Efficient Intelligent Systems for Healthcare Data Management and Delivery

By

Krishna Prasad K

A Research Report Submitted for the fulfillment of the award of Post-Doctoral Fellow Certificate Program in

(Artificial Intelligence System in Health Care)

Under Supervision of

Prof. Dr. P. S. Aithal, Vice Chancellor,

Srinivas University, Karnataka, India

College of Computer Science & Information Science
Srinivas University
(A Statutory University under UGC Act, Govt. of India)
Mangaluru- 574 146, Karanataka, India

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CERTIFICATES

SRINIVAS UNIVERSITY

Srinivas Nagar, Mukka– 574 146, Mangalore.

(Private University Established by Karnataka Govt. ACT No.42 of 2013, Recognized by UGC, New Delhi, & Member of Association of Indian Universities, New Delhi)

TO WHOM IT MAY CONCERN

This is to certify that Dr. Krishna Prasad K, has completed his Research work at College of Computer Science and Information Science, City Campus, Pandeshwar, Mangalore as a Research Centre leading to the award of Post-Doctoral Fellow Certificate Program in Artificial Intelligence System in Health Care under the Guidance of Prof. Dr. P. Sreeramana Aithal, Vice Chancellor, Srinivas University, Mangalore, Karnataka for the topic 'Efficient Intelligent Systems for Healthcare Data Management and Delivery' and further I deem the work fit for the submission as a Research report leading to the award of Post-Doctoral Fellow Certificate Program.

SRINIVAS UNIVERSITY G.H.S. ROAD MANGALORE-575 001

Dean
College of Computer Science and Information Science
Srinivas University

<u>RESEARCH SUPERVISOR REPORT</u>

This is to certify that the Research Report entitled "Efficient Intelligent Systems for Healthcare Data Management and Delivery" submitted to Srinivas University, Karnataka, India by Krishna Prasad K, for the award of Post-Doctoral Fellow Certificate in Artificial Intelligence System in Health Care is a record of bonafide research work carried out by him under my supervision. The Research Report (consist with the Publications) has reached the standard of regulations for the award and it has not been previously formed for the award of any qualifications or any other similar title to the candidate or any other person.

Prof. (Dr.) P. Sreeramana Aithal,

Vice Chancellor, Srinivas University,

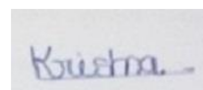
Mangaluru- 574 146, Karnataka, India

DECLARATION

Declaration

I, **Krishna Prasad K,** (Post-Doctoral Fellow Certificate Scholar) hereby declare that the research work presented in this form of Research Report is prepared by me based on my publications (which are never submitted for any qualifications) and all the works have been connected to reach the theme of the topic and its interdisciplinary area. The descriptions and narrations found are purely original and authentic. Moreover, I am responsible for all the contents included in the publications and research report.

Hence, once again I declare that the entire work in this research report is original for the award of Post-*Doctoral Fellow Certificate Scholar* of **Srinivas University, Karanataka, India.**



Krishna Prasad K

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ACKNOWLEDGEMENT

I wish to acknowledge several individuals who provided me with immeasurable help in the completion of this Post-Doctoral Fellow Certificate Programme. First of all, I derive immense pleasure in placing on record my deep sense of appreciation, gratitude and indebtedness to my PDF supervisor, Prof. Dr. P. Sreeramana Aithal, Vice-Chancellor, Srinivas University, Mukka, Mangalore, for his all-round help in suggesting the problem, sustaining the interest, motivating, inspiring, and extending valuable guidance for the successful completion of the present investigation. Also, numerous discussions I had with him have increased my knowledge.

I am happy for the love and support I have had from Sumana S., my wife and Abheeshta Krishna, my son and making life truly exciting. I would like to thank my parents who have blessed me with great tolerance. I would like to thank my Father-in-law, Mother-in-law, and brother-in-law, for their continuous support and motivation for completing my research work. I would like to thank my brother and his family for moral support. Without you all, things would have so much harder. I am wholeheartedly grateful to Sri. CA. A. Raghavendra Rao, President, A. Shama Rao Foundation, Mangalore and also Chancellor, Srinivas University, Mukka, Mangalore, for encouraging me by providing all facilities to carry out this work. I wish to express my sincere thanks to Dr. P. Srinivas Rao, Vice-president, A. Shama Rao Foundation, Mangalore and also Pro-Chancellor, Srinivas University, Mukka, Mangalore, for their support.

I am thankful to Dr. A. Jayanthiladevi, Research Professor, College of Computer Science and Information Science, Srinivas University, City Campus, Mangalore, for her guidance and encouragement.

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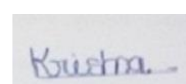
Last but not the least; I thank Almighty, who has made my life blissful. May his name be exalted, honored and glorified.



Krishna Prasad K

DEDICATION

Dedicated to Doctors and Health Warriors

Paper Publications

List of Paper Publications

The following is the details of Paper Publications in respect of Post-Doctoral Research Fellow Certificate Program *in Artificial Intelligence System in Health Care* as per the title of the work '*Efficient Intelligent Systems for Healthcare Data Management and Delivery'* in the specified term.

Serial No.	Title of the Paper	Publication Description	Appeared in	Role
1	An Effectual Data Management Over Healthcare Systems for Improving Privacy in Iot Environment	*Journal of Physics: Conference Series*, 1712(1), 1-10.	Journal	Authored
2	Fusion Based Learning Approach for Predicting Diseases in Earlier Stage	*Applied Soft Computing: Techniques and Applications (Ed. Samarjeet Borah. et. al.)*, Apple Academic Press (AAP-CRC Press), Boca Raton, Florida, United States, Chapter 12.	Edited Research Book	Authored
3	An Integration of Cardiovascular Event Data and Machine Learning Models for Cardiac Arrest Predictions	International Journal of Health Sciences and Pharmacy (IJHSP), *5*(1), 55-71.	Journal	Authored
4	Tracking and Monitoring Fitness of Athletes Using IoT Enabled Wearables for Activity Recognition and Random Forest Algorithm for Performance Prediction.	*International Journal of Health Sciences and Pharmacy (IJHSP)*, *5*(1), 72-86.	Journal	Authored
5	An AI-based Analysis of the effect of COVID-19 Stringency Index on Infection rates: A case of India.	*International Journal of Health Sciences and Pharmacy (IJHSP)*, *5*(1), 87-102.	Journal	Authored

Paper Publications in Interdisciplinary Areas

List of Paper Publications in Interdisciplinary Areas

The following is the details of Paper Publications in Interdisciplinary Areas of Post-Doctoral Research Fellow Certificate Program *in Artificial Intelligence System in Health Care* as per the title of the work '*Efficient Intelligent Systems for Healthcare Data Management and Delivery*' in the specified term.

Serial No.	Title of the Paper	Publication Description	Appeared in	Role
1	Literature Review of Applications of ICT on Solar Cold Chain	*International Journal of Applied Engineering and Management Letters (IJAEML)*, 4(1), 93-111	Journal	Authored
2	An Integrated Solution for Solar Cold Chain Portfolio Management using Internet of Things	*International Journal of Applied Engineering and Management Letters (IJAEML)*, 4(1), 112-130	Journal	Authored

Patent Publication

List of Patent Publication

The following is the details of Patent Publications in respect of Post-Doctoral Research Fellow Certificate Program *in Artificial Intelligence System in Health Care* as per the title of the work '*Efficient Intelligent Systems for Healthcare Data Management and Delivery*' in the specified term.

Serial No.	Title of the Patent	Patent Filing Details	Published in	Role
1	Method For Diagnose Medical Problem Through Medical Image Processing Using Big Data And Machine Learning	Patent Application No: 202031019607 Date of File: 8th Day of May 2020 Docket No: 17961 C. B. R. No: 7903	Indian Patent Office (IPO) and World Intellectual Property Organization (WIPO)	Authored

CONTENTS

Research Proposal

RESEARCH PROPOSAL - Post Doc Research Fellow in Computer Science

NAME OF CANDIDATE: Dr. Krishna Prasad K
RESEARCH FIELD: Artificial Intelligent Systems in Health Care
TOPIC OF RESEARCH: Efficient Intelligent Systems for Healthcare Data Management and Delivery

ADVISOR: Dr. P. S. Aithal
M.Sc.(Physics), M.I.T.(IT), M.Sc.(E-Business), M.Tech.(IT), Ph.D.(Physics), Ph.D.(Management), PDF (PRL, Ahmedabad & CREOL, USA). Vice Chancellor, Srinivas University

Abstract

The advancements in hardware and networking technology are merged with Internet of Things (IoT) which provides flexibility for monitoring the health condition of individuals. This is a smart environment that includes city, homes, and agriculture; as well, it recently includes healthcare systems for disease prediction and for medical advices. To improve the ability of IoT with healthcare system, the layers of data transmission has to be analyzed. This is to validate the faster response of physicians during the time of communication and lower latency. Moreover, this technology encounters various challenges in providing privacy towards the users and to address this privacy issue to certain extent. In the initial stage, the technology runs with a lesser privacy. Hence, this work deals with the modeling of e-healthcare framework that deals with preserving electronic medical records and attempts to eliminate privacy issue. However, the experimentation is done with MATLAB environment that concentrates on the metrics like response time and delay. The anticipated model provides better outcome in contrary to other models. The outcomes of this work are effectual while offering privacy with standardized network factors.

Keywords- Healthcare, latency, privacy, medical records, communication

Introduction

Intelligent healthcare data management system may facilitate patients and sick persons to use these services like diagnostic service, monitoring service and emergency management service whenever in all places. This work concentrates on intelligent data management including task assignment based on SVM, smart device application and sensors with higher sensitivity level.

Numerous researches have been studied in intelligent healthcare system and applications of the nanotechnology. Also, genetic algorithms are already a key player in task assignment. Genetic algorithm approach has been presented to solve task assignment problem. Some investigators developed a task assignment problem in minimizing costs for execution and communication. Some investigators proposed a task distribution framework to support dynamic reconfiguration of PHMS, by means of task redistribution. This framework consists of a coordinator and a set of facilitators. Task assignment problem in arbitrary processor networks was studied.

The recent advancements in digital processing and networking technologies have provided the way for handling the emergency conditions by giving online services. These services make use of Internet of Things (IoT) as a platform to connect with the process, people and the things. Therefore, fulfilling the comfort towards social life of humans is very important. These services make researchers and technologies to move from centralized environment to distributed environment. As an outcome, the smart homes, wearable devices, cities, mobility and healthcare are emerging technologies recently. Subsequently, the present internet technology and its services are improved with the data technology for device proliferation, and it produces huge amount of data. Amazon, Cisco, Microsoft, Google and some other leading Information Technology (IT) industries are deployed with Data Centers (DC) for storing and computing the generated data with diverse application and services with paid-usage mode. Even though, this model is resourceful as per its usage, however it is applicable for latency with finest suit for real-time applications.

Methodology

This section discusses about the E2E architecture of IoT platform for providing solution to healthcare system. This system comprises of four modules like sensing layer, communicating layer, transmission layer and healthcare. The former later comprises of certain network devices and sensors concentrates in the health information for processing and transferring data to successive layers. These devices constantly observe the parameters like temperature, blood pressure, heart rate and other parameters. The sensors are accountable for data transmission, and notifications to carry out necessary actions.
The communication layers comprises of number of connected nodes termed as edges that are accountable for data reception from sensors to IoT devices and process them locally, examine it and examine the health care patterns and report it to them. The edges show communication, storage, processing, and controlling units to acquire lesser delay. The communication module works as interface among the connectivity components over all the layers of communication. The controllers are used for transferring data from sensors to other and forward it to successive layers. The storage unit is nothing but huge database systems that can hold massive amount of data for shorter time period.
To attain better scalability, it is necessary to assist diverse kinds of connection components. This needs support to other network protocols for both wireless/wired connections among the network. The communication module is accountable for handling security and data along with the crucial issues to networked systems among the end systems. There are certain systems that are considered to eliminate attacks. The DC is executed over this layer that provides promising outcomes like holding the healthcare data repositories. The database comprises of three features like integration with other devices, data analysis and decision making system with medical practitioners and other parties. The data comprises of analysis with diseases for prior prediction. This is achieved with the database system like relational database that are adopted for various system levels.

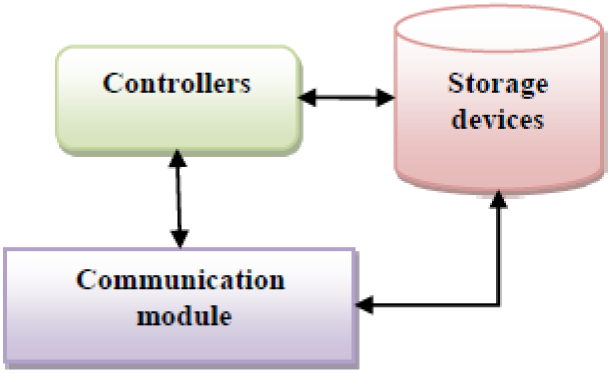


Figure 1: Architectural Model

The architectural model of the anticipated model is given in Fig. 1. There are certain services provided by the healthcare systems like medical record management services and healthcare monitoring. This system is designed and organized as sub-systems. The components are deployed with overall design model specifically for sensing and storing. The IoT device gathers the healthcare data and forwards it to edge devices for data prediction and analysis. The reports are given to patients through PC, mobile or tablet. This unit is accountable for offering certain medical services to patients through data storage system to store and retrieve medical information. This system is responsible for processing and analyzing health data and mining to offer needed information.

Benefits of Anticipated Model

The anticipated model for healthcare system is to offer privacy over the data stored in cloud environment with the use of IoT technologies. The requirements for maintaining the privacy with healthcare data is secrecy, energy efficiency, transmission rate and cost. This healthcare model provides superior QoS requirements like lesser overhead and lesser bandwidth utilization, reduced delay and service availability. The anticipated model helps to enhance the multi-cast communication over the network environment with diverse privacy providing factors and reduces the packet drops by constantly monitoring the layers of communication environment. This model offers secure healthcare communication. In recent times, it is generally surgical processes that are monitored by the physicians remotely. With this condition may harm the patients under treatment, when it moves to distributed environment. Therefore, the anticipated model is more compatible with the available layer monitoring and offers a faster and secure accessibility over patients‟ data with higher reliability and accuracy with healthcare and information system. In future, the process optimization is considered for validating the global solutions for measuring data transmission with IoT.

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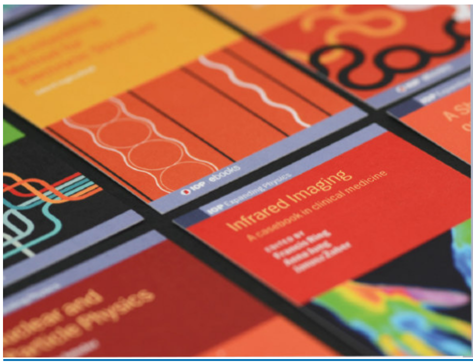

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AN EFFECTUAL DATA MANAGEMENT OVER HEALTHCARE SYSTEMS FOR IMPROVING PRIVACY IN IoT ENVIRONMENT

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Abstract. The advancements in hardware and networking technology are merged with Internet of Things (IoT) which provides flexibility for monitoring the health condition of individuals. This is a smart environment that includes city, homes, and agriculture; as well, it recently includes healthcare systems for disease prediction and for medical advices. To improve the ability of IoT with healthcare system, the layers of data transmission has to be analyzed. This is to validate the faster response of physicians during the time of communication and lower latency. Moreover, this technology encounters various challenges in providing privacy towards the users and to address this privacy issue to certain extent. In the initial stage, the technology runs with a lesser privacy. Hence, this work deals with the modeling of e-healthcare framework that deals with preserving electronic medical records and attempts to eliminate privacy issue. However, the experimentation is done with MATLAB environment that concentrates on the metrics like response time and delay. The anticipated model provides better outcome in contrary to other models. The outcomes of this work are effectual while offering privacy with standardized network factors.

Keywords- Healthcare, latency, privacy, medical records, communication

1. Introduction

The recent advancements in digital processing and networking technologies have provided the way for handling the emergency conditions by giving online services. These services make use of Internet of Things (IoT) as a platform to connect with the process, people and the things [1]. Therefore, fulfilling the comfort towards social life of humans is very important [2]. These services make researchers and technologies to move from centralized environment to distributed environment. As an outcome, the smart homes, wearable devices, cities, mobility and healthcare are emerging technologies recently [3]. Subsequently, the present internet technology and its services are improved with the data technology for device proliferation, and it produces huge amount of data. Amazon, Cisco, Microsoft, Google and some other leading Information Technology (IT) industries are deployed with Data Centers (DC) for

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storing and computing the generated data with diverse application and services with paid-usage mode [4]. Even though, this model is resourceful as per its usage, however it is applicable for latency with finest suit for real-time applications [5].

With the recent usage and accumulation of data, 92% data forecasting with workload is identified and urged with the deployment of control layers over computing environment nearer to the end-to-end devices to assist data locality and mobility [6]. However, the term computing is anticipated by Cisco in 2012 and this domain receives better attention for diverse application by academia, researchers, and industries [7]. The ultimate objective for deployment is to take benefits over the end-devices and at the edge the devices are completely provided with diverse resources like bandwidth, computation, and storage for processing the real-time data connected with neighboring nodes in one-hop transmission with reduced delay [8]. The fog and cloud computing are benefitted mutually and inter-dependent with one another. It is known that the cloud coordination with the successive nodes is handled by diverse heavyweight data [9]. For making comparison, the delay sensitive data is processed with the use of fog nodes in IoT based proximity with end devices.

As discussed previously, IoT provides an open door for handling e-health and other various application which turns to be significant and immense important task to be accomplished by recent investigators. The healthcare system relies over the radio frequency based on ubiquitous functionality and wireless networking technology. Diverse smaller actuators and sensors are placed over the human body and interconnected with other devices for data accumulation [9]. The data is generated with the use of actuators and sensors are stored which is utilized by the medical consultant and other physicians during the emergency conditions. For instance, the first tele-robotic surgery is carried out over the patients from some other remote location with the use of robotically controlled instruments. The pharmaceutical and medical researchers also need the patient's record for performing the research task. The current advancements in cloud and IoT technologies have the ability to improve the e-healthcare services [10]. Moreover, the retrieval and storage of these sensitive health care records are termed as Electronic Medical Record from cloud the hold huge privacy concern based factors specifically to recognize the patients.

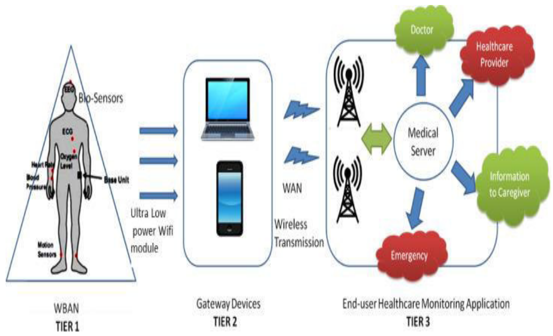

Figure 1. Generic view of IoT devices in healthcare devices (Source: Zhang et al., 2018)

The data privacy is based on four different types: 1) personal information based privacy that refers to data privacy; ii) personal behavior based privacy; iii) personal communication based privacy and iv) individuals' privacy. The privacy toward the EMR cloud data should be compromised and deliberated and therefore the data disclosure is more beneficial for attackers and harms the users. Diverse techniques are considered to resolve this issue over the cloud privacy. The trusted computing, encryption techniques, effectual private information, intention hiding approaches are some tested techniques. However, the huge amount of data and the process of attaining mis-management with cost factors, query support constraints, computational overheads and inappropriate key usage. Henceforth, the mechanism development is utilized for handling the EMRs devoid of exposing the identities or privacies with appropriate access control techniques are needed for certain time period.

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The rest of this work is partitioned as: Section 2 is related works; Section 3 includes methodology; section 4 is results with discussion; section 5 includes conclusion with future research directions.

