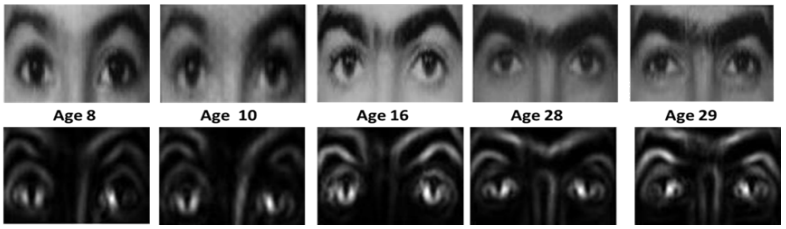


Fig. 9: Examples of Periocular Regions their LBPV Transformations

In the event that the lip-nose complex and periocular region feature vectors are formed, fusion of the two face features vectors is performed at the feature level. The feature sets related to the two face traits are fused at the feature level since it has been observed that, a unimodal biometric system that integrates information at an earlier stage of processing is expected to provide more accurate results than those that integrate information at a later stage, because of the availability of richer information [28]. In order to be concatenated, the feature sets must be compatible. Thus, the two feature sets

are normalized prior to fusion using the well-known Z-score rule.

The feature sets are first normalized separately before concatenating them into a single combined feature vector. The goal of feature normalization is to modify the location (mean) and scale (variance) of the feature values in order to ensure that the contribution of each component to the final match score is comparable. Feature sets normalization is performed using the Z-score rule [29]. The Z-score offers a useful measurement for comparing data elements from different data sets.

Typically, the formula used for calculating the Z-score is represented by Equation (10):

$$z = \frac{x-\mu}{s} \qquad (10)$$

Where z represents the Z-score, x is the feature vector, μ is the mean of the feature vector, and s is the standard deviation of the feature vector. After normalizing the two face features sets two arrangements for concatenating the face feature sets are considered in this research study. In the first arrangement, the normalized face feature sets are concatenated and passed immediately to the classification module. Fig. 10 illustrates the implementation of this arrangement over the FG-NET face aging database [30] which contains 1002 images of 82 subjects. The final feature vector extracted from each image is of size 1x576. The final dataset built using the FG-NET database entire sample images is a feature matrix of size 1002x576.

In the second arrangement, the two normalized face features sets are concatenated and the singular values of the fused features set is projected into a PCA subspace dimensionality reduction as illustrated in Fig. 11. The PCA is one of the most popular linear techniques for dimensionality reduction. It performs a linear mapping of the data to a lower-dimensional space in such a way that the variance of the data in the low-dimensional space is maximized [31].