2. Related works

Conventionally, the centralized data management with cloud computing is examined in various health care systems. Author in [11], anticipated a centralized CC platform that facilitates the physicians to observe the patients and share the healthcare information with some confidentiality. Some other works like [12], concentrates on the use of cloud platform to process, collect and store the information in a unified format. This platform is considered as a completely central authority and trusted environment for all network entities. Subsequently, author in [13], concentrates in semi-trusted CC model and pretends to apply attribute-based encryption model for attaining fine-grained access control with data and eliminate privacy exposure for unauthorized parties. Specifically, various authorities are used for governing successive user subset for role attributes.

Moreover, some works like [14], gives more attention for modeling block-chain based access control for enhancing medical records migration towards cloud-based platforms. Specifically, the progressive block-chain technology was used for facilitating the EMR access towards the identity of membership and verification authentication. Subsequently, data sharing was executed with lesser overheads, scalability and privacy protection. Some works like [15], concentrated on certain block chain nodes and some normal nodes with veto power and voting rights correspondingly. They jointly show the determination of uploading the healthcare data which is acceptable and valid. The objective is to fulfill the modifications towards the prevailing healthcare data that are traced and validated. However, certain prototype is executed with block chain based systems successively like MedRec and contract based clinical trials.

By multiple edge server scheduling process, the authorization established collaboratively to deal with the network based healthcare data in a completely decentralized manner. The task managing is achieved by on-demand secure provisions. In edge computing, the complex processing of this procedure is dealt with the healthcare data that is shifted with edge servers. However, the supervised access control is easily facilitated for facilitating external entities, for instance, data miners and healthcare service providers for accessing healthcare based data with higher security considerations.

For authorized data access to healthcare data, the miners pretend to run huge data mining algorithms with edge servers. The server exploitation is resourceful to deal with execution time and to improve the accuracy of data rate in mining process. With the negotiation of users with data trading, the appropriate decision making towards data miners capability is improved with renting proxy servers are to assist interactions with users.

3. Methodology

This section discusses about the E2E architecture of IoT platform for providing solution to healthcare system. This system comprises of four modules like sensing, transmission and layers based transmission as in Fig. 2. The former later comprises of certain network devices and sensors concentrates in the health information for processing and transferring data to successive layers. These devices constantly observe the parameters like temperature, blood pressure, heart rate and other parameters. The sensors are accountable for data transmission, and notifications to carry out necessary actions.

The communication layers comprises of number of connected nodes termed as edges that are accountable for data reception from sensors to IoT devices and process them locally, examine it and examine the health care patterns and report it to them. The edges show communication, storage, processing, and controlling units to acquire lesser delay. The communication module works as interface among the connectivity components over all the layers of communication. The controllers are used for transferring data from sensors to other and forward it to successive layers. The storage unit is nothing but huge database systems that can hold massive amount of data for shorter time period.

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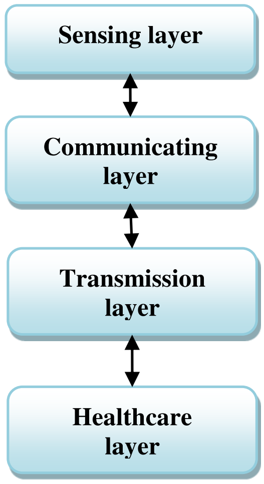

Fig 2: IoT layers for communication

To attain better scalability, it is necessary to assist diverse kinds of connection components. This needs support to other network protocols for both wireless/wired connections among the network. The communication module is accountable for handling security and data along with the crucial issues to networked systems among the end systems. There are certain systems that are considered to eliminate attacks. The DC is executed over this layer that provides promising outcomes like holding the healthcare data repositories. The database comprises of three features like integration with other devices, data analysis and decision making system with medical practitioners and other parties. The data comprises of analysis with diseases for prior prediction. This is achieved with the database system like relational database that are adopted for various system levels.

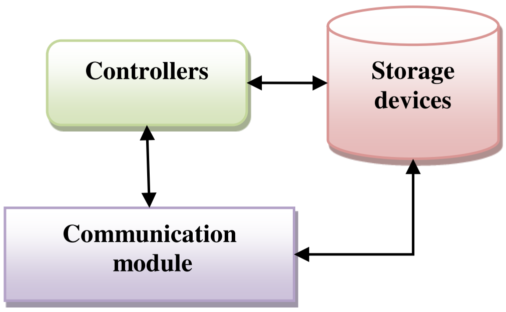

Figure 3. Architectural model

The architectural model of the anticipated model is given in Fig. 3. There are certain services provided by the healthcare systems like medical record management services and healthcare monitoring. This system is designed and organized as sub-systems. The components are deployed with overall design model specifically for sensing and storing. The IoT device gathers the healthcare data and forwards it to edge devices for data prediction and analysis. The reports are given to patients through PC, mobile or tablet. This unit is accountable for offering certain medical services to patients through data storage system to store and retrieve medical information. This system is responsible for processing and analyzing health data and mining to offer needed information.

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For constructing a complete end system, diverse data structures are produced with appropriate flow over the considered system. This system comprises of various IoT devices, where sensors are connected with heterogeneous environment. The device can process and store huge data to facilitate system for delivering services with terminal parts. The centralized database is used for storing data and assists in decision making. The system is not provided for simple application which is used in certain location. This system comprises of distributed system that are merged with other devices. The sub-system deals with certain healthcare data devoid of acquiring access with centralized information.

The database aims in analyzing and collecting data with high efficiency. Subsequently, it is essential to adopt flexible data to conventional database format. This system is more dynamic. The model is required for handling machine generating system. The characteristics are assisted with the system executed by device implementation. The healthcare information is gathered from various systems for monitoring the devices and the partial data is needed for the device units to carry out processing and making appropriate decisions. The end device receives huge amount of network data to storage and retrieve data for making further decisions. There are diverse benefits with relational data where its ability and robustness to deal with huge data. The medications and scan reports are not provided very frequently. The aim is to store and retrieve data from health records. The records comprises of historical attributes to diagnose the disease. This system holds medical information from diverse sources like device sensors, address, personal information, progressive notes, and lab reports, past history and family histories.

It is noted that diverse information are used for multiple formats and structures. Therefore, it is not accountable to distribute data to electronic records as dynamic schemes. Then, the data is migrated and centralized with data storage. The database requires the ability to interchange and merge data among the data schemes to the edge devices. This assists in updating the information and adequately supports in decision making with diverse sources over the networks. The strategies used for data construction holds the comprehensive medical records. The hospitals comprises of various departments. These departments provide information for transmission. Subsequently, some general health information offer services like elderly services, tumors and treatment process. There are certain units that prevail over the hospital to serve various kinds like pharmacy, laboratory and radiology.

The basic concern towards the data is to eliminate privacy violations and provide appropriate solutions when handling the individual data to miners. The users take appropriate data to grant access for privileges. The sensitive information requires privacy preservation. The sensitive information towards healthcare data comprises of users name, ID, and communication details. Recently, the data anonymity is extensively applied to eliminate or modify identifiers. The sensitive information is achieved with privacy preservations. It collects intersecting data from users for carrying out mining tasks. It is acquired from data collection over the network and distributes it to servers to eliminate users for performing data trading in every region. This promotes decentralized data. It needs rewards from local users with incentive. This incentive is eliminating potential risks in privacy and economic to stimulate users.

Based on these principles, the decentralized data among the miners and users is provided with the use of servers. The trusted server acts as a broker for mining data and realizes the request from collected data. The server assists in providing appropriate ownership for the data. Subsequently, the users deal with the server to eliminate unauthorized access and to carry out data modification before publishing data to mining. The server notifies data holders regarding data request by communicating with the users proximally. The servers assist in transmitting reward policy to data owners. At last, the data is gathered from edge servers. The miner allocates the server for mining and tasks the results from individual servers. The servers are crucial for coordinating decentralized data among the users and miners with proper care.

4. Numerical results

Here, simulation has been done with MATLAB simulation environment by constructing a private cloud to make appropriate replication function and for executing privacy based modeling. File availability, replication and limitation related to data replication. Mathematical modeling of data replication is anticipated here. Table I depicts simulation setup of proposed model.

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Table 1. Parameter setup

Parameter	values
Total DC	1
Cost	500
MIPS	2000
Bandwidth	5-10 GB
Total VM	200
RAM	02 GB
Cloudlet	1000 task
Task length	2000
Total files	3
Cost based replication	500
Total users	50

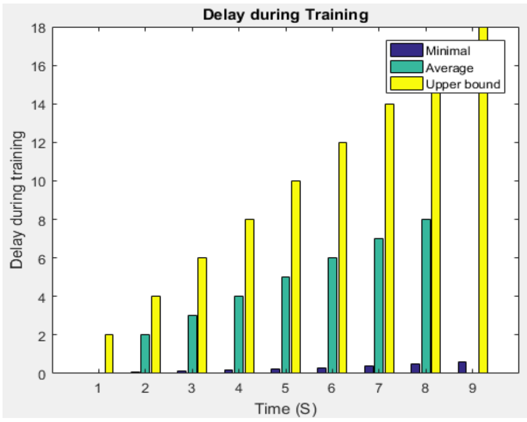

Figure 4. Delay tolerance

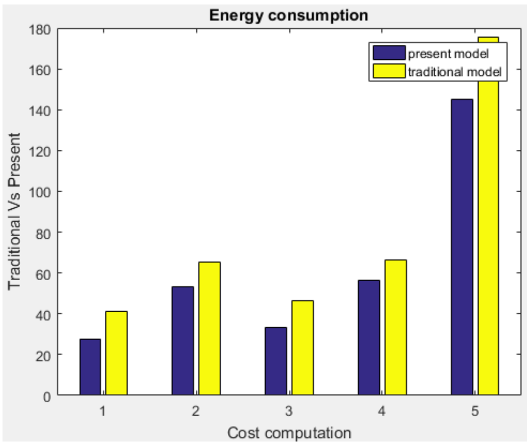

Figure 5. Energy consumption based cost estimation

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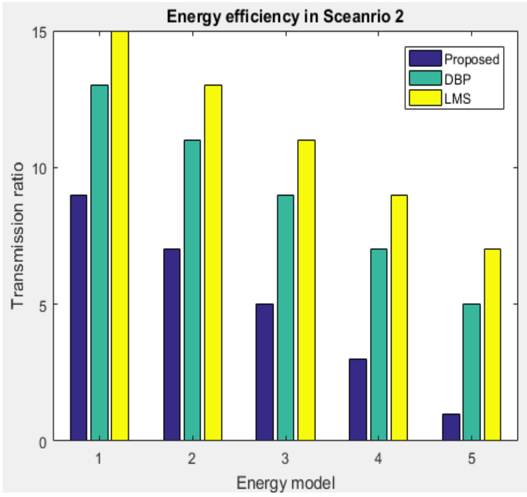

Figure 6. Energy efficiency in Scenario 2

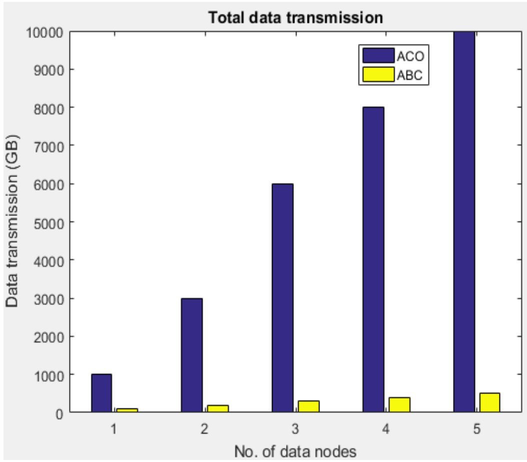

Figure 7. Total data transmission rate

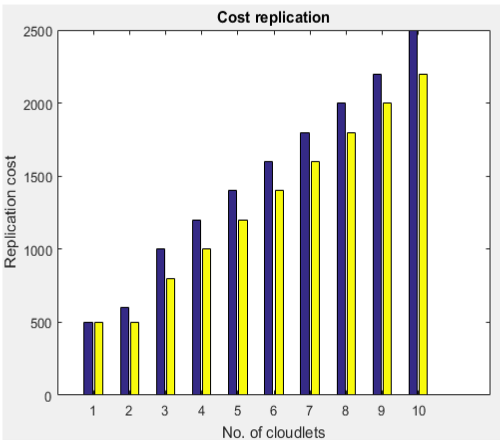

Figure 8. Cost replication

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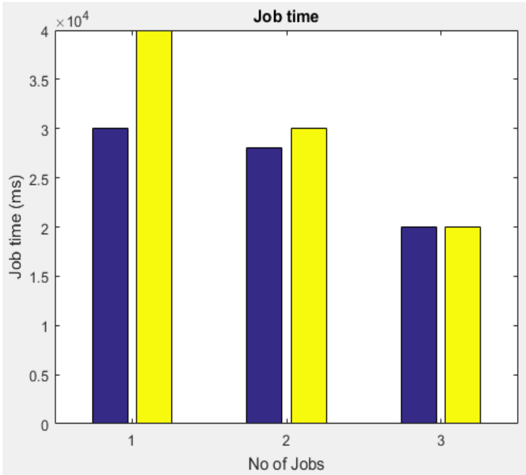

Figure 9. Average job time Vs job number

Fig 4 depicts the delay tolerance of the IoT devices for retrieving data from the source. The anticipated model has the ability to deal with delay. Fig 5 depicts the energy consumption of the devices along with the cost estimation. Fig 6 depicts the energy efficiency of the node connectivity with the end devices. Fig 7 demonstrates the data transmission rate of the node from source to destination (E2E) devices. The cost replication of this model is comparatively lesser than the prevailing approaches. This model pretends to boost the privacy by eliminating the violations. The attackers make the user to violate the rule and dissolve the privacy and security factors. Fig 8 depicts the average job performed over the devices and the total completed tasks from the network model. The anticipated model gives better trade-off in contrast to other models.

5. Conclusion

The anticipated model for healthcare system is to offer privacy over the data stored in cloud environment with the use of IoT technologies. The requirements for maintaining the privacy with healthcare data is secrecy, energy efficiency, transmission rate and cost. This healthcare model provides superior QoS requirements like lesser overhead and lesser bandwidth utilization, reduced delay and service availability. The anticipated model helps to enhance the multi-cast communication over the network environment with diverse privacy providing factors and reduces the packet drops by constantly monitoring the layers of communication environment. This model offers secure healthcare communication. In recent times, it is generally surgical processes that are monitored by the physicians remotely. With this condition may harm the patients under treatment, when it moves to distributed environment. Therefore, the anticipated model is more compatible with the available layer monitoring and offers a faster and secure accessibility over patients' data with higher reliability and accuracy with healthcare and information system. In future, the process optimization is considered for validating the global solutions for measuring data transmission with IoT.

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Chapter 12
FUSION BASED LEARNING APPROACH FOR PREDICTING DISEASES IN EARLIER STAGE

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Abstract- The recent enhancement encountered in healthcare systems, total amount of healthcare data are raised drastically in diverse factors. These sorts of data are generated from diverse sources such as mobile, digital fields and wearable devices. Big data may provide suitable opportunities for data analysis and improvement in health care based services through rising technologies. The ultimate objective of this investigation is to construct a structural mathematical model to improve disease prediction with fused nodes using learning approaches. This node is based on information model for developing certain prediction systems. Learning may in co-operates various difficult approaches like neural network, Bayesian model for extracting data and logical inference. This learning model may combine information paradigm which can be cast off to offer reliable and comprehensive prediction model for healthcare data. With this anticipated model, an experimental analysis with mathematical illustration is provided here. Analysis is done with MATLAB environment for projecting the functionality of anticipated model.

Key terms- Big data, learning model, neural network Bayesian approach, structural modelling

12.1 Introduction

The ability of digital healthcare services is to change complete healthcare process to be more appropriate and effectual patterning. Generalized form of digital healthcare models includes mobile devices, health records and wearable health devices.

Initially, these health records are sourced from check up by patients and diagnosing patient's data. Digitalization may offer health based record sharing over diverse organizations. With these records physicians may show superior concern towards medical history of patients. Moreover, when data gathers over time, these records may gather in larger volumes. This leads to complexity in storing, processing and retrieval. Certain estimation based on these records provides higher information. With association with mobiles, apps that are accessible for numerous functionalities like assessment, decision support system, practical management, treatment and care. Wearable devices may provide fastest growth in changing conventional health care activities and constant health management. Various investigations may estimate wearable devices may attain global functionality. Sensors embedded in those devices may facilitate attainment of healthcare data. For instance, blood pressure and heart rate can be identified using smart phones. With rapid growth in these data, investigators may determine improved value to merge learning and fusion for examining huge amount of data. Learning facilitates Machine learning models at various levels to be cast off diverse non-linear functional layers. Fusing information may constantly facilitate attainment of appropriate data to acquire awareness that may offer decision making functionality.

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With faster growth towards data, investigators may determine rising value of learning and fusing information for examining enormous amount of data. This learning model may utilize continuous procedures to acquire appropriate information to attain essential awareness for assisting decision making support system. With advent healthcare approaches like age associated crisis and chronic diseases, investigators are constantly acquiring solution for predicting diseases and diagnosis in more appropriate manner. With fusion approaches using healthcare data to offer viable outcomes has turned to be prime industrial topics. This investigation attempts to offer an improved structural model for constructing risk prediction model with integration of learning and fusion based approaches.

Various investigators have started to analyse diverse perspectives of heath data from diverse available repositories and to make appropriate decision for predicting disease. Moreover, constant development shows an ability to maintain infancy. Here, overall functionalities and approaches are provided for modelling and examining health care data that are more appropriately developed. Traditional data mining techniques may encounter drawbacks with efficiency and accuracy owing to its constraints towards data processing and quality. Numerous traditional models may feel complexity in examining data context. In certain environments, this idea is considered to be extremely complex. Specifically, when it under goes functional dependencies with complex nature, it shows inability to express data in simpler manner. Industrial model may offers advanced approaches that facilitate information extraction from unstructured data in larger volumes.

The remainder of the work identifies research ability of learning and health data. Section II offers proposed methodologies, Section III explains numerical results and discussions and section IV depicts conclusion of anticipated model and future work directions.

12.2 Methodologies

Healthcare industries have gained potential advantages gained from data analytics. It has extensive investigation of architectural model and execution of data in health care industries.

12.2.1 Architectural design: The essential need of data analytics is to handle variety, volume and data velocity that commences from source for sharing context. Data will be generated and stored in various sources like relational databases, documents, XML and so on. Changing these datasets towards sharable and understandable form needs services that has to be collected, processed and prepared from those datasets. Architectural modelling of big data is healthcare is alike of conventional data analytics model that performs references towards conventional data analytics. There are diverse attempts that have been made towards healthcare domains. This system comprises of five layers: 1) data 2) aggregation 3) analytics 4) exploration 5) data governance.

12.2.2 Fusion model: By merging this differentiation, fusion may carry out mining to dimes uncertainty and acquire superior functionality of information. By adopting these statistics, this work may offer numerous approaches for fusing information. For instance, Bayesian classifier is used. This fusion approach is cast off to gain inference regarding event identity in observation space. This may uses probability distribution for fitting model towards unobserved and observed data. It process may be applied to merge information sources. While processing inference, Bayesian fusion procedure for all data sources may offer hypothetical observation and source based process. Hypothesis like $H^n(k = 1,2, \dots n)$ is cast off to compute probability of every entity with functionality $P(H^k|O_i)$, where $'i'$ specifies data types and O_i is data source entity. Data source probability may be merged with bayesian inference. Output may be merged with probability of $P(H^1, H^2, \dots, H^n|O_i)$. this logic is cast

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to optimize merged probability when there are constraints on last outputs. This procedure is termed as fusion identity. Ground truth of inference is based on rules with probability grounded on reasoning. This may be computed with hypothetical probability on event which is provided as in Eq. (1):

$$P(H|E) = \frac{P(H,E)}{P(E)} \quad (1)$$

Where $P(H,E)$ is intersection probability of hypothesis and event $'E'$. This classifier inference is provided as in Eq. (2):

$$C_i = \arg\max_{c_i} P(C_i|x) \quad (2)$$

Where $C_i(i = 1,2,\dots,m)$ specifies $'m'$ class set, $P(c_i|x)$ is posterior probability and $'x'$ is unidentified feature vectors. These attributes are provided based on its class for all its maxima probability. This rule may facilitate appropriate computation of prior probability for diverse unknown event when probability evidence regarding event are determined. Assumptions are known based on unknown event and proofs are independent. Moreover, there are numerous unknown events and diverse evidence. Henceforth, this work is initiated to specify joint probability between provided variables by DAG, where nodes may specify directed edges and random variables which specifies dependencies among variables. This structural model is termed as DAG. Joint probability is depicted as in Eq. (3) – Eq. (5):

$$P(U) = P(X_1,..,X_n) \quad (3)$$

$$P(U) = \prod_{X_i \in U}^{1} P(X_i|X_1,\dots,X_n) \quad (4)$$

$$P(U) = \prod_{i=1}^{n} P(X_i|P_a(X_i)) \quad (5)$$

Where $U = \{X_1,\dots,X_n\}$ is random variables set termed as universe and $P_a\,(X_i)$ is parental variables of DAG. Nodes in graph to factor $P(X_i|P_a(X_i))$. This network is fusion method that is more appropriate for uncertainty measurement for property extraction with graphical structural and calculus probability. Association among these models are $\{X_1,X_2,\dots,X_M\} = \{X_{m+1},X_{m+2},\dots,X_n\}$ where nodes specify edges and variables in direct specification. Probability distribution of network is depicted as in Eq. (6) – Eq. (9):

$$P(X_1,X_2,\dots,X_mX_{m+1},\dots,X_n) = \prod_{i=1}^{n} P(X_i|p(X_i)) \quad (6)$$

$$P(X) = \prod_{i=1}^{n} P(X_i) \prod_{j=m+1}^{n} P(X_j|X_1,\dots,X_m) \quad (7)$$

$$P(X) = \prod_{i=1}^{n} S(\{X_i\}) \prod_{j=m+1}^{n} \frac{P(\{X_j,X_1,\dots,X_m\})}{P(\{X_1,X_2,..,X_m\})} \quad (8)$$

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$$P(X) = \prod_{i=1}^{n} S(\{X_i\}) \prod_{j=m+1}^{n} \frac{S(\{X_j, X_1, X_2, \ldots, X_m\})}{S(\{X_1, X_2, \ldots, X_m\})} \quad (9)$$

Here, $'S'$ is support confidence of item set. Fusing can be based on feature selection that is extremely complex in various approaches. For instances, this recognition task over noisy circumstances is complex owing to interference of inappropriate features. These approaches can be cast off to haul out essential features.

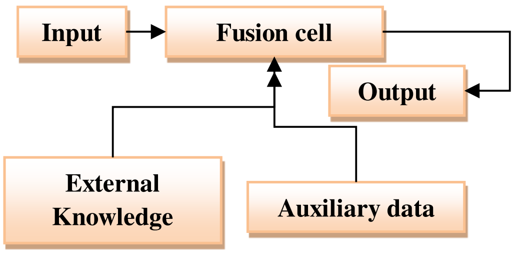

Fig 12.1: Fusion model

An associate neural network is cast off for categorizing data types. This network is trained to generate identity approximation based mapping among inputs/outputs with back-propagation model. Network with i/o nodes and hidden layers with linear activations. In training model, projection matrix is computed with input dataset for normalization. Output from network model is provided to neurons. In this non-linear process, tangent process is known as activation function. This function is depicted as in Eq. (10):

$$z = A(u) = 1 - \frac{2}{1 + \exp(2u)} \in (-1,1) \quad (10)$$

Where $'u'$ is specified as input dataset and $'Z'$ is dataset output. This may be compared with appropriate outputs of all these data types, weights may be adjusted for reducing errors. After training, weights may be preserved on fusion modelling. As data types are determined, format specification is provided as external specification that is utilized to validate identification outcomes, meta-data extraction of object files are normalized based on object content in common specification.

12.3 Numerical results

For executing Bayesian rules, feature extraction based selection is cast off for accessing libraries. Simulation has been done in MATLAB environment For modelling these networks, regression model for time series analysis in state estimation components may use libraries. Benefits of using file support and volume for higher efficiency for appropriate data access. It is utilized for handling raw data and data alignment. It may offer fault tolerance in handling huge data in sparse data. Communication among data and system is through services executed in MATLAB. To validate selection performance of CNN selection execution, this may execute CNN with learning model in SVM, k-NN for comparison. Health records may be roughly 20,000 were samples for computation. Original records are based of sample members. There may be duplicate records that are generated

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from source systems. For instance, users may upload similar data for numerous times. Subsequently, invalid records may prevails owing to malfunction systems or inappropriate software operations. Data quality is needed for fulfilling performance and accuracy of analytics. This is attained by executing filter in data alignment that may screens duplication and outlier for processing. Accuracy and kappa measures for certain execution are provided in Fig. 12.2

Table 12.1: Accuracy computation

Methods	SVM	k-NN	CNN
Duration (Min)	1248	890	1600
Throughput (r/sec)	4148	5700	3200
Throughput (KB/sec)	3380	4600	2620

Table 12.2: Overall disease prediction

Risks	SVM	k-NN	CNN
Diabetes	80	66	97
Obesity	54	85	72
Heart disease	74	85	73
Stroke	66	68	48
Blood pressure	69	53	76
Cancer	61	60	84
Overall accuracy	68	66	75

Table 12.1 and Table 12.2 depicts overall disease prediction model based on accuracy. Various diseases are analyzed here. Diabetes, obesity, stroke, heart disease, cancer and so on.

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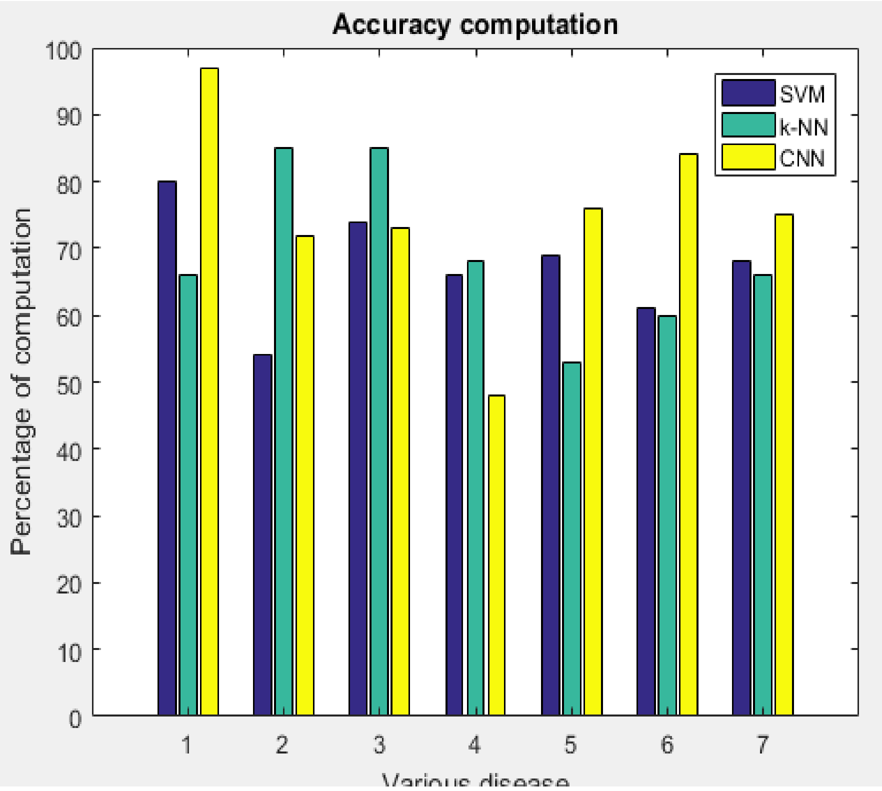

Fig 12.2: Accuracy computation

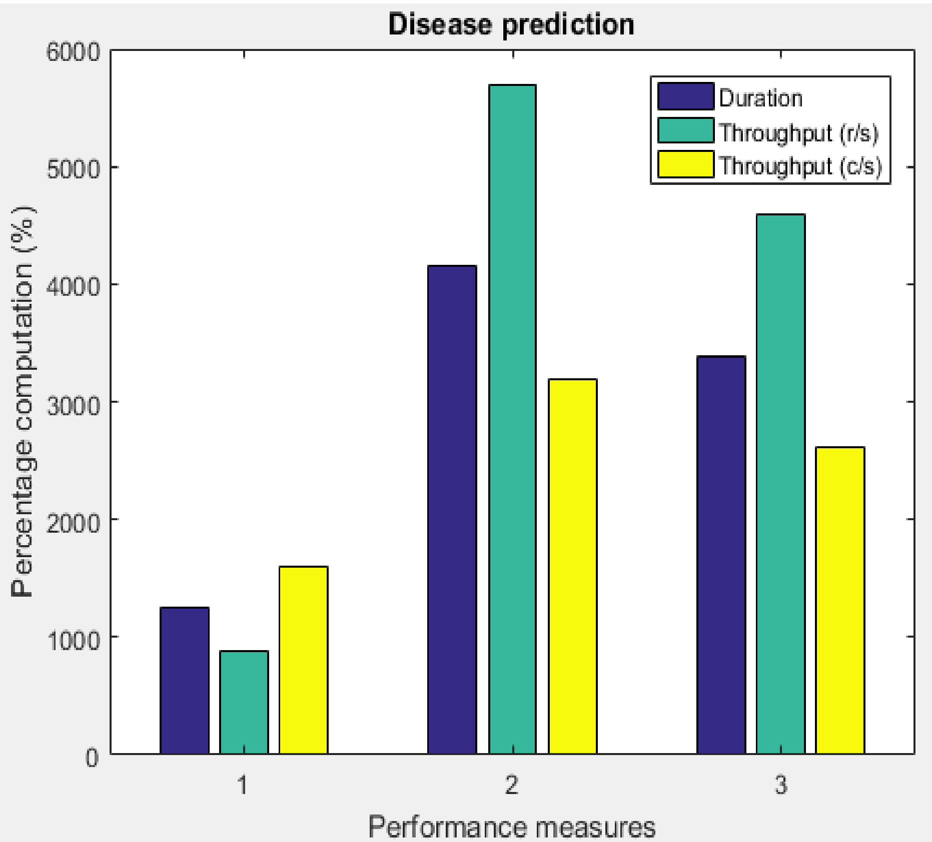

Fig 12.3: Disease prediction

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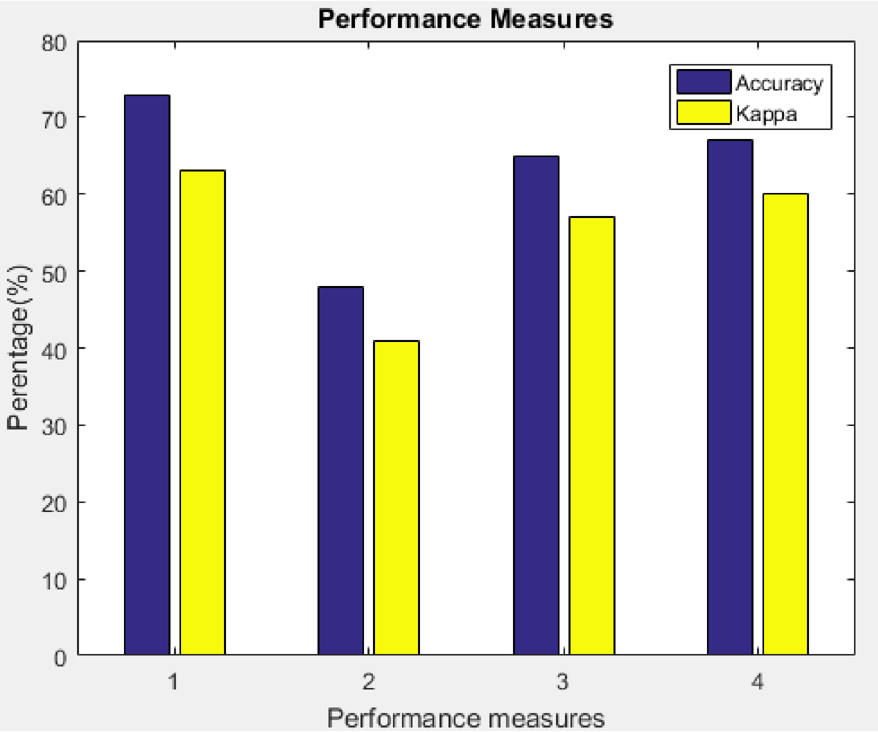

Fig 12.4: Performance measures

Fig 2, Fig 3 and Fig 4 depicts performance measures of anticipated approach. Here, SVM, k-NN and CNN models are used for comparison.

12.4 Conclusion

This investigation utilizes potential competency for using fusion concept and learning model to improve healthcare analytics, therefore this process may be done with effectual computation. In machine learning process, complex functionality has been done for enhancing analytical performance. With this learning process, it may facilitate risks to identify prediction in more appropriate manner. Here, network model has the ability to improve analysis for training accuracy. This specification has enormous training sets. This is because of analytical components and workflow. The architectural model is based on anticipated framework to organize components of analytical system to acquire fusion. In future, mapreduce concept will be used for enhancing the approach.

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An Integration of Cardiovascular Event Data and Machine Learning Models for Cardiac Arrest Predictions

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ABSTRACT

Purpose: Predicting and then preventing cardiac arrest of a patient in ICU is the most challenging phase even for a most highly skilled professional. The data been collected in ICU for a patient are huge, and the selection of a portion of data for preventing cardiac arrest in a quantum of time is highly decisive, analysing and predicting that large data require an effective system. An effective integration of computer applications and cardiovascular data is necessary to predict the cardiovascular risks. A machine learning technique is the right choice in the advent of technology to manage patients with cardiac arrest.
Methodology: In this work we have collected and merged three data sets, Cleveland Dataset of US patients with total 303 records, Statlog Dataset of UK patients with 270 records, and Hungarian dataset of Hungary, Switzerland with 617 records. These data are the most comprehensive data set with a combination of all three data sets consisting of 11 common features with 1190 records.
Findings/Results: Feature extraction phase extracts 7 features, which contribute to the event. In addition, extracted features are used to train the selected machine learning classifier models, and results are obtained and obtained results are then evaluated using test data and final results are drawn. Extra Tree Classifier has the highest value of 0.957 for average area under the curve (AUC).
Originality: The originality of this combined Dataset analysis using machine learning classifier model results Extra Tree Classifier with highest value of 0.957 for average area under the curve (AUC).
Paper Type: Experimental Research
Keywords: Cardiac, Machine Learning, Random Forest, XBOOST, ROC AUC, ST Slope.

1. INTRODUCTION :

Cardiac arrest caused by coronary artery stiffness caused by the artery that carries oxygen rich blood to the heart is blocked by cholesterol plaques [1]. These cholesterol plaques are built up over the course of period, and eventually, when one of the cholesterol plaques ruptures there is a formation of blood clots that cause a blockage [2]. Because of this blockage, blood flow is cut off and oxygen-starved heart cells in the heart muscles start to die. When all the cells in the heart die, it causes cardiac arrest or a heart attack. A normal cardiac arrest indicates symptoms before they occur, symptoms such as tiredness, shoulder pain, nausea, crushing chest pain and sudden shortness of breath [3]. Alternatively, the silent cardiac arrest can be asymptomatic, and requires a prompt medical diagnosis. The asymptomatic cardiac arrest is mainly caused

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by diabetes and other similar disorders. Patients with diabetes and other similar disorders suffer from nerve damage, and such patients are always at risk of having silent cardiac arrest. The heart sends signals, which are known as cardiac biomarkers to other parts of the body by triggering symptoms by seeking help, while the heart looses out oxygen flow. The nerve damage of patient prevents the cardiac biomarkers sent from the heart to other parts of the body and results in silent cardiac arrest. The machine learning classification techniques can be used to identify the possibilities of cardiac arrest in the patient. The process of categorizing a collection of data into groups is known as classification. Predicting the class of provided data points is the first step in the process. Classification techniques of machine learning are, Naïve Bays Classification, K- Nearest neighbor algorithms, Decision Trees, and Random Forest. Some features used as an input in classification techniques are Age, Sex, Chest Pain Type, resting BP, Cholesterol, Fasting Blood Sugar, resting ECG, MAX Heart Rate, Exercise Angina, Old Peak, and ST Slope. Using machine learning to predict cardiac arrest, initially the dataset must be loaded, then feature engineering must be performed, then feature selection, feature scaling, model selection, save the suitable model, and deploy the model [3].

2. RELATED WORK :

The authors investigated the high risk of cardiovascular disease and modified artificial plant optimization (MAPO) is applied on real life example i.e., cardiovascular disease, MAPO is a tool for measuring heart rate count using a fingertip video [3]. A determination of pulse wave velocity in an Outpatient can be used to assess the cardiovascular risks [4]. Machine learning and image fusion are used for predicting heart disease [5]. Wearable soft sensor transducer and patients interview results. Classifiers are compared with k-fold procedure. The cardiovascular status is divided into three categories: stable, non-critical unhealthy, and critical unhealthy [6]. Also, the noise robustness test is carried upon the data. A machine learning way of predicting patients with extreme dilated cardiomyopathy are more likely to experience cardiovascular events. (DCM) [7]. Prediction of risk in patients with diabetes using machine learning. A new approach for predicting Cardiovascular disorder has been developed in patients with type 2 diabetes. this model could identify the patients at high risks. The cardiovascular disease is predicted on the triage levels of the patient, and the prediction is done only at the time of triage. Atherosclerotic plaque tissues in RA (Rheumatoid Arthritis) are used for predicting cardiovascular disease in machine learning [8]. The possibility of Cardiac Arrest is predicted using machine learning classification methods. This model is specifically designed and trained with ICU data. The review summary of the related work is explained using Table 1.

Table 1: Review Summary of related work

Sl. No	Research Area	Research Focus	Reference
1	The cardiovascular disease is predicted in diabetic patients using pulse wave velocity and machine learning.	A determination of pulse wave velocity in an Outpatient can be used to assess the cardiovascular risks.	Rafael Garcia-Carretero et al. (2019) [3]
2	Artificial plant optimization technique to prevent heart disease. This technique evaluates based on MAPO to predict high risk.	This study has investigated the high risk of cardiovascular disease and modified artificial plant optimization (MAPO) is applied on real life example i.e. cardiovascular disease, MAPO is used to calculate the pulse count using fingertip video	Prerna Sharma et al. (2019) [4]
3	Machine Learning is used to detect heart rate and the possibility of heart disease.	Classification model is used for prediction.	Manoj Diwakar et al.(2020) [5]
4	Conceptual design of a wearable soft sensor based on machine learning for noninvasive cardiovascular risk assessment. The models used here is predicts the collected data from the sensor.	Wearable soft sensor transducer and patient's interview results are collected then data set is analysed using Machine learning models, also Classifiers are compared with k-fold procedure. The data	Pasquale Arpaia et al. (2020) [6]

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		is divided into three categories: safe, non-critically unhealthy, and critically unhealthy cardiovascular status.	
5	Machine Learning Solution on Spark for Using Patients' Social Media Posts to Detect Heart Disease. The social media post will help know the eating habits and life style of a patient.	A predictive framework for heart disease was developed using Apache Spark and Apache Kafka. Our real-time architecture is made up of three components: Stream Processing Pipeline, Online Prediction, and Stream Processing Pipeline.	Hager Ahmed et al. (2019) [7]
6	Clustering of heart disease and chemo informatics datasets using a machine learning algorithm.	For defined data points, the CBDCGAN + DBC approach will cluster mixed categorical and numerical attributes. The addition of synthetic samples to the training set greatly improves classification tasks, which are notoriously difficult in mixed datasets.	K. Balaji et al., (2020) [8]
7	Machine learning as a supplementary method for detecting cardiac arrest in emergency calls.	Predictions made on the quality of audio calls, and predictions performed before the end of the call.	Stig Nikolaj Blomberg et al. (2019) [9]
8	Machine learning was used to predict cardiovascular events in patients for up-coming year with severe dilated cardiomyopathy.	Using machine learning, a method for predicting cardiovascular events (DCM)	Rui Chen et al. (2019) [10]
9	A technique for predicting cardiac arrest in the patient using sensitivity analysis.	OHCA rescue system is used to predict the disease.	Samuel Harford et al. (2018) [11]
10	Out-of-hospital cardiac arrest predictions are performed. The data is collected for a certain period of time for certain locality.	A favourable machine learning model is prepared. The models help to differentiate the data set.	Yohei Hirano et al. (2020) [12]
11	Predictions of risks in type 2 diabetic patients. The diabetic data set can be sub merged with the training set.	The diabetic patient data set is evaluated for the predictions with help of evaluated data set using diabetic information.	Md Ekramul Hossain et al. (2021) [13]
12	Emergency in triage modeled for risk of heart disease. The triage helps to know the risk of cardiac arrest.	Low risk and high risk patients are predicted based on triage.	Huilin Jiang et al. (2021) [14]

3. OBJECTIVES :

The objects of this paper are;

- To detect cardiac arrest in a patient with the aid of data collected from various sources.
- To identify the possibility of cardiac arrest, caused by coronary artery disease with asymptotic or with symptoms
- To identify and analyse the possibility of heart disease using machine learning Classifier models through the collected sample dataset.