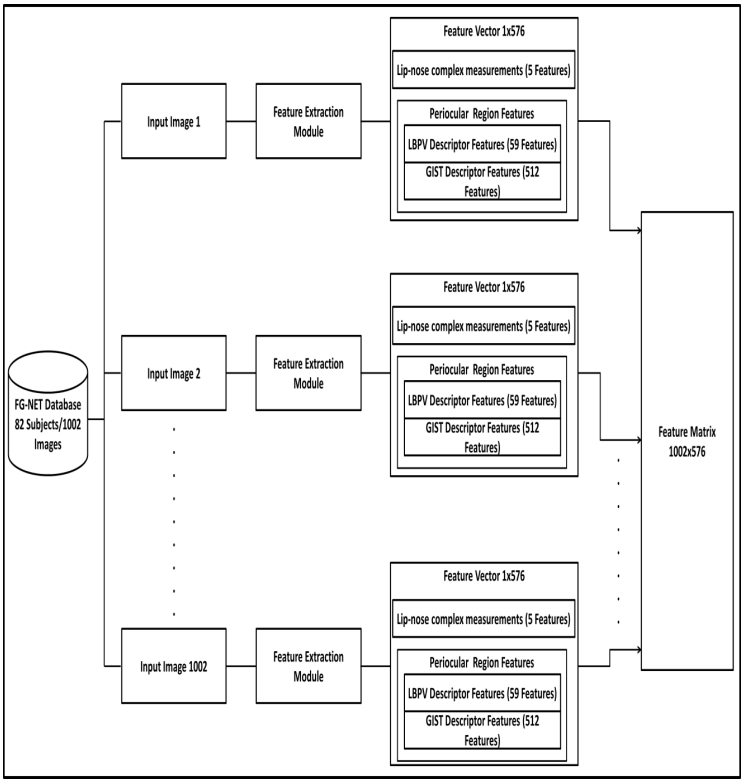


Fig. 10: First Arrangement of Feature Sets Concatenation

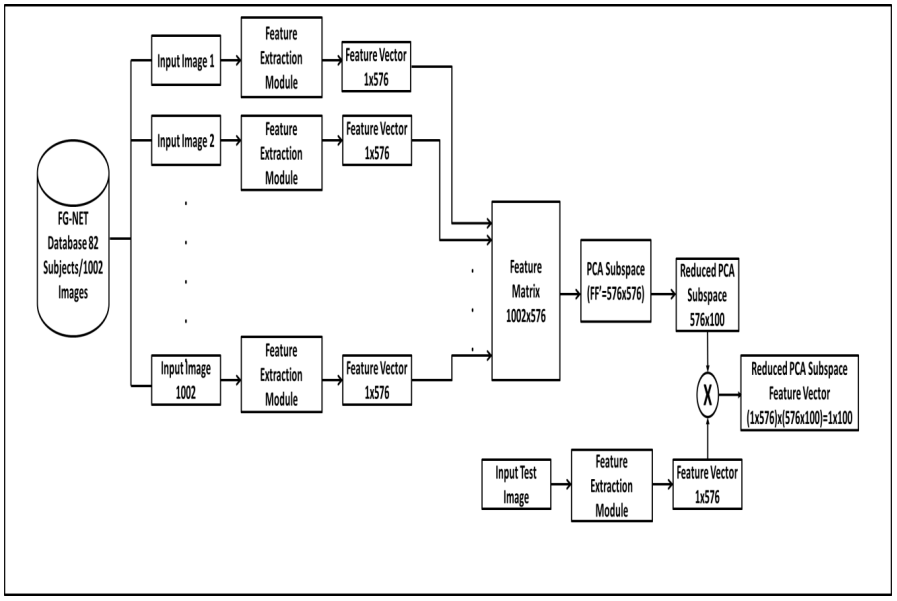


Fig. 11: Second Arrangement of Feature Sets Concatenation

The main idea of PCA is to find a reduced set of vectors that can be used to describe the full data with high accuracy. The advantage of PCA comes from its generalization ability. It reduces the feature space dimension by considering the variance of the input data. The method determines which projections are preferable for representing the structure of the input data. Those projections are selected in such a way that the maximum amount of information is obtained in the smallest number of dimensions of feature space. In order to obtain the best variance in the data, the singular values of the data are projected to a subspace of the feature space which is built by the eigenvectors from the data. In that sense, the eigenvalue corresponding to an eigenvector represents the amount of variance that eigenvector handles.

The principal components analysis (PCA) is performed as given below, and returns the principal component coefficients Co, also known as loadings. Co is a 576-by-576 matrix, each column containing coefficients for one principal component. The columns are in order of decreasing component variance. Projecting the singular values of the feature matrix into a PCA subspace is performed in the following steps:

1. The Feature matrix F is first centered: the deviation of the features from its mean is calculated by subtraction off the mean feature vector. Thus, F is transformed from the original space to the zero mean space F_0. Subtracting the mean makes variance and covariance calculation easier by simplifying their equations as illustrated in Equations (11) and (12):

$$F_{0i} = f_{ij} - \mu_i \tag{11}$$

$$F_0 = \{F_{01}, \ldots, F_{0576}\} \tag{12}$$

where μ_i is the mean of each feature column, f_{ij} is a data point in feature vector i, $i = 1, \ldots, 576$ is an index of feature column, and $j = 1, 2, \ldots, 1002$ is an index of a data point. F_{0i} is the zero mean space of feature i.

2. The covariance matrix V can then be obtained as $V = F_0 F_0^T$.
3. The eigenvectors E_k are calculated from V and sorted according to their corresponding eigenvalues γ_k.

The first n eigenvectors are then selected to span a space of reduced dimensionality onto which the original data can be projected (given by the ratio of the sum of neglected eigenvalues to the sum of all eigenvalues).

4. In the proposed framework 95% of information was kept, and the resulting

number of eigenvalues is 100. Thus, the final size of the reduced PCA subspace is 576 x 100.

5. Each feature vector of the 1002 feature vectors in the feature matrix F is projected to the reduced PCA subspace, which results in a feature vector of size 1x100 as illustrated in Fig 11.

In the final stage of the proposed framework classification is performed to produce the final output of the proposed framework. In the classification module two classifiers were adopted in this research study. The first classifier is the well-known k-means clustering unsupervised classifier [32]. K-means [33] is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed a priori. In this research study K-means unsupervised classification scheme1 is adopted. In this classification scheme, K-means is applied over each class separately to produce a set of prototypes for each class where each class is related to an individual subject. The main steps of K-means unsupervised classification scheme (1) can be summarized in the following points:

- Apply k-means clustering to the training data in each class separately, to produce M prototypes for each subject class.
- Assign a class label to each of the K x M prototypes. Where K is the number of subjects classes.
- Classify a new feature vector x to the class of the closest prototype. The closest prototype is the prototype that has the smallest square Euclidean distance from the feature vector x.

The main steps of performing K-means unsupervised classification scheme (1) are illustrated in Fig. 12 where the FG-NET database was used as a model for illustrating the process.

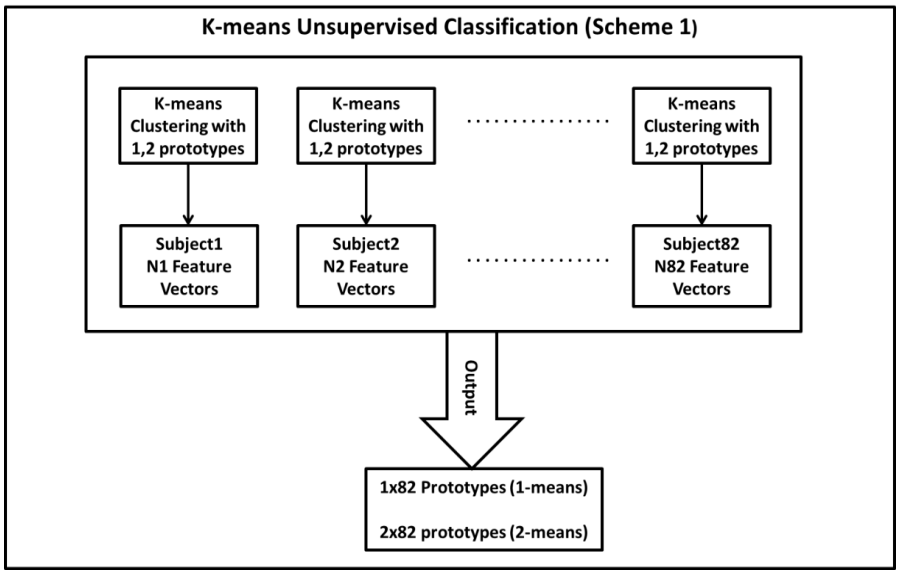


Fig. 12: K-means Unsupervised Classification

K-means clustering is performed over each subject class separately in the following steps:

Initialize Cluster Centers: In K-means it is assumed that there are M prototypes (cluster centers) denoted by $P = \{p_1, p_2, ..., p_M\}$ where this set is smaller than the original data set. If the data points reside in a Euclidean space, the prototypes reside in the same space. They will also be n dimensional vectors (n=576 in the proposed framework.). They may not be samples from the training data set; however, they should well represent the training data set. In the experimental setup, k-means clustering was performed with $M = 1$ and with $M = 2$ respectively i.e. one-means and two-means clustering was used in the experiments. Also, initialization of cluster centers was performed

using randomly selected feature vectors from each cluster.

Assign each Feature Vector to Nearest Cluster Center: Each training sample is assigned to one of the prototypes. This is denoted using the assignment function by $A(\bullet)$ using Euclidean distance. Thus, $A(x_i) = j$ means the i^{th} training sample is assigned to the jth prototype, that is, the jth prototype is used to approximate or represent point x_i.

where

$$A(\bullet) = argmin_{j\in\{1,2,\ldots,M\}}\|\bullet - z_j\| \quad (13)$$

Calculate Means of New Cluster Centers: The centroids are updated by computing the average of all the samples assigned to it. For example, if a set of samples $(x_1, x_2, \ldots, x_n)$ were assigned to a prototype j. The centroid will be updated such that the new value of j is calculated as follows:

$$j = \sum_{i=1}^{n} x_i \quad (14)$$

Check the termination conditions: In K-means, the optimization criterion is to minimize the total squared error between the training samples and their representative prototypes. This is equivalent to minimizing the trace of the pooled within covariance matrix. The objective function is:

$$argmin_{\smile P,A} \sum_{i=1}^{N} \|x_i - Z_{A(x_i} \quad (15)$$

For every pointx_i, a prototype z_j is found to represent x_i. As mentioned above, if $A(x_i) = j$ then the prototype z_j will be used. Hence, the distance between xi and $Z_{A(x_i)}$ is computed. The norm in the equation (3.15) denotes the Euclidean distance. The objective function is represented by equation (3.16):