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- In the implementation phase, to find the classifier model, to evaluate which performs better than other classifier models based on the accuracy.

4. METHODOLOGY :

In this paper different dataset are considered for cardiovascular a problem which includes Cleveland Dataset of US patients with total 303 records, Statlog Dataset of UK patients with 270 records, and Hungarian dataset of Hungary, Switzerland with 617 records. These datasets are analyzed using various statistical measures.

5. DATASET :

The description of data set is briefly described in this section; we are explaining the dataset used for cardiac arrest prediction model. Also, comprehensive overviews of the dataset's structure for real-time evaluation are made.

5.1 Dataset Description

We have collected and merged three data sets, Clevel and Dataset of US patients with total 303 records, Statlog Dataset of UK patients with 270 records, and Hungarian dataset of Hungary, Switzerland with 617 records. This dataset is the most comprehensive data set with a combination of all three data sets consisting of 11 common features with 1190 records. This collection of data is used to train and evaluate machine learning algorithms. Descriptive data about our dataset are summarized in Table 2. The total 11 independent input features are described, age of the patients, age is described in years, gender of the patient either Male or Female, Male is denoted as one and female is denoted by 0, and gender is nominal variable and nominal is a categorical and does not follow any order, chest pain type is a type of chest pain what patient is experiencing, and it is categorizing in to 4 types, typical angina, atypical angina, non–anginal pain, and asymptomatic [9]. Typical anginal are chest pain, which is caused by reduced blood flow to the heart. It can be observed by an individual by a heaviness or tightness in the chest. Atypical angina, causes pain, but unrelated to heart, but it is caused by respiratory, musculoskeletal, and gastrointestinal or due to some heavy exercises [10]. Non – anginal pain is completely irrelevant to heart disease, and lastly, asymptomatic, without any symptoms. The resting blood pressure is measured in mm/HG [11]. Cholesterol measured in mg/dl. Fasting blood sugar is a Numeric variable in this dataset, here it is taken as 0 and 1.Fasting blood sugar is considered as one, if it is greater than 120 mg/dl else 0. Resting ECG is represented in 3 distinct values 0 for Normal, 1 for abnormality in ST-T wave, 2 for left ventricular hypertrophy. Abnormality in ST-T wave can be found in a heart patient and it is measured using ECG waves, left ventricular hypertrophy is, heart left pumping chamber has some stiffness and not pumping efficiently, and leads to cardiac arrest or heart attack [12].

Table 2: Patient Characteristics of Serious Cardiac Disease

Features	All Patients (n = 1190)	Patients with Events (n = 629)	Patients without Events (n = 561)
Baseline			
Age, years (mean ± SD)	54 ± 9	56 ± 9	51 ± 9
Sex, n (%) **Male** **Female**	 909 (76%) 281 (24%)	 559 (89%) 70 (11%)	 350 (62%) 211 (38%)
Chest Pain Type	3 ± 1	4 ± 1	3 ±1
Resting BP(mm/HG)	132 ± 18	134 ± 20	129 ± 16
Cholesterol	210 ± 101	191 ± 120	232 ± 70
Fasting Blood Sugar (mg/dl)	0.2 ± 0.4	0.29 ±0.45	0.11 ± 0.32
Resting ECG	0.69 ± 0.87	0.63 ± 0.86	0.75 ± 0.86
Max Heart Rate (bpm)	137.7 ± 25.5	129 ± 23.7	150 ± 22.7
Exercise Angina	0.38 ± 0.48	0.60 ± 0.48	0.13 ± 0.34
Old Peak	0.92 ± 1.08	1.33 ± 1.18	0.46 ± 0.73

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ST Slope	1.62 ± 0.61	1.91 ± 0.51	1.29 ± 0.53

Maximum Heart Rate is calculated in Numerical Values [13–15]. Exercise angina is feeling of pain after an exercise and it is a nominal variable, if pain is observed then 1, else 0. The old peak is exercise induced ST depression compared with the state of rest. Then, the ST slope measured in terms of slope during peak exercise as shown in Fig.1, they are three types, up sloping, down sloping and horizontal. After peak exercise, for a normal patient blood pressure will be up sloping, if the blood pressure of the patient is down sloping or horizontal, there is a possibility of cardiac arrest in future or it can be observed that the patient has heart disease [16–20].

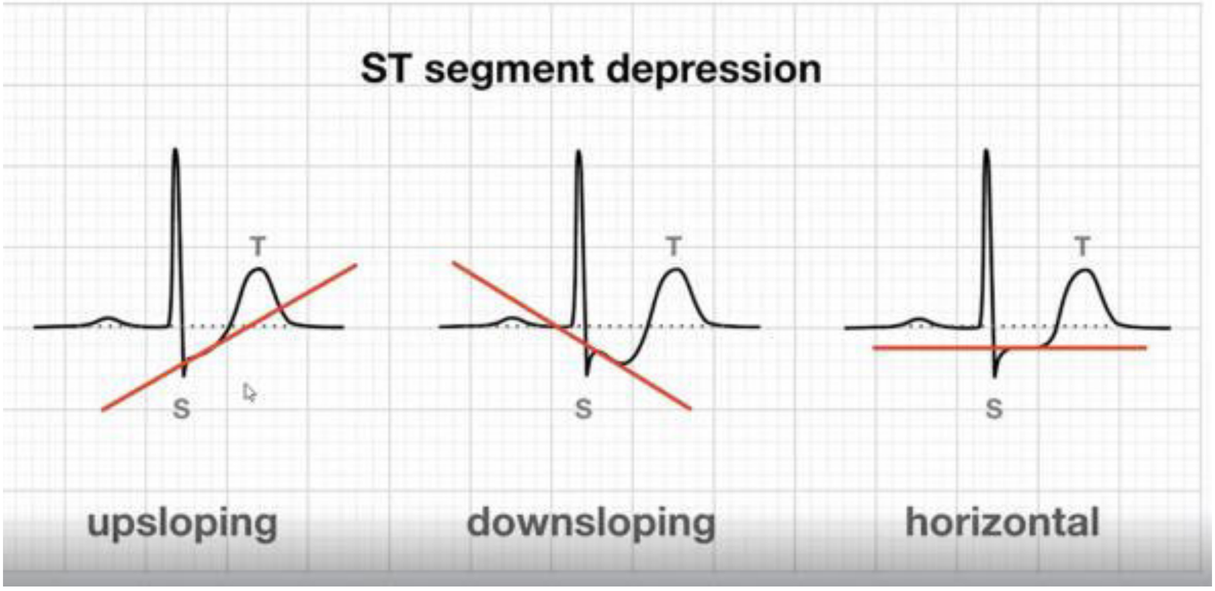

Fig. 1: ST - Slope depression

5.2 Building the Classifier Model using the dataset

The main goal of building model is to use several machine learning algorithms to achieve the highest accuracy. Model building consists of different stages : a) Data Pre-processing, b) Exploratory Data Analysis, c) Outlier Detection & Removal, d) Training and Test Split, e) Cross Validation, f) Model Building, g) Model evaluation & comparison, h) Feature Selection, and i) Model Evaluation.

a) Data Pre-processing

Data pre-processing are an essential step in machine learning to represent data suitable for the algorithms and classification. In this work, we have included necessary data pre-processing, such as missing values removal, feature encoding, and then transformed in to categorical variables and the generation of baseline characteristics of the study sample known as and prediction variables are given in the Table.2, and baseline characteristics are generated using a statistics tool R studio.

b) Exploratory Data Analysis

In this stage, we have analysed the shape of the dataset and generated the statistics of numerical and categorical features as shown in Table 2. And we also checked whether the selected dataset is balanced or not, as we can see in Fig. 2. The percentage of heart patients in data is balanced.

In this dataset (figure 2), 53% of patients are heart patients and 47% are normal patients. In addition, in numerical terms, the number of normal patients is 561 and number of heart patients are 628.

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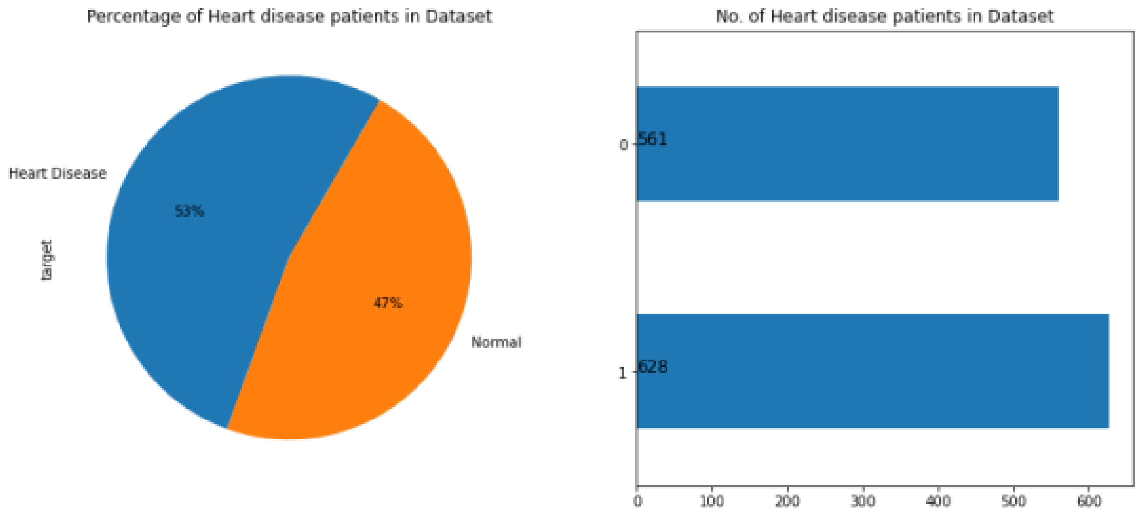

Fig. 2: Percentage and number of Heart disease patients in dataset

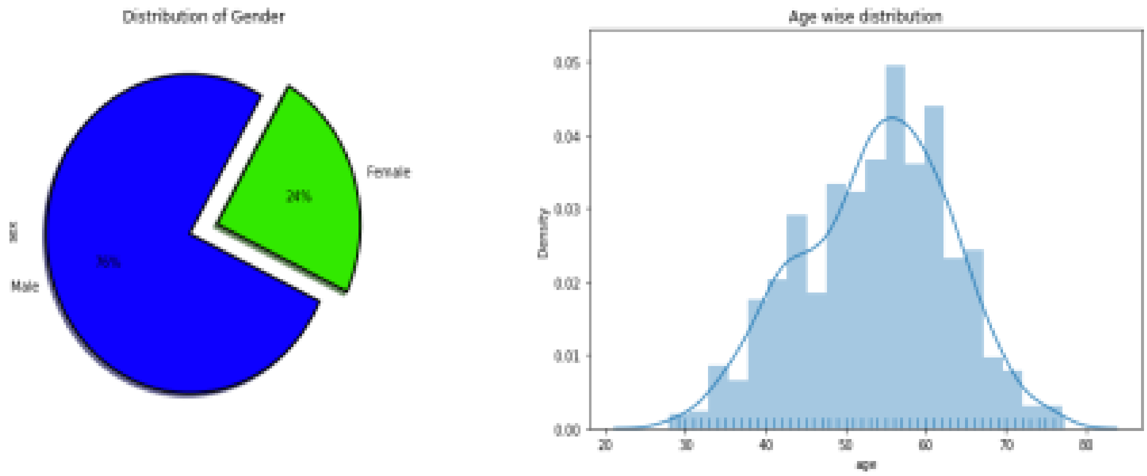

Fig. 3: Distribution of Gender and Age

The demographic part of the patients is also analysed based on the statistics generated in Table 2. The demographic analysis is performed on the age and gender of the patients, as shown in Fig. 3, showing that 76% of the distribution is male and 23% of the distribution is female. In addition, in the age wise distribution, mean age is 54 years. In Fig.3 the age distributions of healthy patients are shown and mean age is 51 for normal patients. In addition, the gender distribution of male and female is shown in Fig.3, as it is observed that numbers of normal patients are high in male patients.

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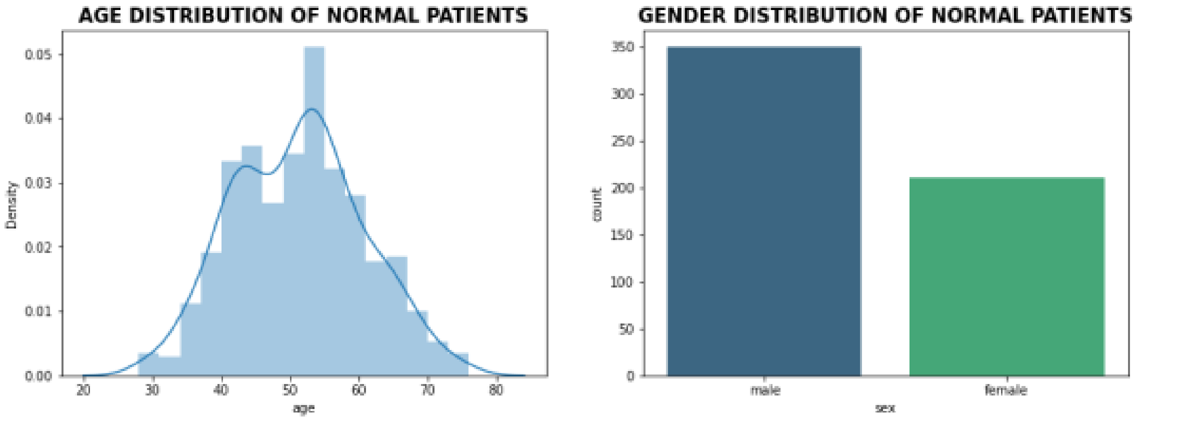

Fig. 4: Distribution of Gender and Age for healthy patients

It is also observed in Fig.4, the age distribution of heart disease patients, which is high at the age of 56 and 60. And in the gender distribution of heart disease patients, it can be observed that male patients have a high risk of heart disease. In addition, female patients are low in number compared to males.

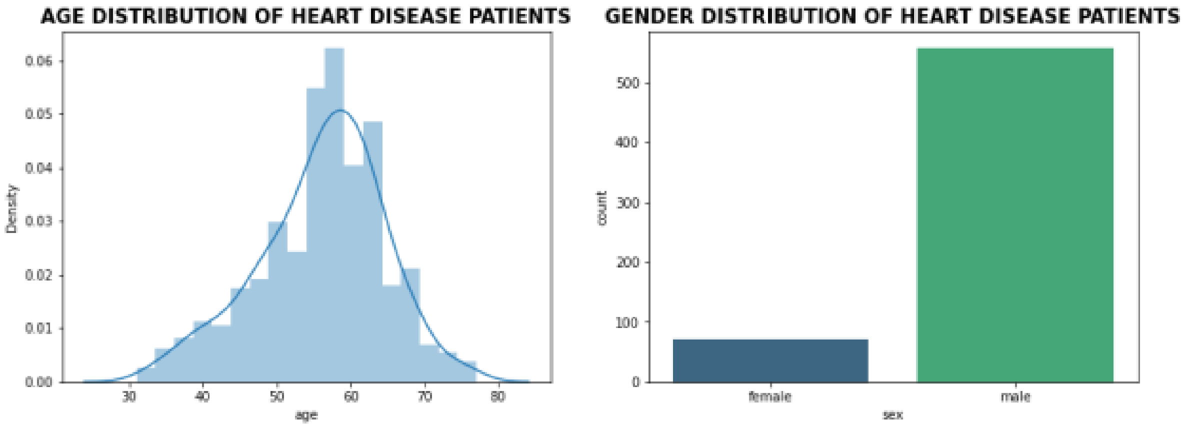

Fig. 5: Age and gender distribution of heart disease patients

The chest pain of healthy patients is analysed in Fig.5, and all the four types of angina are analysed and it is observed, and shows that typical angina of normal patients are less. It is mainly observed that asymptomatic angina is high in heart disease patients. The ECG of normal and heart patients is compared, as shown in Fig.6, and it is observed that rest ECG of healthy and heart patients is normal, left ventricular hypertrophy and ST wave abnormality is much higher in heart patients. As shown in Fig.7, the ST slope of normal and heart patients is also analysed, after the exercise and if the patient has heart disease ST slope will be either down sloping or flat [21–25]. So, in our analysis, it is observed that ST slope of normal patients are up sloping and ST slope of a heart patient is flat. The distribution of numerical features in terms of pair plot is analysed in Fig.8, and in pair plot we have plotted based on the pairs cholesterol, resting blood pressure and age, as shown in the scatter

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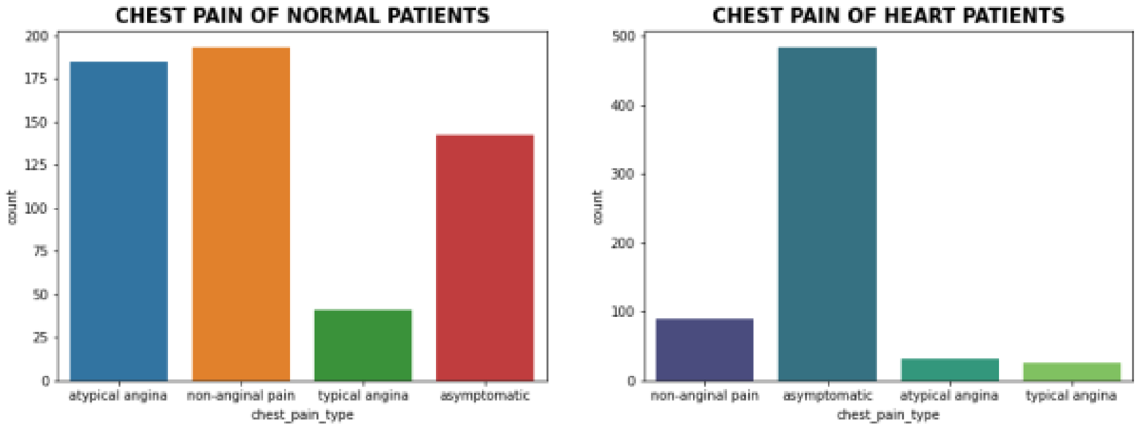

Fig. 6: Anginal pain analysis of normal and heart patients

In pair plot analysis (Fig. 9) it is observed according to the dataset, as age increases the chances of cardiovascular disease and cardiac arrest risk increases. It is also observed that in terms of peak in age, the risk is higher when age of patient is more than 70. After the observation of scatter plot, the pear analysis done for resting blood pressure and Cholesterol, as shown in Fig.8, in this scatter plot, it is possible to see the outliers clearly, and it is observed that some of the patient's cholesterol and blood pressure is zero.

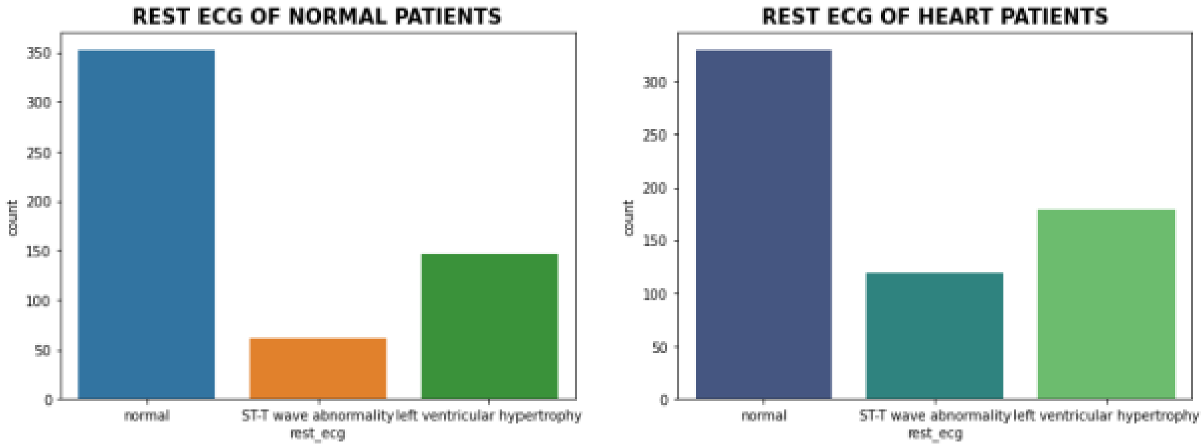

Fig. 7: Rest ECG analysis of Normal and Heart Patients

c) Outlier Detection and Removal

The outliers can be removed and rectified from the data using the Z score, and outliers are sometimes unusual or usual data, it can be detected and filtered using Z score. After that data are segregated into features and target variables. After the segregation, the analysis is also done to find the correlations of the features with the target variable i.e., diabetes, as shown in Fig.9, in the correlations, it is observed that some values are positive and some are negative, and it can be observed that ST_SLOPE Up sloping is negative and ST slope Flat is positive. ST slope flat has correlations with the diabetes and this positive.

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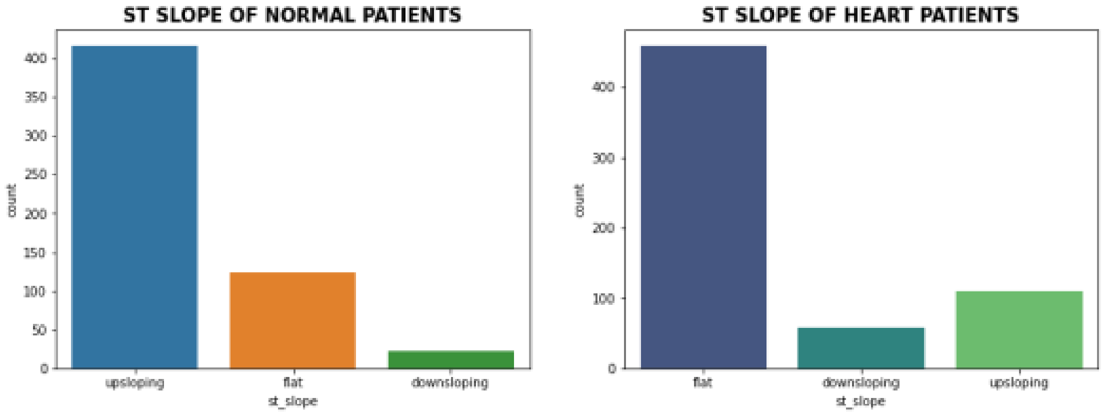

Fig. 8: ST slope analysis of Normal and Heart Patients.

The correlation shows the possibility of cardiac arrest in the patient. And ST_slope value is closer to 1 so it is positive, and some other positive correlative variables are, ST_Slope down slop, rest ECG left ventricular hypertrophy, sex_male, ST depression, exercise-induced angina, fasting blood sugar, resting blood pressure, and age.

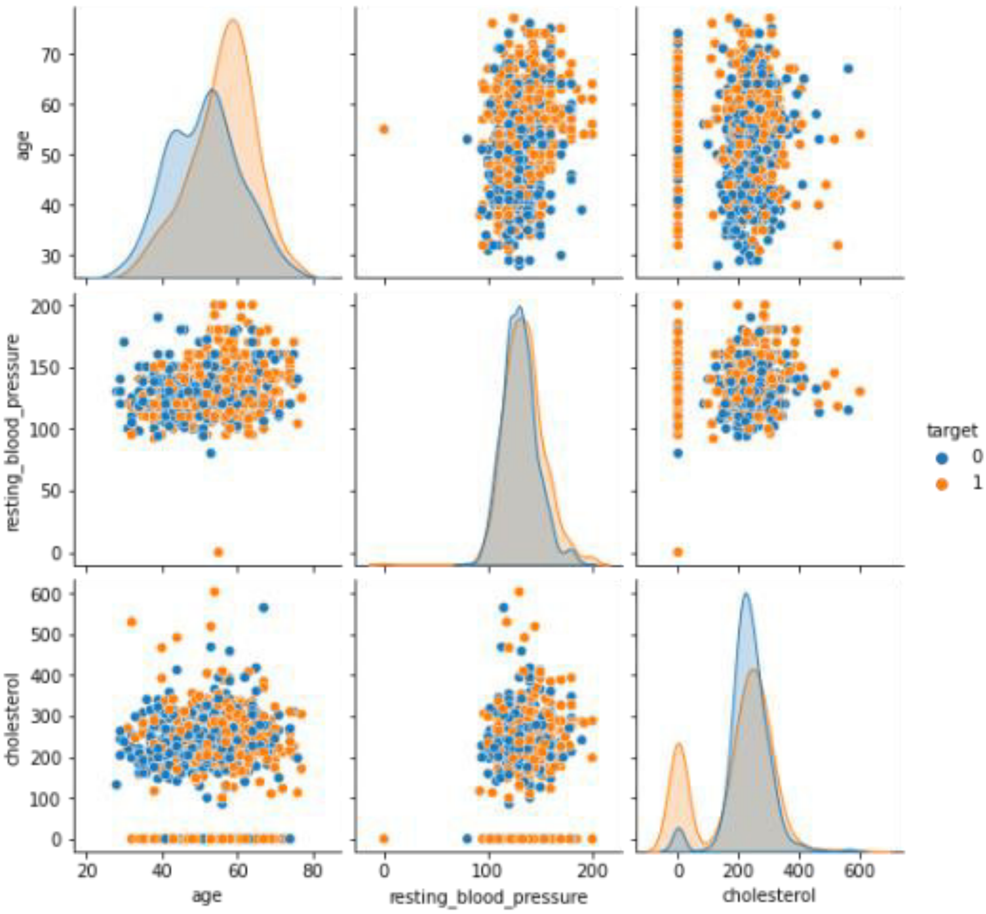

Fig. 9: Pair plot analysis of Patients.

d) Training and Test Split

In the next phase, further analysis preferably can be done by performing train-test split of the dataset. Here, 80% is used as training data and 20% as testing data. The distribution of the target variable in the training

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set is, 491 is heart patients and 446 is the number of healthy patients. In addition, in the test kit distribution of target variable,

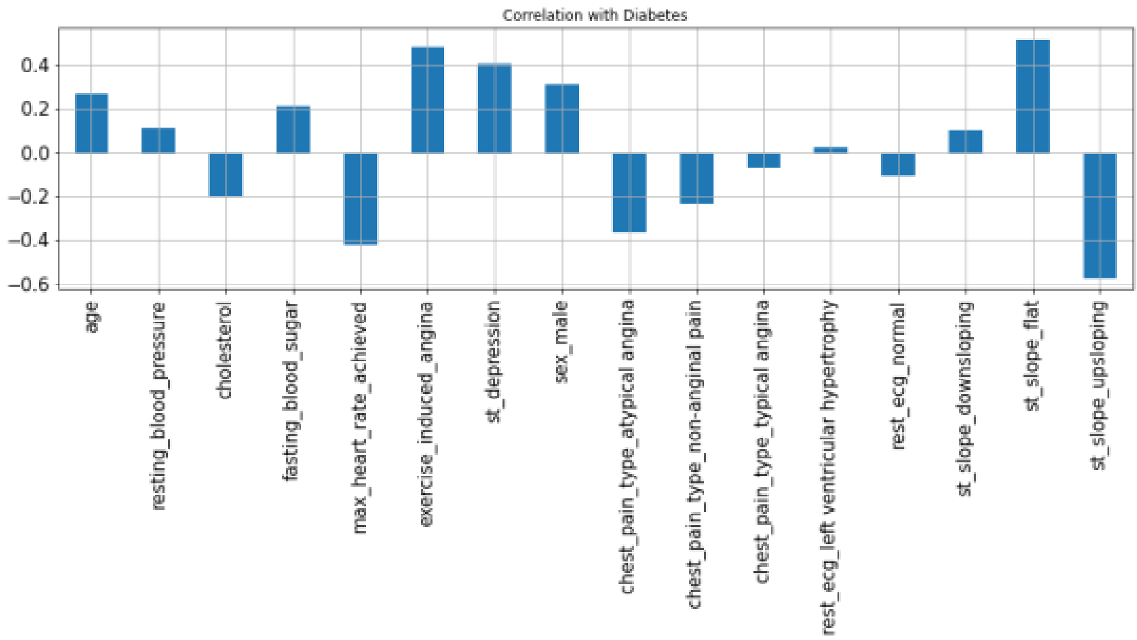

Fig. 10: Correlations of all features with the target variable.

Heart patients are 123 and normal patients it is 112. In, training set total 937 and in Test kit 235 patients are included. After this phase, feature normalization is done

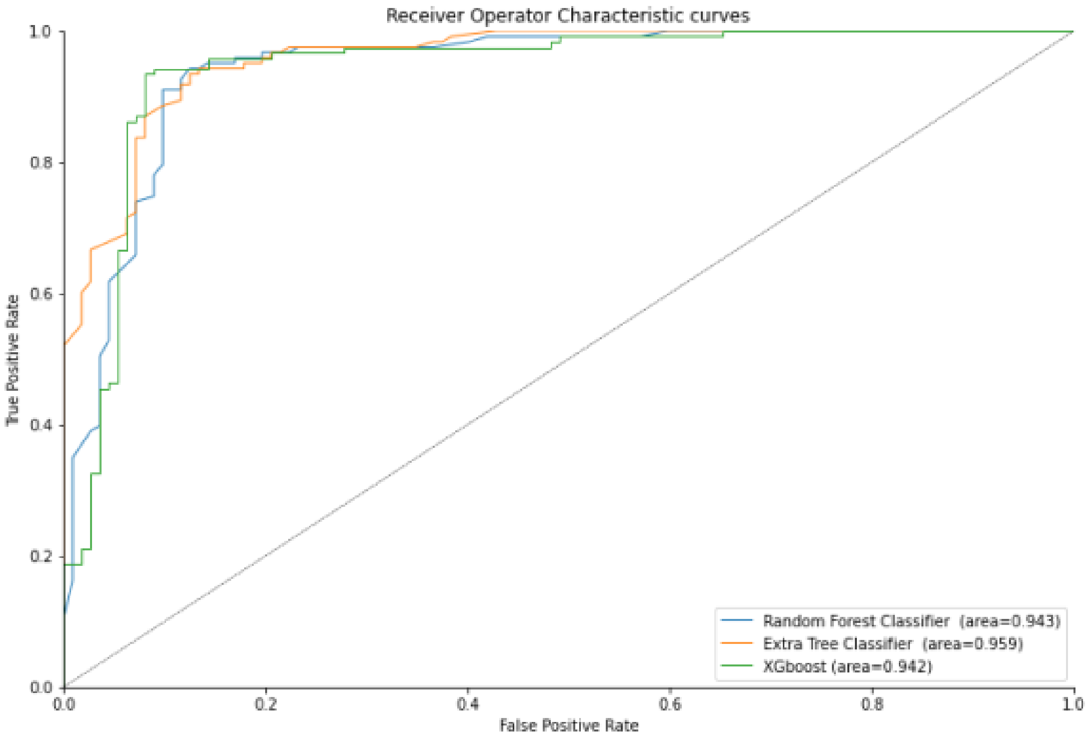

Fig. 11: ROC AUC curve.

The using MinMax Scalar method. We have used feature-normalization because, in the dataset the values are stored as either 0 or 1 for most of the variables. After the implementation of MinMax Scalar

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normalization method for feature scaling [26], and we have selected only variables continuous from the training set, such as age, resting blood sugar, cholesterol, max_heart_rate_received, and st_depression, and these features are scaled down in the range of zero and same is applied to the test set.

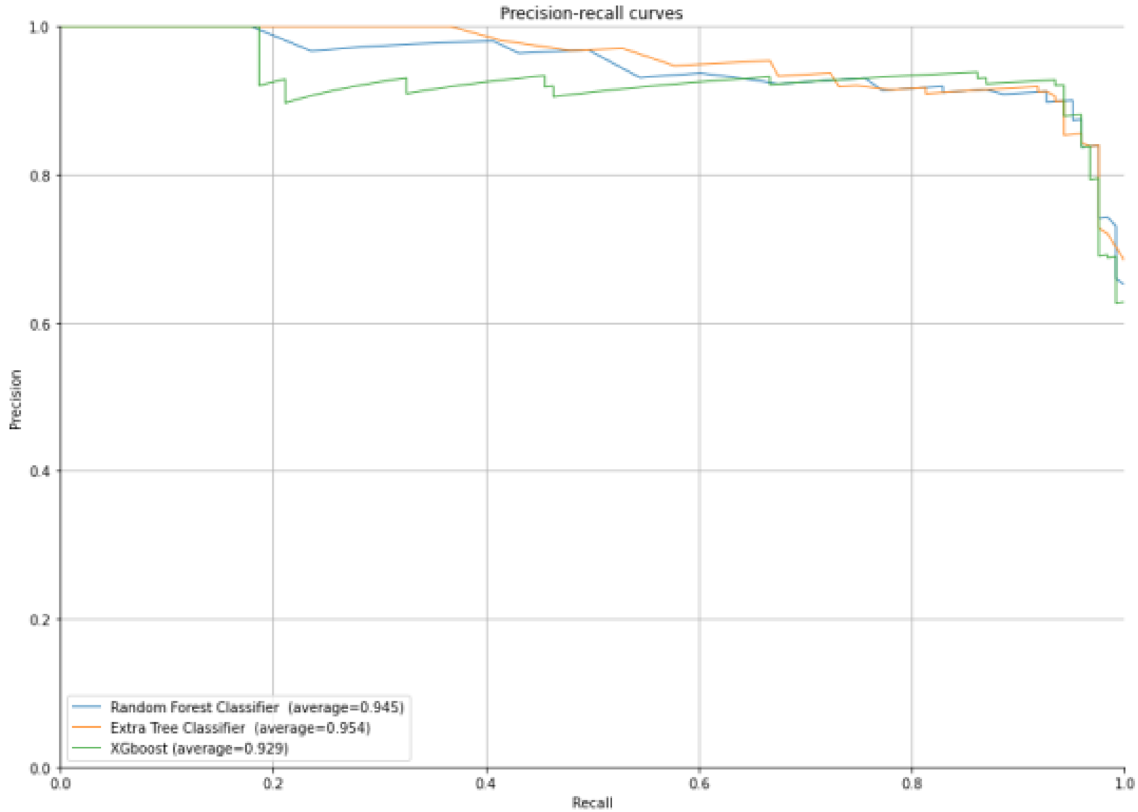

Fig. 12: Precision Recall curve.

e) Cross Validation

We construct different baseline models in this process and use 10-fold cross-validation to filter the best baseline models for use in level 0 of the stacked assembly system. Here, we have used all key machine learning algorithms. Various numbers of trees are used in classifiers to analyze the classifiers and performance is compared.

f) Model Building

In this phase, the Machine Learning classifiers are assigned by their criterion, Random Forest Classifier (criterion = 'entropy'), Multi-Layer Perceptron, nearest neighbor (n=9), Extra Tree Classifier (n_estimators=500), XGBoost (n_estimators=500), Support Vector Classifier (kernel='linear'), Stochastic Gradient Descent, Adaboost Classifier, decision Tree Classifier (CART), gradient boosting machine. These classifiers are built and analysed for selecting the best model.

g) Model Evaluation

We completed the most important evaluation metric for this problem domain during this phase, such as as sensitivity, specificity, Precision, F1-measure, geometric mean and Mathew correlation coefficient for a classifier model and we evaluated XGBoost Classifier is the best performer as it has highest test accuracy of 0.9191, sensitivity of 0.943 and specificity of 0.89 and highest f1-score of 0.9243 and lowest Log Loss of 2079. and finally, we have evaluated the models in ROC (receiver operating characteristic curve) under AUC(Area under the ROC Curve) curve [27–29].By plotting ROC, we can observe that, which machine learning algorithms have the highest area under ROC, and which ever machine learning algorithms highest area under ROC and whichever are more generalized.

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Fig.11 clearly shows that Extra Tree Classifier has performed very well and more generalized, Extra Tree Classifier has achieved the highest average area under the curve (AUC) of 0.950. In the next step, we have evaluated the classifier model using precision recall curve as shown in Fig.11, precision recall curve is opposite to the AUC curve, and after the evaluation it can be clearly observed that Extra Tree Classifier has performed very well.

h) Feature Selection

In this phase, we have used several feature selection algorithms such as simple coefficient correlations, chi selector, RFE, Embedded LR selector, and Embedded Random Forestselector, Embedded LightGBselector, for selecting only those features, which are evaluated by the algorithms that, these features cause cardiac arrest in a patient [30–31].

Table 3: Feature selection

	Feature	Pearson	Chi-2	RFE	Logistics	Random Forest	LightGB M	Total
1	st_slope_flat	True	True	True	True	True	True	6
2	st_depression	True	True	True	True	True	True	6
3	max_heart_rate_achieve d	True	True	True	False	True	True	5
4	exercise_induced_angina	True	True	True	False	True	True	5
5	cholesterol	True	False	True	True	True	True	5
6	age	True	True	True	False	True	True	5
7	st_slope_upsloping	True	True	True	False	True	False	4
8	sex_male	True	True	True	True	False	False	4
9	chest_pain_type_non-anginal pain	True	True	True	True	False	False	4
10	chest_pain_type_atypical angina	True	True	True	True	False	False	4
11	resting_blood_pressure	False	False	False	False	True	True	2

We have used a total of six algorithms for feature selection that causes cardiac arrest, after the evaluation, it is observed as given in the generation of Table.3 that all six algorithms have voted for ST_Slope flat and ST_depression. Furthermore, the Logistics algorithm has not voted for max_heart_rate achieved, and exercise_induced_angina, chi-2 has not voted for cholesterol. So, we have selected the features, which obtained five votes from the feature selection algorithms and we also selected st_slope_upsloping feature because it is a linked feature and cannot be bypassed. In this phase 7 features are selected.

i) Model Evaluation

After the feature selection, all steps starting from cross validation to model evaluation are repeated, and another new classifier model in implemented on the selected feature known as soft voting classifier, then the selected features again evaluated in ROC AUC curve as shown in Fig.13 and precision recall curve as shown in Fig. 14.and Extra Tree Classifier has obviously performed very well and, more generalized, has achieved the highest average area under the curve (AUC) of 0.957. In precision recall curve evaluation, as shown in Fig. 14, it can be clearly observed that Extra Tree Classifier has performed very well.