$$L(Z, A) = \sum_{i=1}^{N} \|x_i - Z_{A(x_i)}\|^2 \quad (16)$$

The necessary conditions for an optimal solution (termination conditions) are as follows; If the set of prototypes ,Z, is fixed, the optimal assignment function $A(\bullet)$ (using the Euclidean distance) should follow the nearest neighbor rule, that is,

$$A(x_i) = argmin_{j\in\{1,2,\ldots,M\}}\|x_i - . \quad (17)$$

Given the assignment function, $A(\bullet)$, fixed, the prototype z_j should be the average (centroid) of all the samples assigned to the jth prototype:

$$z_j = \frac{\sum_{i:A(x_i)=j} x_i}{N_j} \quad (18)$$

where N_j is the number of samples assigned to prototype j. The algorithm converges since after each iteration, the objective function decreases (non-increasing). Based on the necessary conditions, the algorithm improves the prototypes and the assignment function iteratively.

It is possible that the steps taken might not lead to any change in either the prototypes or the partition. When either becomes static, the algorithm has converged and there is no need to continue. Figure 3.13 depicts the main steps of K-means clustering.

The second classifier adopted in the proposed framework is a distance-based classifier. The distance-based classifier used in this research study is a KNN classifier [34] combined with cosine score [35]. The cosine score is used for producing the s between two feature vectors. The cosine score has two advantages over other distance metrics; 1) it is scale invariant since it is an angular distance between two vectors. 2) It gives more weight to dimensions having high value (peaks in the histogram) while the Euclidean distance weighs all dimensions equally [36]. The cosine score is calculated using the formula presented in Equation (19).

$$d_{cos}(F_i, F_j) = 1 - \frac{F_i . F_j}{\|F_i\|\|F_j\|} = 1 - \left(\frac{\sum_{i,j=1}^{n} F_i \times F_j}{\sqrt{\sum_{i=1}^{n}(F_i)^2} \times \sqrt{\sum_{j=1}^{n}(F_j)^2}}\right) \quad (19)$$

Where F_i and F_j are the feature vectors matched using the distance-based classifier. Once the s are produced using the cosine score, they are compared with a predefined threshold. Based on the results of comparing the s with the reference threshold, the KNN classifier makes a final decision.

The different feature representations illustrated in Fig 10 and Fig 11 are combined with the K-means classifier and the cosine distance-based classifier in an alternate way. Such combinations resulted in eight different age-invariant face recognition algorithms. The proposed algorithms were mainly designed to perform face verification, but they were validated in the identification mode as part of the experimental work. The proposed algorithms were given names as 1.a, 1.b, 2.a, 2.b, 3.a, 3.b, 4.a, and 4.b for simplicity. A brief description of the proposed age invariant face recognition algorithms is illustrated in Table III to remind the reader of the differences between the proposed algorithms.

Table 3: The Proposed Age Invariant Face Recognition Algorithms

Samples	Class (subject ID)
1.a	PCA+K-means with one prototype.
1.b	PCA+K-means with two prototypes.
2.a	Non-PCA+K-means with one prototype.
2.b	Non-PCA+K-means with two prototypes.
3.a	PCA+Cosine-based classifier with mean prototype.
3.b	PCA+Cosine-based classifier with max prototype.
4.a	Non-PCA+Cosine-based classifier with mean prototype.
4.b	Non-PCA+Cosine-based classifier with max prototype.

IV. EXPERIMENTS

All the face images in the FG-NET and MORPH databases were properly normalized and pre-processed. The pre-processing stage comprised converting the color input images into 8-bit grey-scale images, locating the eyes manually, normalizing (scaling and rotating) the images geometrically in such a way that the centers of the eyes were localized at predefined positions, cropping the face parts of the images, and resizing the cropped area to a standard size of 200x200 pixels, and finally, normalizing the face images photometrically by eliminating their mean and scaling their pixels to unit variance [37]. A number of examples of the normalized images from the FG-NET and MORPH databases are shown in Fig 13 and Fig 14 successively.

Fig. 13: Pre-processed Sample Images of 5 different subjects from the FG-NET

Fig. 14: Pre-processed Sample Images of 5 different subjects from the MORPH

For all experiments, frontal faces were normalized using the location of 68 manually established face feature points. These points are triangulated and the image warped with a piecewise affine warp onto a coordinate frame in which the canonical points are in fixed locations.

This process is similar to the preprocessing used prior to the computation of AAMs [38], [39]. Finally, pose correction was performed for non-frontal face images using the same method adopted by Kambhamettu et al. [40], which uses AAM technique as proposed by Cootes et al. [41].

As mentioned before, the images from FG-NET are annotated with 68 face feature points; consequently, a generic model was used to fit these points and calculate the pose of the face.

Finally, pose correction was performed by warping the image onto the model. A number of pose corrected sample images from the FGNET and MORPH databases are illustrated in Fig 15, where the images in the top row are the original images and the images in the bottom row are the pose corrected images.

The verification tests were performed using the leave-one-person-out (LOPO) scheme adopted by Ling et al. [9] and Park et al. [6] (most commonly used for evaluating face recognition systems). In the first experimental setup, verification was performed using k-means clustering unsupervised classification. Each image in the FG-NET and MORPH databases was used once as a test image.

The feature vector acquired from the test image is matched with all the prototypes of the different clusters (classes) related to the different subjects.

The genuine similarity scores are produced when a test feature vector is matched with a prototype that belongs to the same subject as the test feature vector. The imposter scores are produced when a test feature vector is matched with a prototype that belongs to a different subject. In the case when k-means clustering is performed with two prototypes, the maximum similarity score produced from matching the test feature vector with the two prototypes of each cluster is considered the final matching score.

Fig. 15: Sample Images Collected Before and After Preprocessing

In the second experimental setup, identification was performed using K-nearest neighbor classification to acquire the verification rate for the proposed approach. In the LOPO scheme, the

entire set of images of a single subject was used as test images and the rest of the images were used for training the framework. When a test feature vector is matched with a training feature vector that has the same true class label as the test vector a genuine matching score is produced. When a test feature vector is matched with a training feature vector that has different true class label than the test vector label, an imposter similarity score is produced. Finally, the genuine and imposter scores in both of the experimental setups are used to calculate the verification rate.

The close-set identification tests were also performed using the leave-one-person-out (LOPO) scheme. In the first experimental setup, identification was performed using k-means clustering unsupervised classification. Each image in the FG-NET and MORPH databases was used once as a test image. The feature vector acquired from the test image is matched with all the prototypes of the different clusters (classes) related to the different subjects. In the case of the FG-NET database there are 82 classes. Then, the test feature vector is assigned the label of the prototype that yielded the maximum similarity score. In the case when k-means clustering is performed with two prototypes, the maximum similarity score produced from matching the test feature vector with the two prototypes of each cluster is considered the final similarity score. In the second experimental setup, identification was performed using K-nearest neighbor classification to acquire the identification rate for the proposed approach. In the LOPO scheme, the entire set of images of a single subject was used as test images and the rest of the images were used for training the framework. This procedure was performed for all the subjects to ensure that each subject was used only once for testing. Also, the purpose of this evaluation scheme was to make sure that the images of one subject were not in the training and testing sets at the same time. The LOPO was combined with K nearest neighbor (KNN) classifier in a way that every single image in the face aging databases is used as a query image and cosine score is computed between each query and each of the remaining images. Then, the identity of the subject presented in the query image is recovered using the KNN match. In the experiments over the FG-NET database one-Nearest Neighbor was used. Since the MORPH database is a very large database, the optimum value of K was 3 based on the empirical validation.

V. RESULTS

In this section the results of evaluating the performance of the proposed framework and the proposed algorithms within the framework are presented and discussed. As mentioned before, the proposed algorithms within the framework were evaluated over the FG-NET and MORPH databases in the verification and identification modes.

The performance of the k-means unsupervised classifier degrades when the feature vectors (feature matrix) was passed to it immediately without projecting it to a PCA subspace. This can be observed when the performance of algorithms 2.a and 2.b is compared with the performance of algorithms 1.a and 1.b. Such results show the effect of projecting the data into a PCA subspace in enhancing the performance of k-means unsupervised classifier. The ROC curves depicted in Figure 4.3 shows clearly that replacing k-means clustering classifier with a distance-based classifier (cosine distance based classifier [42, 43]) has led to a degradation in the verification performance even when the data was projected to a PCA subspace prior to classification. The lowest performance was reported when the feature matrix was derived to the cosine distance based classifier without projecting it to a PCA subspace as shown in Fig 16.