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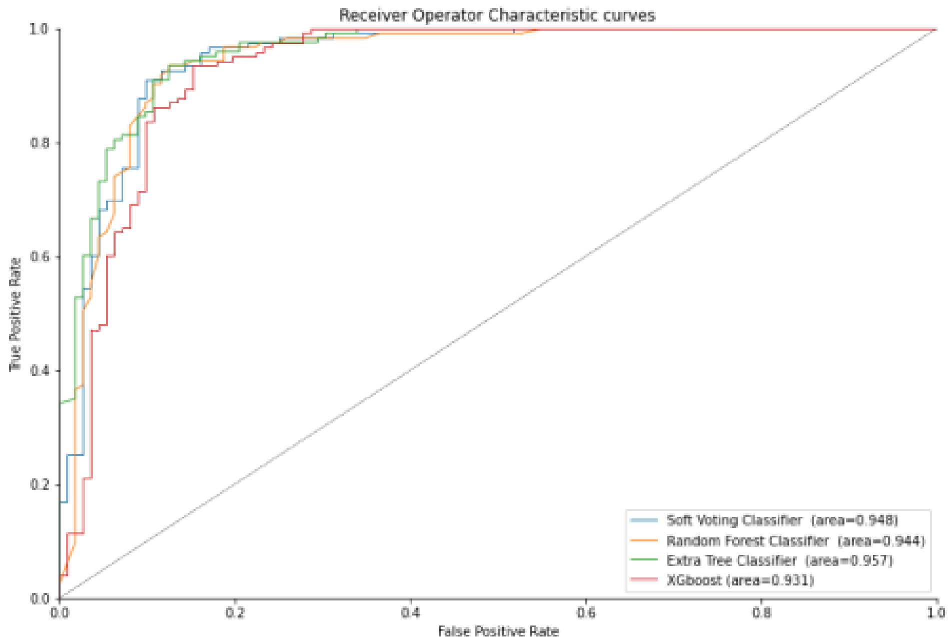

Fig. 13 : ROC AUC curve after feature selection.

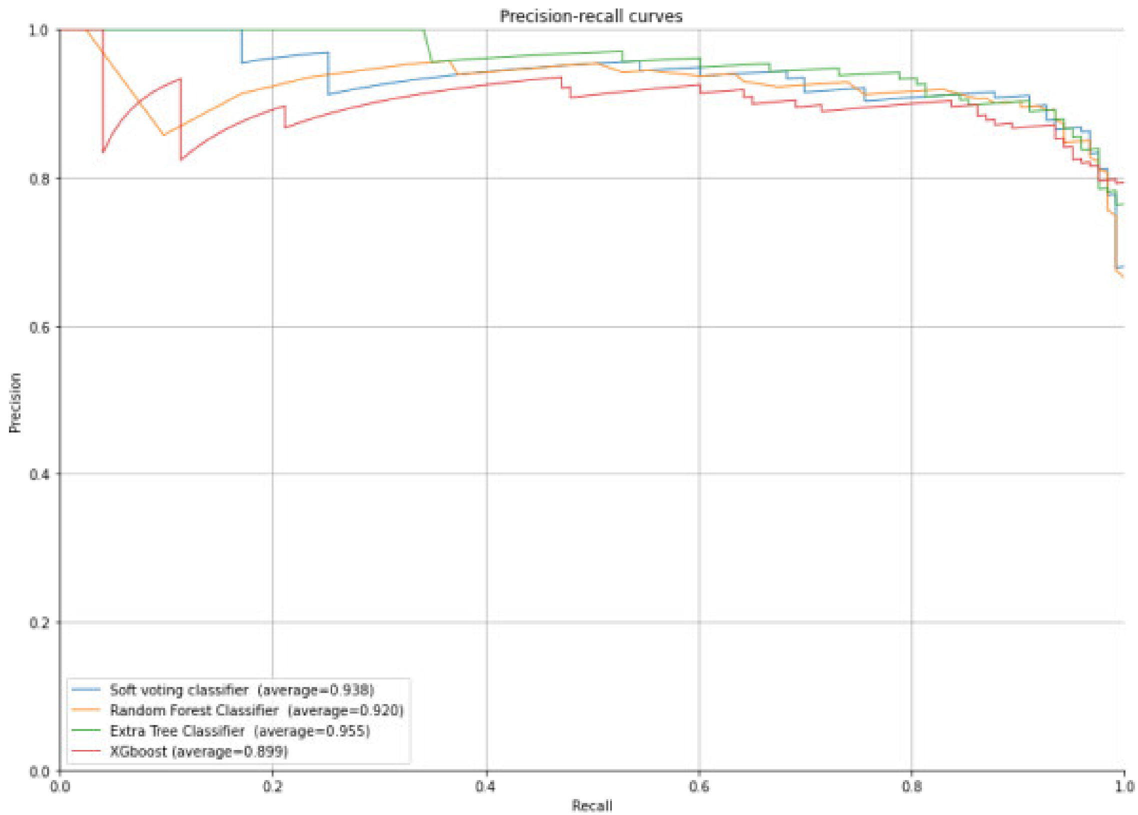

Fig. 14: Precision Recall curve after feature selection.

j) Feature importance

In the last phase, we have selected the features based on the attributes and contribution of these features to

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the analysis. Fig. 15 shows the impact of each feature for cardiac arrest and their level of contributions.

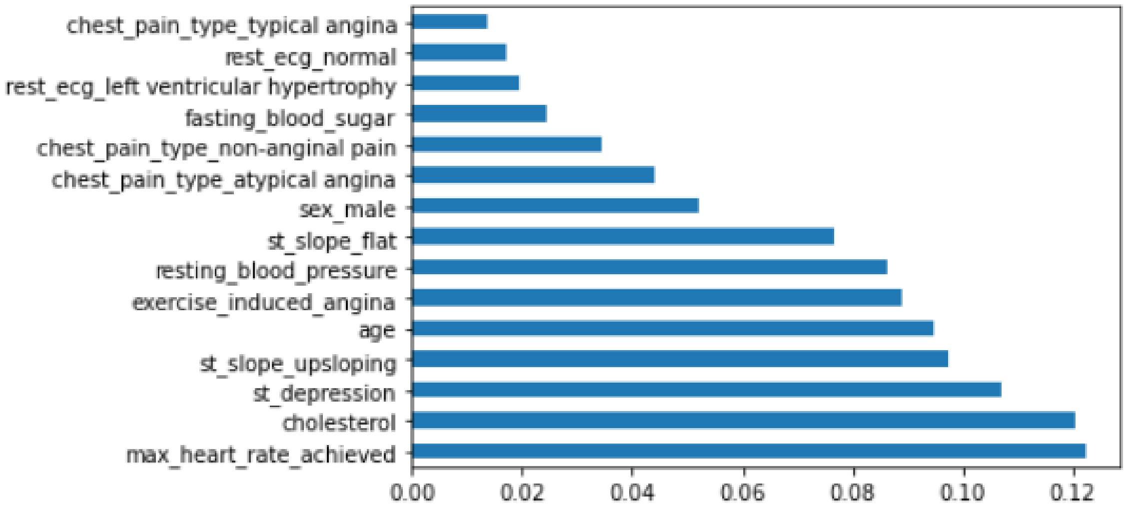

Fig. 15: Ranking of features

6. CONCLUSION :

In this study, the evaluation of cardiovascular disease is done using popular machine learning algorithms, data. The dataset used in this study are from famous Cleveland datasets of US, Statlog Dataset of UK, and Hungarian dataset of Hungary, Switzerland. The dataset collected is then verified for the changes by splitting into training and test set. Data are then given for feature extraction; this phase extracts 7 features, which contribute to the event. In addition, extracted features are used to train the selected machine learning classifier models, and results are obtained and obtained results are then evaluated using test data and final results are drawn. Extra Tree Classifier has the highest value of 0.957 for average area under the curve (AUC).

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Tracking and Monitoring Fitness of Athletes Using IoT Enabled Wearables for Activity Recognition and Random Forest Algorithm for Performance Prediction

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ABSTRACT

Purpose: The progression in technology is made the best use of in every field. Sports analytics is an essential sector that has gained importance in this technology-driven era. It is used to determine the hidden relationships among different quantitative parameters that affect the performance of athletes. This type of analysis requires a large amount of data to be stored periodically. Cloud acts as a scalable centralized repository that can store the massive data essential for analysis purpose. From the technological perspective there are numerous wearable activity tracking devices, which will be able to provide feedback of physical activities. With the help of random forest (RF) algorithm it is possible to classify huge datasets to perform predictions. In this paper, different smart devices that can be used to measure physical activity, use of RF algorithm for converting data obtained from smart devices into knowledge are explored. A conceptual model that uses wearable devices for tracking and monitoring and RF algorithm to predict the performance is suggested.
Methodology: The study was conducted by referring to scholarly documents available online and by referring to websites of companies offering healthcare and sports related services. A conceptual model is developed based on the theoretical perception that incorporates the components needed for measuring the physical activities to predict the performance of athletes.
Findings/Result: In this paper the proposed system contains four major activities as Capture, Store, Analyze, and Predict. The model considers use of IoT-enabled wearable devices to measure the physical activities of athletes and the information collected will in turn be used to analyze predict their performance and suggest them how to increase the chances of winning. However, the outcome of a game does not only depend upon the PA of athletes. It depends also upon the physical, mental, emotional health, nutrition and many other factors.
Originality: In this paper, a theoretical model is deduced to integrate IoT and RF Algorithm to track and monitor fitness of athletes using wearables for activity recognition and performance prediction.
Paper Type: Conceptual Paper
Keywords: Physical Activity, IoT, Wearable Devices, Fitness Tracking, Performance Prediction

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1. INTRODUCTION :

Health and fitness are the most prominent sectors that utilize the technological advancement to a large extent. Physical activity (PA) increases the blood circulation without stressing the body. It tones the muscles and enhances strength, endurance and flexibility. It is through PA the cardiovascular system is strengthened and hence heart and lungs will be stronger. Researchers have demonstrated several advantages of PA and negative impact of sedentary behavior. PA reduces the risk of heart attacks by 50% and decrease the blood pressure and blood-glucose levels. Hence, PA has become increasingly prominent when determining the fitness of athletes. Sports are a type of physical activity that enhances a person's overall health. Obesity, asthma, diabetes, and a variety of other health issues develop as a result of physical inactivity at an early age. Taking part in sports and games decreases the risk of cardiovascular disease, diabetes, and some cancers. Compared to others, athletes would have a more positive outlook. According to studies, athletes are less prone to use drugs or tobacco. People who compete in athletics during the school days do not drop out from schools and score much well in tests and examinations. Sports participation helps instill character values such as honesty, equality, team spirit, and respect for teammates and competitors. It teaches people to be humble, humane, and self-confident. It allows people to strengthen their leadership capabilities. It has a stronger influence on personal characteristics including consciousness, assertiveness, and communication abilities. Sports have a pivotal role in promoting positive youth. It necessitates a great work ethic, dedication, determination, and commitment. Training sessions and involvement in sports meet is needed to increase the performance [1].

Sports and games are organized PAs that can be practiced by people of all age groups. The one who participates in sports and games demonstrate leadership quality, team spirit and disciplined behavior. Participation is sports helps all-round development of an individual. The positive effects in sports are because of PAs. If an athlete wants to participate in sports and games, he is expected to practice organized PAs, which aim at the betterment of results. Because of PAs, the muscles get strengthened and excess fat will be reduced. Physical fitness will increase the energy level and boost mood. Participation in sports makes the students physically fit and mentally steady [2].

Athletes' success is influenced by their fitness. In the early stages of training, individual athletes show varying levels of progress and skill sets. Athletes are to be appropriately prepared for game-specific variables in order to gain fitness and increase performance. Two types of training models that are used include: general training and sports-specific training. For the sporting case, the generic model excludes any technical skills. Athletes are prepared for short-term training using this model, with 2-4 training sessions a week. Athletes who participate in sports-related training are taught how to use techniques and strategies that are specific to their sport. Athletes are prepared for long-term training using this model, with 5–6 workout sessions. Athletes who participate in sports-related training are taught how to use skills and tactics that are specific to their sport. Athletes are expected to keep fit throughout their careers. Athletes will benefit from sports-specific preparation and coaching activities that will help them develop the skills they should enhance their performance. Throughout an athlete's career, their fitness should be closely monitored [3].

The field of sports and gaming has been influenced by the influx of info. As a result, the term "scientific athletism" has become common. Athletes' diet and physique have been altered by a powerful surge of information. It is possible to assess all the athletes do with the aid of sufficient data. Data analytics is also used to guide decision-making in the sports and gaming industry. IoT devices, GPS trackers, smart cameras, and other similar devices track athletes' on-field performance, while machine learning (ML), artificial intelligence (AI), and predictive analytics are used to identify the next champion or superhero. Anything in sports has become computer-driven, thanks to the professional sports world's embrace of analytics and data. Athletes and coaches will be under continuous pressure to improve their performance. This has opened up many opportunities for analytics in sports to get reliable and real-time insights. These days, teams hire data management specialists to offer them a data advantage to maximize their performance [4].

In the world of sports and games, the use of data to calculate the success is not new, but the use of state-of-the-art data to forecast future performance is. Athletes' essential parameters can be measured using wearable IoT devices. It creates a massive database for a single athlete. It is also possible to store an athlete's former performance. In the analysis process, historical experience is used as a training set. All of the raw data collected from various sources are processed to provide useful information. Every move an athlete performs

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on the field generates data that can be analyzed in some way. Information comprehension demonstrates an athlete's precise health and fitness. By analyzing asymmetric movements, it can be used to assess possible injuries. It will be used to decrease the risk of serious injuries. Athletes will learn precisely what they performed to be good or unsuccessful by evaluating their performance. Coaches and athletes will be able to make the best decisions in real - time and produce consistent outcomes because of the information gathered in this manner. It facilitates athletes in areas such as preparation, game planning, and post-performance assessment. It facilitates athletes in the development of technical ability, technical expertise, decision-making abilities, and confidence. It helps coaches recognize athletes' strengths and shortcomings, improve coaching style and conduct in-depth performance reviews [5].
IoT is a network of physical devices or 'things' that can communicate and share data. Several sensors are built into IoT products to track critical parameters. Wearable technology has given physical fitness a whole different dimension. They use various sensors to capture real-time data and display the current fitness of whoever is wearing them. They can immediately send the data to the monitoring program; using advanced processing tools, the data will be analyzed and improvements recommended. Based on exercise data and calorie intake, the system can also prescribe nutritional plans. A wearable device's sensors generate data. The data obtained in this manner requires a huge centralized storage system that can efficiently hold the data. The cloud platform is used to store the vast amounts of data produced. IoT systems can be used to monitor athletes' progress and assess their performance. Wearables that monitor vital parameters such as blood pressure, heart rate, and body temperature are examples of IoT products. On-body, off-body, and in-body devices are examples of different types of devices. IoT sensors are also be embedded on various pieces of equipment, such as footballs, basketballs, and other sports equipment, to monitor data in real time throughout the event [6].
A large amount of data that is generated using wearables have to be analyzed for effective decision-making. The data can also be used for performing predictions. For analysis, the data need to be classified properly. There are numerous classifications to predict the outcome of an event or to identify hidden relationships among various parameters. RF algorithm is a powerful tool to classify the data and convert it into knowledge, which is most crucial for predictions. It divides the huge amount of data into smaller subsets and constructs trees using some criteria. To enhance the accuracy of results multiple decision trees can be constructed based on different criteria. When multiple trees provide the same output that is treated as the final one. To increase the success rate, the RF algorithm also use boosting technique [7].
This paper highlights the objectives of the study, different parameters that are used to measure the PA, different methods that can be used to measure PA, the architecture of the conceptual model and technologies that are adopted in the conceptual model.

2. OBJECTIVES OF THE STUDY :

The objectives of the study are

1. To analyze the quantitative parameters affecting the PA
2. To explore different methods and techniques to measure the PA
3. To elucidate the use of IoT-enabled wearable devices to measure PA
4. To design a conceptual model that uses IoT enabled smart devices to measure PA
5. To understand the use of RF algorithm in analyzing the PA

3. RESEARCH METHODOLOGY :

The study was conducted by referring to scholarly documents available online and by referring to websites of companies offering healthcare and sports related services. A conceptual model is developed based on the theoretical perception that incorporates the components needed for measuring the PA to predict the performance of athletes. The model is built through the analysis of existing information and it is in its infantile stage. It uses only abstract ideas. To test the feasibility of the model, further study is necessary.

4. MOTIVATION :

Monitoring the performance and fitness of athletes continuously is considered the key to their success. It is essential for athletes to sustain or improve the performance. If there is constant monitoring, the coaches will

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realize the progress of the athletes easily. Monitoring is also needed to check whether the athletes are following the prescribed amount of PA, keeping their body hydrated, following the necessary diet, taking adequate rest, etc. The real challenge is how to gather the necessary data? If athletes follow a self-reporting mechanism, there is a possibility of miscomprehension, error or bias. During the process of selection, there is a chance of "faking good/sick". Monitoring is a continuous process it develops a bond between coaches and athletes. Hence, if coaches are asked to create activity logs, there is a chance of inaccurate or biased log information. Also, there are several parameters to be measured on a daily basis. Entering all the essential data is time-consuming job. If there is a means by which the data related to the essential quantitative parameters is sent directly to the monitoring system it would help the coaches to identify the strength and weaknesses of athletes. Hence if the accurate data related to the PAs of athletes are recorded properly, it will enable the coaches to train the athletes. Use of IoT-enabled wearable devices makes monitoring process easy and interesting. All data gathered will be of no use if it is not used for the improvement. If algorithms are used to identify the hidden relationship different parameters, it would help the athletes improve their performance.

5. RELATED WORKS :

Table-1: Summary of Related Works between 2010 and 2021 by different researchers

SN	Author(s)	Year	Inventions/Findings/Results
1	Magalhaes *et al.* [8]	2014	Analyzed the use of inertial sensor-based IoT devices such as an accelerometer, gyroscope in swimming for the purpose of continuous monitoring of swimmers.
2	Ahmadi *et al.* [9]	2014	Developed a layered architecture containing wearable devices, cloud infrastructure, internet, smartphones and other related technologies to motivate the use of IoT in sports.
3	Rein & Memmert [10]	2016	Explicated the use of big data to perform tactical analysis in a team game. The analysis is performed using ML algorithms.
4	Gowda *et al.* [11]	2018	Illustrated the application of IoT in cricket. Explained how different objects included in the game can be made smart and help effective decision-making.
5	Tang, F., & Ishwaran [12]	2017	Explained how to handle missing data and several types of data by using RF algorithm. Also explained how RF algorithm is efficient to handle premature, impute and pre-impute data when constructing the forest
6	López *et al.* [13]	2018	Identified different factors involved in injury-risk prediction. Compared numerous ML methods for injury prediction and found RF algorithm is the most accurate one. Developed a model that performs injury prediction using RF algorithm
7	Wilkerson *et al.* [14]	2018	Analyzed different types of injuries and developed a model that uses IoT devices to mitigate injury-risks.
8	Morgulev *et al.* [15]	2018	Explained how sports data can be analyzed to determine human behavior.
9	Apostolou & Tjortjis [16]	2019	Explained how ML algorithms enable the coaches to identify reason for decline in the performance of athletes
10	Silva *et al.* [17]	2019	Explained different artificial intelligence techniques that can be used to perform injury prediction among athletes

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6. PARAMETERS USED TO MEASURE PA :

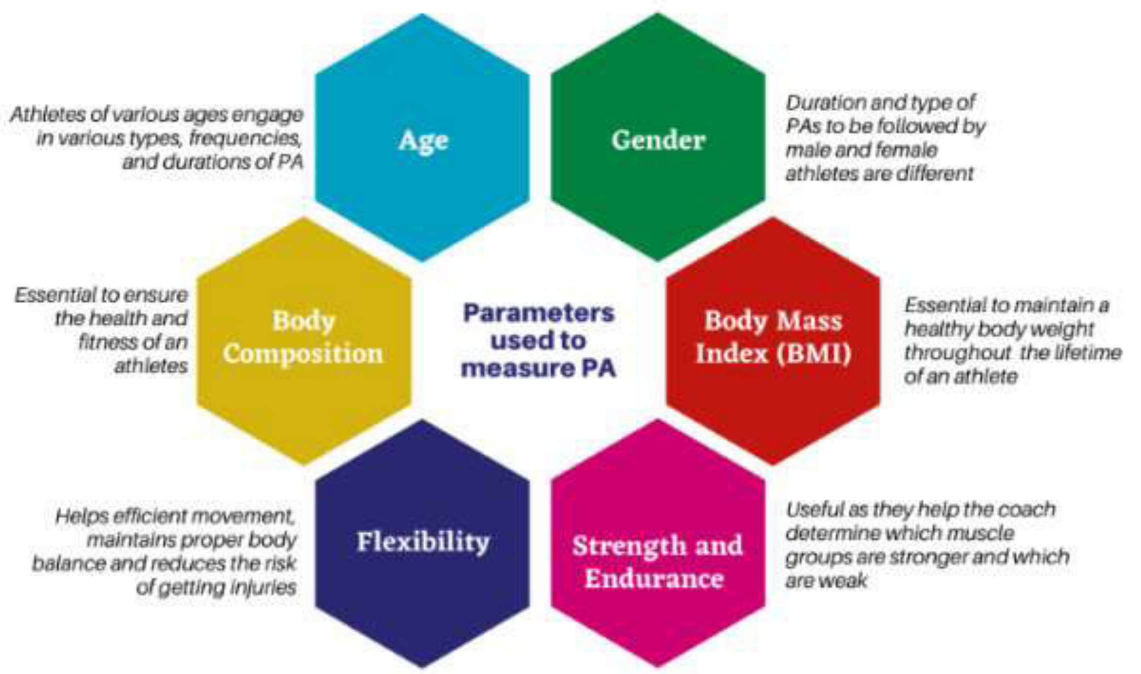

Fig. 1: Parameters used to measure PA

- **Age**: As far as PA is concerned, age of an athlete plays a crucial role. Athletes of different age groups different type, frequency and duration of PA. There is a tendency that adults are more likely to skip the PA when compared to youngsters. Age, lack of motivation, improper time management, lack of interest in PA, pre-existing medical conditions, injuries, etc. act as hinderance for PA among adult athletes. Researches show that youngsters are keener to meet the guidelines of PA when compared to adults. Following same type and duration of PA for athletes of different age groups is not recommended.
- **Gender**: It is recommended to design gender-specific PAs. Duration and type of PAs to be followed by male and female athletes are different. Female athletes prefer lighter PAs like walking, running, etc. where male athletes are more interested in PAs that strengthen their muscles. Fatigue, overtraining, muscle pain, etc. are more faced by female athletes than males. When designing the PAs, the coaches ensure that male and female athletes follow different set of activities and have different targets to achieve.
- **Body Mass Index (BMI)**: It is much essential to maintain a healthy body weight throughout the lifetime of an athlete. If athletes are overweight or obese, they tend to show poor performance in their motorability skills. Overweight leads to serious health issues such as diabetes, hypertension, etc. Athletes must follow a healthy diet to maintain an optimal BMI because overweight hinders the PAs and in turn acts as a hurdle in the fitness of athletes. Hence, PAs are to be tailored in such a way that they ensure a steady BMI in athletes.
- **Strength and Endurance:** Strength is the amount of force the group of muscles can exert at unit time. Strength and endurance assessments are useful as they help the coach determine which muscle groups are stronger and which are weak and in need of focused attention PAs are to be designed to increase the strength and endurance of athletes.
- **Flexibility**: It is the ability to move the muscles without straining them. It helps efficient movement, maintains proper body balance and reduces the risk of getting injured. Forward bending, backward

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bending and stretching are used to measure the flexibility of athletes. After the PA the flexibility should be increased.

- **Body Composition**: It describes the amount of fat, bones, muscles and water in the body. Body composition and growth are essential to ensure the health and fitness of an athlete. Based on the analysis of parameters such as skinfold thickness, BMI, waist circumference, etc. it is possible to predict the body composition of athletes using ML algorithms. A healthy body contains adequate proportion of muscles, fat, bones and water. The body composition of an athlete important to measure the fitness [19–21].

7. APPROACHES TO MEASURE PA :

As shown in Fig. 2, there are four different approaches to measure PA of athletes.

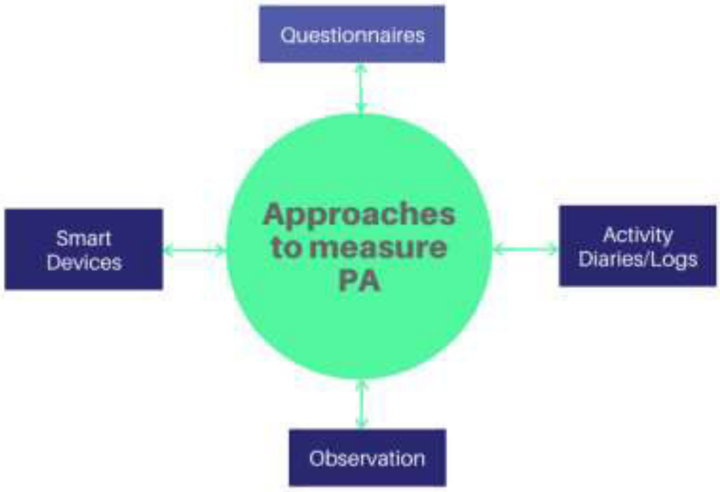

Fig. 2: Different Approaches to measure PA

- **Questionnaires**: Questionnaires are the most common way of gathering data from a group of respondents. In case of monitoring PA, the athletes are asked to fill a form containing multiple questions related to their PA. These questions seek quantitative information related to athletes such as mode of PA, type of PA, frequency, duration and calories, etc. These questionnaires mainly depend upon the athletes' recall ability. Questionnaires are more specific and cost-effective way of gathering personal data. With the help of questionnaires, it is possible to collect data from a large set of respondents. Hence, the technique is fast and scalable. However, this technique of collecting data has some inherent limitations. When the personal data are entered by individual athlete, the accuracy of data is a major issue. The truthfulness of responses depends upon the athlete. There is a chance of inaccurate information about the personal data of PA. Also, there are chances of misinterpretation of questions. In most of the cases, questionnaires do not contain personalized questions.
- **Activity Diaries/Logs**: Activity log is the best way to measure the progress of athletes. They enable athletes to record their activity every day. They enable athletes to store the real-time data related to the amount of PA done by them. In case of activity logs, athletes are asked to create a table that is used to store the details of PA such as date, duration, time spent, goal, etc. Athletes can get a clear picture about the improvement in their performance. It will boost their confidence and keeps them committed to the regular PA. The log contains descriptive answers in the form of explanation of activities. The athletes also need to record the future goals to improve or sustain their performance. These logs increase the time-management skills of athletes. Activity logs contain more explanatory data and hence creating them is a time-consuming task. Also, they are not recommended for athletes in the age group 5–10 years because athletes of this age group find it extremely difficult to write explanatory answers.
- **Observation**: In this case PAs of athletes are monitored by another person. In many situations coach himself observes and records the PA of athletes or else a person is appointed to monitor. The observation is practiced worldwide where coaches become mentors and keenly observe the PA of athletes to identify their strengths and weaknesses. However, this method is also not free from problems. It is hard for a

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single person to focus on variety of parameters and is even harder to retain the vast information collected. Also, there is a chance of personal bias when using this method. This method is useful for athletes in the age group 5–10 years.

- **Smart Devices**: Smart devices are containing sensors and are portable devices that can monitor the PA effectively. They can be easily connected with other devices such as smartphones to share the information. The information from smart devices can easily be transmitted to the external storage medium and in the future the same can be used to track the progress of athletes. These devices are cost-effective and energy-efficient. They contain multiple sensors and can measure numerous parameters and are trendy these days [22–23].

8. WHY SMART DEVICES IN SPORTS :

Health and fitness are the largest industry that extensively uses smart devices. These smart devices ensure ubiquitous monitoring of athletes. They contain numerous sensors and are extensively used by athletes these days. They can sense many parameters such as temperature, speed, blood pressure, calories, etc. during the PAs. The data they created can easily be sent to the external storage medium without any human intervention. Hence, the accuracy of data will be high. Since the activity data can automatically be stored there will not be errors when entering data [24].

A balanced workout is as important as a balanced diet. It enables athletes to maintain fitness. It requires a combination of standing workouts, twists, leg exercise, forward bending, back bending, running, weight training, etc. If athletes fail to perform balanced workouts, they feel strain and sprains. It causes injuries at later stages. IoT enabled tracking system allows hassle-free workout sessions as they provide detailed tracking of workout sessions. The devices can be implanted on gym-equipment to improve the quality of the workout.[25].

Table 2: List of PAs that can be measured using wearable IoT devices

S.N.	PA	Description
1	Squats	It is a PA that is practiced by athletes specially to burn more calories and strengthen the muscles. It also increases the mobility and flexibility of an athlete. Number of squats done by an athlete can be counted by wearable devices such as wrist-bands
2	Box Jumps	They strengthen the muscles and increase the swiftness.
3	Deadlifts	This PA strengthens many muscles. They improve body balance and prevent injuries.
4	Planks	It is an abdominal PA, which used to strengthen the core. It mainly helps to stabilize and balance the body. The duration of planks and number of planks can be counted using wearable devices. The aim here is to increase the duration of plank.
5	Walking	It is a PA used to increase cardiovascular and pulmonary fitness. Using smartwatches, it is possible to count the footsteps, distance covered, duration and calories burnt.
6	Running	It is a weight-burning and bone-strengthening exercise, which also improves cardiovascular fitness. Using smartwatches, it is possible to count the footsteps, distance covered, duration and calories burnt.
7	Bench Press	This PA is mainly used to strengthen the upper-body. It has many variations in this PA and the basic one is using a barbel without weights. The number of bench presses can be counted.
8	Ladders	This PA is used to enhance their speed. It is the most effective lower-body workout especially practiced by athletes during their warm-up sessions.

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9	Dot Drills	In this type of PA, several dots are placed on the floor in different patterns and the athlete is made to jump from one dot to another. It is mainly practiced to increase quickness, agility and balance.
10	Swimming	It is practiced by athletes of all age groups. It strengthens the muscles and the cardiovascular system. It is considered the whole-body exercise without putting stress on the body. Almost all the wearable devices are water-resistant and hence they can be used to measure distance, speed, stroke type, velocity, efficiency, lap time, etc.
11	Cycling	It is an aerobic PA which enable the athletes to increase cardiovascular fitness. It regulates blood circulation and improves overall fitness of the body.
12	Pull-ups	This PA is used to strengthen the upper-body. It requires the involvement of multiple-joints and is good to improve explosiveness and body balance. The PA also involve weight training.

This list of generic PAs the quality of which can be assessed using wearable devices. Besides these there will be event-specific PAs, which are in the athletes are also suggested to practice games like football, golf, soccer and relaxing techniques such as Yoga and Pranayama. The ultimate aim of any PA is to enhance the fitness and enhance the chance of winning [26-27].

9. LAYERED ARCHITECTURE OF THE PROPOSED SYSTEM :

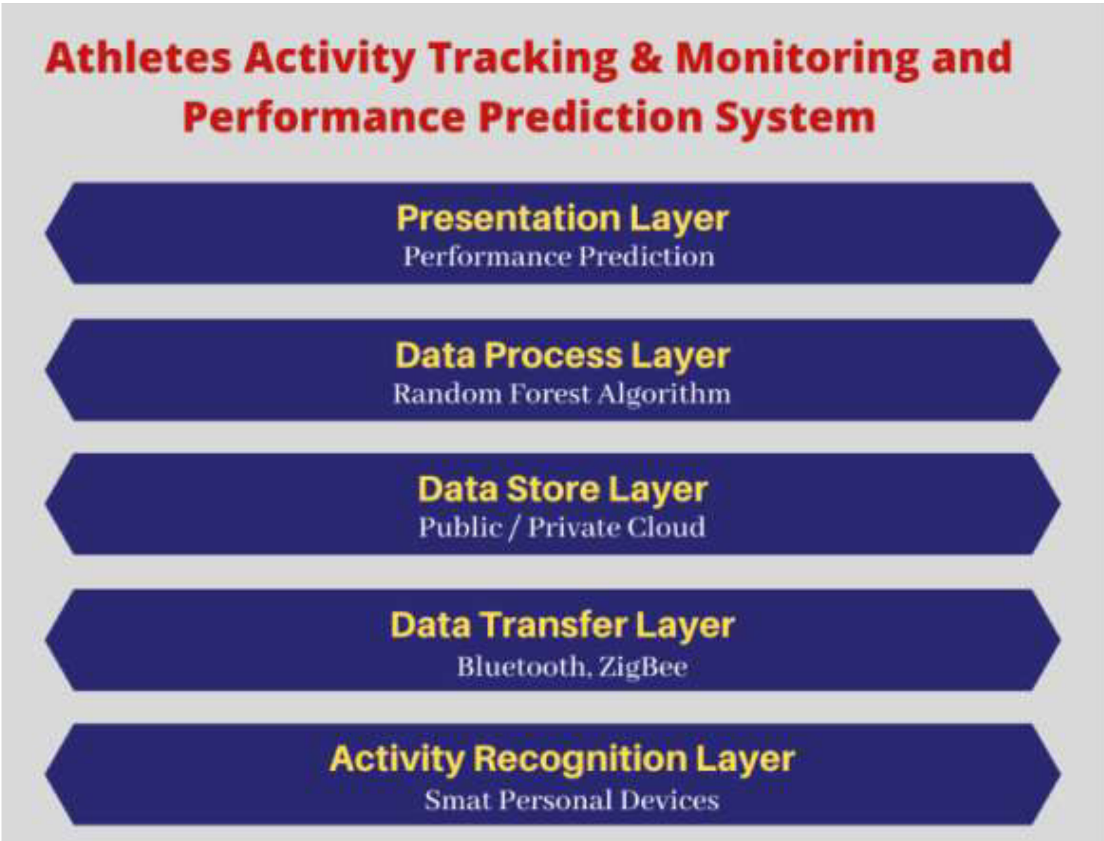

Fig. 3: Layered Architecture of the Proposed System

The layered architecture represents the design in smaller pieces so that it is easy to understand, code, test and debug. Fig-3 indicates the layered architecture of the proposed system.

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- **Activity Recognition Layer:** This layer comprises sensors or wearable devices that are used to capture parameters such as body temperature, blood pressure, heart rate, respiration rate, calories burned, etc. While designing this layer, cost and energy consumption capability of the sensing devices are important aspects to be considered. Due to the advancement in technology, several power-efficient, accurate IoT devices are available in the market these days.
- **Data Transfer Layer:** The job of IoT is to connect a number of 'things' for data sharing reason. Bluetooth, ZigBee are a few examples of the technology used for connectivity. The Device management, energy consumption, protection and privacy of are some points to remember when designing this layer. The data generated by smart devices are to be sent to the central repository using mobile applications. To connect wearable devices and mobile applications, Bluetooth or ZigBee are extensively used.
- **Data Store Layer:** The wearable devices produce voluminous data that that must be stored efficiently and processed for decision-making purposes. The voluminous data create a data pile and every bit of information is needed for the analysis. Keeping entire data at a single location makes it easy to store, access and analyze. Several cloud services available to efficiently store the data.
- **Data Process Layer**: This layer contains the processing units and the software required to aggregate the data. Raw data generated by the devices can be converted to standard format. This layer converts information stored on the cloud into valuable knowledge that is much needed for decision taking purposes. In this step algorithms are used to learn from sample data automatically and when test data is given, they easily categorize the same to arrive at conclusion.
- **Presentation Layer**: Once analysis is over there are numerous data visualization tools that present the data in an appealing manner. This step provides a visual summary of findings with the help of maps, graphs, etc. when the data are presented in a pictorial format human brain can easily comprehend the same. Also, it is easier to identify trends, patterns and outliers within a large dataset [28].

10. COMPONENTS OF THE PROPOSED SYSTEM :

The proposed system contains four major activities, as shown in Fig. 4. IoT enabled wearable devices are used to capture the essential parameters.

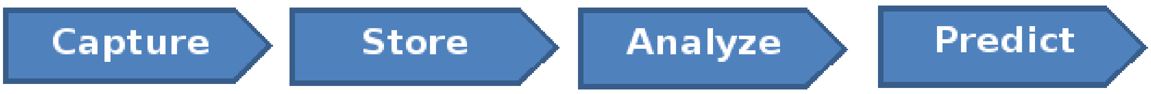

Fig. 4: Activities in Performance Analytics

- **Capture:** The first step of every activity that involves data analysis is data acquisition. Data related to PAs of athletes is generated using wearable devices and is collected automatically. The data is periodically transferred to mobile applications using technologies such as Bluetooth to the access point. Every wearable device comes with a mobile application which can be used as access point that sends the data to the data store. All quantitative data collected using wearable devices that contain multiple sensors is collected by the data acquisition system.
- **Store:** Once all the required parameters are collected using wearable devices it has to be stored safely in a centralized repository. Since the data is growing exponentially the conventional DBMS may not be of much use to store and manage data. Cloud platform provides a scalable storage medium.
- **Analyze:** The purpose of collecting and storing a huge amount of data is to utilize the same in the future to make predictions. Different events require different strategies to be adopted to improve performance and maximize the chance of winning. In most cases, analysis is based on the statistical pieces of evidence obtained from the performance records. However, it is not recommended to solely depend upon the statistical techniques for prediction.

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- **Predict:** Based on the analysis, a prediction model is to be designed to predict the performance of athletes based on their PA. The model should be designed in such a way that it generates reliable and accurate results.

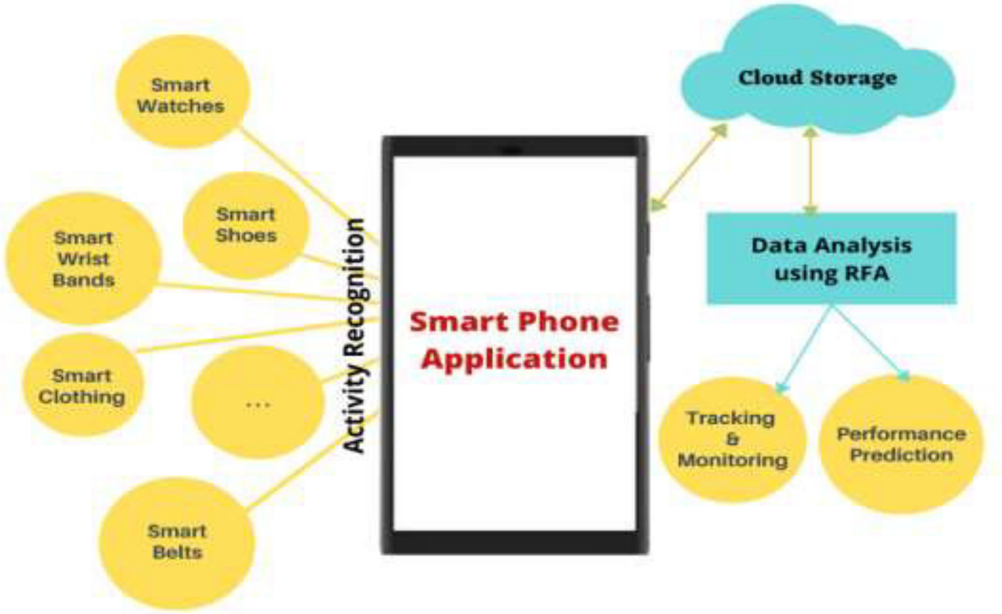

Fig. 5: The Conceptual Model

Fig. 5 gives the block diagram that indicates the functioning of the conceptual model. During PA athletes use wearable IoT devices that measure the required parameters. Data generated by these wearables is communicated to the mobile application using Bluetooth or ZigBee technology and the smartphone will send the data to the cloud storage. Once the data are stored in cloud ML algorithms can be applied so that the data can be analyzed to predict the performance.

11. TECHNOLOGIES USED :

- **IoT**: It is an emerging technology that uses sensor-based wearable devices to capture the activity data of athletes. The intelligent devices such as arm bands, smartwatches, smart shoes, smart clothing, etc. capture data related to the quantitative parameters involved in the PA of athletes. IoT is not a single technology, instead it incorporates multiple elements such as devices, sensors, actuators, etc. These days it has become the backbone of every sector, including sports. The sensing devices, which are the heart of IoT infrastructure collect tons of data that can be used to gain insights. IoT is mainly used to decrease the burden of data collection and make it more accurate one [29].
- **Communication Technology**: Data from wearable IoT device are to be sent to the cloud for effective storage. Every wearable deice can be mapped to a mobile application so that the smartphone of an individual can be paired with the wearable device for data sharing purpose. Bluetooth and ZigBee are two popular short-range wireless technologies that can be used to send the data from wearables to the smartphone [30].
- **Cloud Computing**: The data captured using wearable devices undergo into three different stages. The first stage is data creation which is done at the device-end based on the PA of athlete. In the second stage, the created data are sent to the mobile application using Bluetooth or ZigBee technology. In addition, in the third step it is stored in the centralized repository for further analysis. Due to the dimension of data its storage, retrieval, analysis and management become major issues. Having data in a centralized repository reduces redundancy and updating time. Cloud computing can be used to store the voluminous data effectively [31].