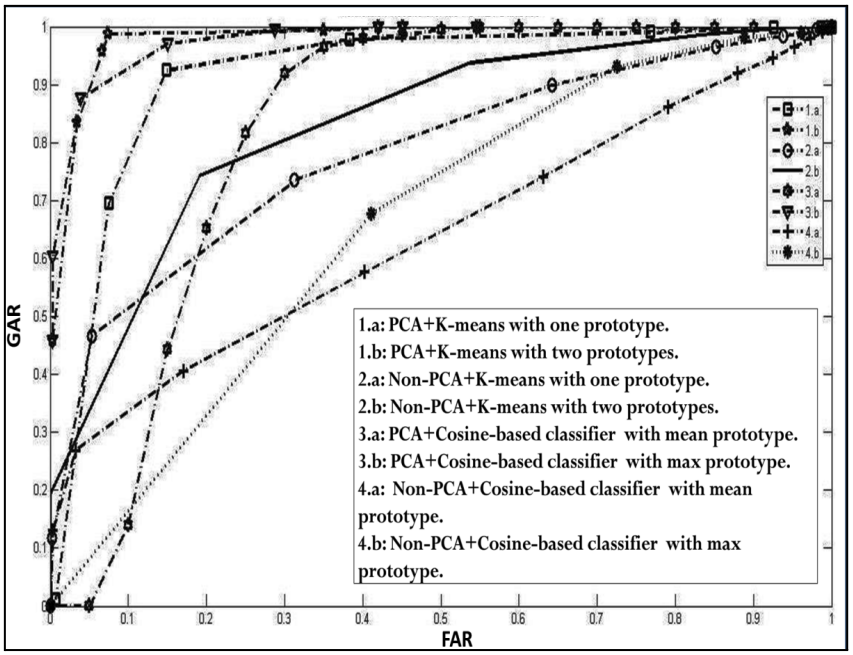


Fig. 16: The ROC Curves of the Proposed Algorithms Over the FG-NET Database

Moreover, the performance of the cosine distance based classifier degraded when the test feature vectors were matched with the mean of training feature vectors (algorithm 4.a) instead of matching the test feature vectors with each training feature vector (algorithm 4.b). Algorithm 1.b was able to achieve an average verification rate (GAR) of 94.31% over the FG-NET database.

The results of evaluating the proposed algorithms over the MORPH face aging database in the verification mode were in line with the verification results reported over the FG-NET database. Again, Algorithm 1.b presented itself as the best performing among the proposed algorithms with an average verification rate of 96.67%. Such results support the conclusions that has been made earlier in the combined effect of PCA subspace and k-means clustering unsupervised classification with multiple prototype in improving the verification performance. The results of evaluating the proposed algorithms over the MORPH face aging database in the verification mode were in line with the verification results reported over the FG-NET database. Again, Algorithm 1.b presented itself as the best performing among the proposed algorithms with an average verification rate of 96.67%. Such results support the conclusions that has been made earlier in the combined effect of PCA subspace and k-means clustering unsupervised classification with multiple prototype in improving the verification performance.

The results of evaluating the proposed algorithms in the closed-set identification mode over the FG-NET and MORPH face aging databases are illustrated in Fig 17 and 18 respectively. The figures depict the precision-recall curves of the proposed algorithms. Varying the reference threshold moved the operating point along the precision-recall curves. Algorithm 1.b was able to achieve the highest rank-1 identification accuracies of 93.20% over the FG-NET database and 95.22% over the MORPH database.

Moreover, the precision-recall curves have shown the superiority of algorithm 1.b over the other proposed algorithms. Table IV illustrates the identification performance of algorithm 1.b in terms of rank-1 identification accuracy, precision, recall, and F-measure.

Table 4: The Close-Set Identification Results

Database	Rank-1 Identification Accuracy	Precision	Recall	F-measure
FG-NET	93.20	0.941	0.939	0.939
MORPH	95.22	0.9612	0.9592	0.960

The results depicted in Table VI show that only the performance of the proposed framework was validated in both verification and identification modes. The rest of the systems were either validated in the verification or identification mode. Moreover, the proposed framework was able to achieve equal error rates of 7.22% over the FG-NET database and 6.51% over the MORPH database. The equal error rates achieved by the proposed framework are the lowest rates among the reported results in the literature review.

Also, the rank-1 identification accuracy reported by the proposed framework exceeds the highest rank-1 identification accuracy reported in the literature review by Park et al.[6]. Except Mahalingam et al. [11], all of the existing age invariant face recognition systems were tested over subsets of the MORPH and FG-NET databases.

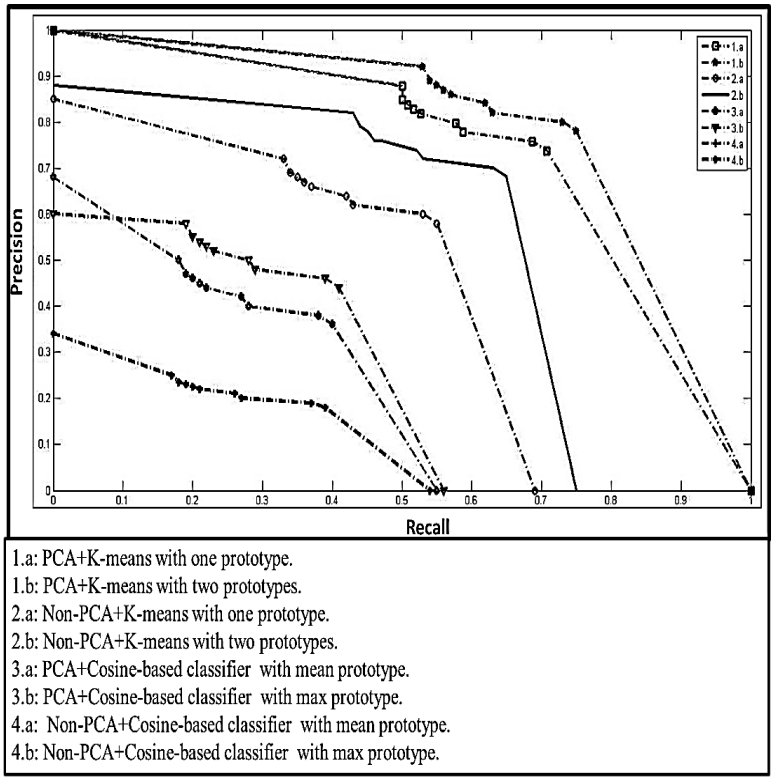
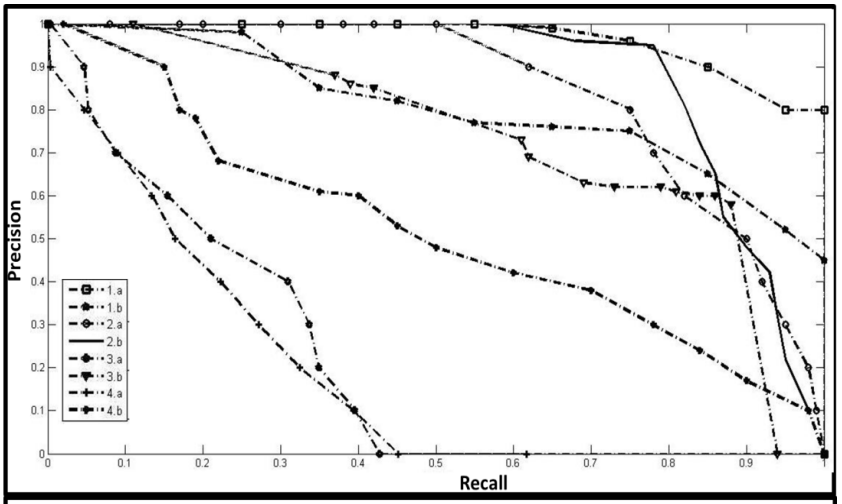


Fig. 17: FG-NET Database Close-Set Identification Results



1.a: PCA+K-means with one prototype.
1.b: PCA+K-means with two prototypes.
2.a: Non-PCA+K-means with one prototype.
2.b: Non-PCA+K-means with two prototypes.
3.a: PCA+Cosine-based classifier with mean prototype.
3.b: PCA+Cosine-based classifier with max prototype.
4.a: Non-PCA+Cosine-based classifier with mean prototype.
4.b: Non-PCA+Cosine-based classifier with max prototype.

Fig. 18: MORPH Database Close-Set Identification Results

The results of the periocular biometrics experiments have shown that it is more effective in terms of verification rate and processing time to use the Periocular region as a biometric trait rather than a full face. Also, the results of the Periocular biometrics experiments have shown that the LBPV and GIST descriptors are the optimal face descriptor to be used for extracting the face features from the Periocular region.

Accordingly, the Periocular region was selected to be adopted as a face biometric trait in the proposed framework. Also, both of the GIST and LBPV descriptors were used for extracting the face features from the Periocular region.

The proposed system is the only system that was validated in both the verification and identification modes over the entire FG-NET and MORPH databases. Using algorithm 1.b, the proposed framework achieved equal error rates of 7.22% and 6.51% over the FG-NET and MORPH database respectively. Moreover, the proposed framework achieved maximum rank-1 identification accuracies of 93.20% and 95.22 over the FG-NET and MORPH database respectively. To the best of the researcher's knowledge such results are the highest results reported in the literature review so far.

Table 6: Comparing the Performance of the Proposed Framework with the Existing Age Invariant Face Recognition Systems Results

Method	Database	EER reported (%)	Rank-1 Identification Accuracy (%)
Ramanathan et al.[5]	Private Database (109, 109)	-	15.00
Geng et al. [7]	FG-NET (10, 10) (only a subset)	-	38.10
Park et al.[6]	FG-NET (82, 82) (only a subset)	-	37.40
	MORPH (612, ,612) (only a subset)	-	66.40

Ling et al.[8], [9]	FG-NET (62, 272) (only a subset)	24.10	-
	MORPH (5060, 20,140)	29.38	-
Mahalingam et al. [11]	FG-NET (82,1002) (entire database)	24.08	-
	MORPH (5060, 20,140)	16.49	-
Lip-Nose Morphometry Amal et al. [44]	FG-NET (82,1002) (entire database)	36	85.89
	MORPH Album2	27.14	78.21
Periocular Region Features Amal et al. [45]	FG-NET (82,1002) (entire database)	26.42	89.68
	MORPH Album2	17.02	93.35
The Proposed Framework Algorithm 1.b: PCA+K-means with two prototypes.	FG-NET (82,1002) (entire database)	7.22	93.20
	MORPH Album2	6.51	95.22
Lip-Nose Morphometry Amal et al. [44]	FG-NET (82,1002) (entire database)	36	85.89
	MORPH Album2	27.14	78.21

VI. CONCLUSION

This research study proposed a novel age-invariant face recognition framework based on two simple yet effective face traits. The proposed approach addresses the face aging problem in a more direct way without relying on a generative aging model. This obviates the need for a training set of subjects that differ only in their age with minimal variations in illumination and pose, which is often a requirement in building a generative aging model. The first trait is a set of anthropometric measurements related to the lip-nose complex. Several physiological studies have proved that the arithmetic range of the lip-nose complex measurements is different for different ethnicities, and thus, can be adopted for ethnicity classification. The same studies have proven that such measurements have a different arithmetic range of different genders within the same ethnicity. Moreover, some of the studies concluded that there is a possibility that the growth rate of such measurements is unique for each individual. The second trait is based on extracting texture features that are robust and rotation invariant in the periocular region using the LBPVar and GIST descriptors.

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46. Dr. Amal S. Osman Ali received her BSc in Communication Engineering from Sudan University of Science and Technology Khartoum, Sudan in 2007, and MSc in Computer Architectures and Networks from University of Khartoum, Sudan in 2009. She is currently working as PhD scholar in Department of Electrical and Electronics Engineering at University Teknologi

PETRONAS since Jan 2012. Her research focuses on developing an Age-Invariant Face Recognition system to reduce the effects of facial aging on face recognition performance.

47. AP. Dr. Aamir S. Malik received his MSc in Information and Communication and PhD in Information and Mechatronics from Gwangju Institute of Science and Technology, South Korea. He has more than 15 years of research experience and is currently Associate Professor at the Department of Electrical Engineering and Director of Biomedical Technology group at Universiti Teknologi PETRONAS. His research interests include biomedical signal & image processing, visual surveillance, remote sensing and brain sciences.
48. *Dr. Azrina Aziz:* is with the Universiti Teknologi PETRONAS Bandar Seri Iskandar, 31720 Tronoh, Perak, Malaysia (phone: 605-368-7881; fax: 605-365-7443; e-mail: azrina_aaziz@petronas.com.my).
49. AP. Dr. Vijanth S. Asirvadam studied at the University of Putra, Malaysia for the Bachelor Science, BSc. (Hon) majoring in Statistics and graduated in April 1997. He received his Master's Science, MSc. degree in Engineering Computation with a Distinction in December 1998. He took employments as a system administrator at the Multimedia University (MMU) Malaysia prior joining the Intelligent Systems and Control Research Group at Queen's University Belfast in November 1999 where he completed his Doctorate (Ph.D.) in March 2003, researching on Online and Constructive Neural Learning methods. his Master's Science, MSc. degree in Engineering Computation with a Distinction in December 1998. He took employments as a system administrator at the Multimedia University (MMU) Malaysia prior joining the Intelligent Systems and Control Research Group at Queen's University Belfast in November 1999 where he completed his Doctorate (Ph.D.) in March 2003, researching on Online and Constructive Neural Learning methods.

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