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- **Machine Learning (ML)**: ML uses statistical analysis with the help of which computers learn from examples and to detect hidden patterns from huge noisy or complex data. Several ML algorithms are extensively used in predicting the performance. They automatically analyze the stored data and the result of which is used in decision-making. The building blocks of ML are algorithms that categorize enormous amount of data to provide variety of decisions, predictions or suggestions. Training or sample data are fed to the ML algorithm and the algorithm creates a new set of rules based on the inferences. Then the test data or actual data is given to the ML algorithm and it generates a set of solutions. One ML algorithm can be used for many problems. Arriving at a conclusion by using new data supplied is the major role of an ML algorithm. This conceptual model used RF algorithm for analysis [32–33].

12. USE OF RF ALGORITHM FOR ANALYZING THE DATA :

The study of different sets of skills in athletes is most essential for predicting their performance. Performance is not only dependent on skills; it relies on various other parameters. Surprisingly, there is no linear relationship between these parameters and their performance. It is required to identify the hidden relationships between different these so that it allows coaches to see the strengths and weaknesses of their athletes and to design their training programs following the individual needs of their athletes [33].
The accuracy of performance prediction requires a predictive model that uses ML techniques. It is a real challenge to choose the one which is best suitable for the problem under consideration, since many algorithms are used in ML. Different models and algorithms show a different level of accuracy. A model is to be chosen in such a way that it provides the most accurate results to increase the trustworthiness.
Random forest is a supervised learning algorithm that contains "forests", which is a group of multiple decision-trees. The decision-trees drawn using this algorithm are constructed either by using "boosting" or "bagging" technique. RF algorithm is flexible, simple and easy to use. Hence it is extensively used in healthcare, business and other sectors for accurate decision-making. It can be applied for both classification as well as regression types of problems. Random forests incorporate expected values from a set of trees to make predictions. Each tree predicts the outcome as a function of the values of the predictor variables [34]

The decision-making process in RF algorithm starts with the root node X and then gets split into several nodes. This process is repeated until the leaf node is reached. In each node there will be a question and the branches represent different possibilities that the question in the node may lead to. RF contains several trees, each with same nodes but use different data that leads to the leaf node. Finally, the trees are merged and the average of all decision trees will be the answer. When using RF algorithm to solve regression type of problems the mean square error (MSE) is used as the parameter. It is calculated using the formula

$$MSE = \frac{1}{N} \sum_{i=1}^{N} (f_i - y_i)^2 \qquad (1)$$

In equation (1) N is the number of data points f_i is the output of the node and y_i is the actual value of data point i. It estimates how well the RF forecasts the outcome.
When using RF algorithm for classification type of problems, the parameter used is Gini index instead of MSE.

$$Gini = 1-\sum_{i=1}^{C} (p_i)^2 \qquad (2)$$

In equation (2) p_i is the frequency of the class under consideration, c is the number of classes.
When branching nodes in decision tree entropy is used to determine how nodes are branched in a decision tree. It is calculated using formula (3)

$$Entropy = \sum_{i=1}^{c} - p_i * \log_2 (p_i) \qquad (3)$$ [35].

13. DISCUSSION & FUTURE WORK :

Application of technology in sprots and games has undergone an exponential growth these days but still remains in its infancy. Undoubtedly IoT has automated the process of data collection and made it error-free but the process of data capture is not accurate as anticipated because of the sensors. The model designed in this paper is a conceptual one and the implementation issues related to the same are yet to be explored. The

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model considers use of IoT-enabled wearable devices to measure the PA of athletes and the information collected will in turn be used to analyze predict their performance and suggest them how to increase the chances of winning. However, the outcome of a game does not only depend upon the PA of athletes. It depends also upon the physical, mental, emotional health, nutrition and many other factors. In future an integrated model can be built that incorporates all the factors related to athletes and analyses them to improve the performance. In this model only one ML algorithm is considered and hence the accuracy of prediction depends solely on that algorithm. In future a comparative study of different algorithms can be conducted. Also, the conceptual model only predicts the performance of athletes. With ML algorithms it is possible to perform personalized training, injury prediction, nutrition predictions and many more. In future they can also be implemented. It is also possible to provide personalized training based on the skillsets of athletes.

14. CONCLUSION :

The success of athletes depends mainly on their fitness. Fitness is attained by PA. Athletes of different age groups require different types of PA to gain fitness and optimize their performance. Monitoring the PA of athletes makes the coaches learn their strengths, weaknesses, habits and behavioral patterns. The data captured using IoT-enabled wearable devices can be evaluated and analyzed so that the coaches can guide the athletes to perform to the best of their ability. The building blocks of an intelligent sports framework are wearable devices or smart objects. PAs make a bigger difference in physical and mental health of athletes. Athletes and health enthusiasts can benefit from wearable sports equipment in many ways. These systems are low-cost and have revolutionized the way sports are played. To automate the data collection process, smart devices can be linked together. As several devices are connected in order to simplify the data collection process. Protocols must ensure safe data transfer while data from these devices is used. Smart devices can be used to actively track events and gain more insights into them.

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An AI-based Analysis of the effect of COVID-19 Stringency Index on Infection rates: A case of India

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ABSTRACT

Purpose: The impact of the COVID-19 pandemic has already been felt worldwide, disrupting the unremarkable life of individuals. Social consequences and viral transmission are challenges that must be resolved to effectively overcome the problems that occur throughout this pandemic. The COVID-19 infection data about India were represented using different statistical models. In this paper, the authors focus on the data collected between 1st January 2020 and 12th April 2021, try analyzing the different indexes related to India, and predict the number of infected people in the near future. Based on the infection rate, it is possible to classify a country as "fixed," "evolving" and "exponential." Based on the prediction, some recommendations are proposed to contain the outbreak of the disease. This will also help the government and policymakers to identify and analyze various risks associated with 'opening up' and 'shutting down' in response to the outbreak of the disease. With the help of these models, it is possible to predict the number of cases in the near future.

Methodology: COVID-19 Stringency Index, Government Response Index, and Containment Health Index calculated, published, and updated real-time by a research group from Oxford University (https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker) on 21 mitigation and suppression measures employed by different countries were analyzed using a few mathematical models to find the relationship between Stringency Index and infection rates and forecast trends. A new model was proposed after analyzing a few mathematical models proposed by the researchers. Data analytics was also conducted using AI-based data analytics tools available online. The dataset was kept updated until the date April 20, 2021, was downloaded for this purpose. The appropriate values were extracted from the original dataset and used to construct a sub-dataset, which was then used for the analytics. An AI-based online Data Analytics tool provided by datapine was used to forecast trends.

Findings/Result: It was observed that in India, as in other countries, there is a close association between Stringency Level and COVID-19 cases. The higher the degree of stringency, the lower the cases, and vice versa. The same can be said about the government's role and degree of containment & health.

Originality: In this paper, we analyzed various mathematical models for predicting the total number of COVID-19 cases and deaths due to COVID-19 in India. We also examined the relationship between total cases and the Government's Response Index, Containment & Health Index, and

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Stringency Index indicators. The model we proposed to predict COVID-19 cases on a day-by-day basis had a 98 percent accuracy rate and a 2% error rate.

Paper Type: Analytical. With prerecorded datasets obtained from online resources, and data analysis was conducted using mathematical models and AI-based analytical tools.

Keywords: COVID-19, Stringency Index, Infection Rate, Prediction, Statistical Model

1. INTRODUCTION :

The COVID-19 is caused by 'Novel Coronavirus'. The first case of COVID-19 was reported at the end of December 2019 in China. More than 200 countries affected by the disease and as a result, the World Health Organization has declared it a pandemic. During the COVID-19 disease outbreak, many countries, including India, are struggling difficult to combat the adversities that came with it. Every country is exploring out ways to deal with the disease's numerous challenges. Humanity's struggles and challenges stimulated the creation of new theories, strategies, and processes. The entire planet is undergoing massive transformations right now. Infections and deaths have been a major impediment to humanity's progress. Overall, the pandemic has brought a new era, especially in the case of developing countries [1].

The COVID-19 has caused panic worldwide due to the high rate of disease transmission and lack of adequate therapeutic interventions. The successful implementation of containment and mitigation methods necessarily requires the effective usage of technology. There is a tremendous need for technological inventions as the number of infected individuals grows exponentially each day. Since up-to-date data related to the infected people, government policies, etc. are readily available, advanced analytics will greatly speed up the decision-making process. To learn more about the infected and disease probable emerging technologies and statistical analysis can be of great help [2].

Different countries implement different levels of restrictions to reduce the infections and death rates caused by the COVID-19. The OxCGRT follows a systematic technique to measure the responses followed by different governments to flatten the curve. The OxCGRT collects data on policies implemented by various countries, such as school closures, travel bans, and so on. The OxCGRT efficiently assembles all the information data across 187 countries on 21 key indicators. The analysis of these data enables the countries to determine the various threats associated with 'opening up' and 'shutting down' as a response to the coronavirus emergency. A dataset that holds numerous key indicators identified by various governments is constantly updated by a group of 100 Oxford Community Members. The key indicators identified contribute to the implementation of containment policies. Data from 21 key indicators were compiled into various indices. These indices have a magnitude ranging from 0 to 100. The level of government action in each field is represented by this ranking [3].

The overtly available data can be used to analyze and predict future outcomes using Artificial Intelligence (AI), Machine Learning (ML) with the help of some statistical models. Based on the data the disease outbreak in the near future can be predicted accurately. This will enable the authorities to take preventive measures to contain the spread [4].

In this paper, the authors focus on the data collected between 1st January 2020 and 12th April 2021, try analyzing the different indexes related to India, and predict the number of infected people in the near future. This will also help the government and policymakers to identify and analyze various risks associated with 'opening up' and 'shutting down' in response to the outbreak of the disease.

2. RELATED WORK :

Different papers that performed an analysis of real-time data using AI and ML between 2018 and 2021 are referred to during the analysis. Blood lactate concentration is one of the crucial factors that are used to determine the fitness of athletes. The authors developed a model to measure the blood lactate level using ML algorithms the model is tested by real-time data [5]. To maximize the performance and minimize the risk of injuries among the athletes' AI and ML algorithms are used [6]. The authors developed a generalized methodology to classify the data related to different diseases. The essential features required for classification are ranked and ML algorithms are applied to classify the dataset [7]. With the help of the AI technique, the authors analyzed the openly accessible data related to COVID-19 patients to predict the severity of the disease and concluded that boosting will help to enhance the accuracy of predictions [8]. To ensure the optimum utilization of healthcare resources and extreme safety of patients a model is developed. The authors concluded that there is a hidden relationship among various safety parameters and found ML as an effective technique

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to identify them [9]. The challenging task of classification of clinical data is done using ML algorithms. They used the SIRD model to predict the outbreak of COVID-19. The analysis is carried out based on the reproduction rate of the virus that causes COVID-19[10]. They analyzed different game-specific parameters that are used to measure the performance of athletes AI and ML are used [11]. The authors applied different matrices to analyze the effect of COVID-19 on the number of publications during the outbreak of the pandemic [12]. Researchers explored different ML algorithms and devised a model that predicts the possibility of cardiac arrest among the patients who are in intensive care units of hospitals. Different features that contribute to the expected events are extracted, the model developed is trained using the openly available data, and found that classifier has maximum accuracy when compared to other ML techniques [13]. To analyze various pandemics such as Ebola ML techniques are extensively being used. The authors developed different models using ML to predict the vulnerability of people to the disease based on different risk factors [14]. The summary of findings is given in Table 1.

Table 1: Analysis conducted by researchers on a similar set of datasets using mathematical models

S. No	Authors	Finding
1	Etxegarai et al. (2018) [5]	Designed a model that helps the estimation of lactate threshold which is a crucial parameter in determining the fitness of athletes.
2	Naglah et al. (2018) [6]	Accurate prediction of injuries is done using AI and ML models and the models are tested based on the injury data of different athletes and found to be of expected accuracy.
3	Alam et al. (2019) [7]	Developed a generalized model to classify the clinical information related to different diseases and trained the model using different ML algorithms. Attribute selection for classification is carried out based on the rank of the attribute.
4	Iwendi et al. (2020) [8]	Developed a model that uses data related to COVID-19 patients to predict the severity of the disease and the time taken to recover. Explored different AI techniques and found out the accuracy of a technique is increases with boosting.
5	Qazi et al. (2020) [9]	Used tree-based ML algorithms to evaluate the safety of patients. The analysis revealed a hidden relationship among different parameters that enable the safety culture of patients.
6	Anastassopoulou et al. (2020) [10]	Proposed a technique to calculate different parameters associated with the outbreak of COVID-19 pandemic based on the openly available data. Used SIRD model and basic reproduction rate to predict the outbreak of the disease.
7	Oytun et al. (2020) [11]	To identify the non-linear relationship among different parameters of athletes and to increase the chance of winning ML models are developed.
8	Homolak et al. (2020) [12]	Performed analysis of COVID-19 data using different tools and matrices to evaluate the response of researchers during the outbreak of COVID-19 when the SI was at its maximum.
9	Krishna Prasad et al. (2021) [13]	Performed analysis and prediction of cardiac arrests occur among the patients who are under emergency care using different ML algorithms. The analysis is carried out using publicly available datasets.
10	Agrawal & Gupta (2021) [14]	Performed analysis of COVID-19 data related to different countries using ML techniques to predict the vulnerability of people to the pandemic.

3. OBJECTIVES :

1. To represent COVID-19 India's cases using appropriate statistical models
2. To perform future prediction of COVID-19 infection using a suitable statistical model
3. To examine the interconnections between Government Response Index (GRI), Containment & Health Index (CHI) and Stringency Index (SI) of the total number of COVID-19 cases in India
4. To forecast COVID-19 cases and related deaths in India for next three months

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4. METHODOLOGY :

COVID-19 Stringency Index, Government Response Index, and Containment Health Index calculated, published, and updated real-time by a research group from Oxford University (https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker) on 21 mitigation and suppression measures employed by different countries were analyzed using a few mathematical models to find the relationship between Stringency Index and infection rates and forecast trends. A new model was proposed after analyzing a few mathematical models proposed by the researchers. Data Analytics was also conducted using AI-based Data Analytics tools available online. The dataset was kept updated until the date April 20, 2021, was downloaded for this purpose. The appropriate values were extracted from the original dataset and used to construct a sub-dataset, which was then used for the analytics. An AI-based online Data Analytics tool provided by datapine (https://secure.datapine.com/#onboarding) was used to forecast trends.

5. ABOUT DATASET :

The OxCGRT collects data from different sources that are publicly available. These sources include news articles, press notes, government information portals, etc. Data were collected by 100 well-trained Oxford Community Members, including University students, staff, and trusted collaborators. Data are periodically being updated by the authorized members and are publicly made available for analysis. When storing the data in the database utmost care is taken to ensure that it originates from a trusted source. After the data entry, it is being reviewed and certified by another person to ensure truthfulness.

The publicly available information about 21 key indicators of government responses to COVID-19 is recorded in the database. The key indicator is a measure on a scale of 0–10, a specific monetary value, or a free response that is preferably text-type data. If the indicators are 'targeted' then they are applied only to a specific region, if they are generic, they are applied throughout the country. Data collection occurs periodically, the database is updated and reviewed to provide precise up-to-date information. Figure 1 gives the list of key indicators identified by the OxCGRT. The key indicators are categorized as Containment and Closure, and Economic Response, and Health System, and Miscellaneous. The category Containment and Closure have eight indicators, which are coded C1-C8. They are C1-School Closing, C2-Workplace Closing, C3-Cancel Public Events, C4-Restrictions on Gathering Size, C5-Close Public Transportation, C6-Stay at Home Requirements, C7-Restrictions on Internal Movement, and C8-Restrictions on International Travel. The Economic Response category has four indicators, which are coded E1-E4. They are E1-Income Support, E2-Debt/Contract Relief for Households, E3-Fiscal Measures, and E4- Giving International Support. The Health System category has eight indicators, which are coded H1-H6. They are H1-Public Information Campaign, H2-Testing Policy, H3-Contact Tracing, H4-Emergency Investment in Healthcare, H5-Investment in COVID-19 Vaccine, H6-Facial Coverings, H7-Vaccination Policy, and H8-Protection of Elderly People [15-16]. Only one indicator is placed under the category Miscellaneous, i.e. M1- Other responses. The 21 indicators mentioned under various categories are depicted in Figure 1.

Fig. 1: Key Indicators Identified by the OxCGRT

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The different indicators that are used to calculate the Government Response Index (GRI) are shown in Figure 2 below. The values of 8 (C1-C8) Containment and Closure, 2 (E1, E2) Economic Response, and 6 (H1-H3, H6-H8) Health System indicators are put under evaluation to calculate Government Response Index.

Fig. 2: Key Indicators Identified by the OxCGRT to calculate GRI

Fourteen indicators that are used to calculate the Containment and Health Index (CHI) are shown in Figure 3 below. 8 (C1-C8) Containment and Closure, and 6 (H1-H3, H6-H8) Health System indicators are used to calculate Containment and Health Index.

Fig. 3: Key Indicators Identified by the OxCGRT to calculate CHI

Nine indicators that are used to calculate the Stringency Index (SI) are shown in Figure 4 below. 8 (C1-C8) Containment and Closure, and 1 (H1) Health System indicators are used to calculate Stringency Index.

Fig. 4: Key Indicators Identified by the OxCGRT to calculate SI

According to OxCGRT the key indicators used to calculate GRI, CHI and SI are shown in Figure 2, Figure 3, and Figure 4, respectively. SI is calculated based on C1 to C8 and H1. The parameter C1 represents the closing of schools and can take a value between 0 and 3. If the value is 0, it indicates no closure of schools and the value 3 indicates all schools and universities should remain closed. If the value is 1, it is recommended to close the schools and if the value is 2 it must close schools. The key indicator C2 can also take a value

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between 0 and 3. The meaning of parameters is the same as that of C1, whereas when the value of C2 is 3 all workplaces except essential services such as hospitals, grocery shops, diagnostic centers, clinics, medical insurance offices, banks, pharmacies, etc. remain closed. C3 expresses the cancelation of public events. The possible values are 0, 1, and 2. The value 2 means all the public events are to be canceled. The key indicator C4 is the counterpart of C3. However, it takes 5 levels from 0 to 4. The value 0 means there is no restriction on private events. 3 means only 11 to 100 people are permitted [17].

6. POLICY INDICES COVID-19 GOVERNMENT RESPONSES :

Different governments have responded differently to contain the outbreak of COVID-19. A comparison of responses related to each country is a tedious job. There are different indices to measure responses related to each country. They depend upon various key indicators. Different indices identified include

Different indices identified include

- Government Response Index (GRI), which indicates how the response of the governments has changed the overall indicators. Governments are taking various policies during the COVID-19 outbreak. If the value of this index is more, it indicates the response of the government is stronger during the disease outbreak.
- Containment and Health Index (CHI): combines many key indicators such as the closure of schools and workplaces, travel restrictions, measures taken for contact tracing, emergency measures to be taken in the healthcare sector such as the purchase of testing equipment, ventilators, vaccine policies, etc.
- Economic Support Index (ESI): is used to measure the economic status of the country. It includes key indicators such as lockdown policies, tax policies, various credit policies, business support schemes adopted by the governments during the outbreak of COVID-19
- Stringency Index (SI): provides a clear picture of measures taken by the country to contain the outbreak of COVID-19. The key indicators include the closure of schools and workplaces, travel bans, a ban on public gatherings, the cancelation of public events such as rallies, processions, cancelation of public transports, international travel restrictions, etc. SI is an important consideration when determining a country's response to the COVID-19 outbreak. It gives a clear understanding of the various restrictions that a government introduced. The greater the level of stringency, the higher will be the value of SI [3][18].

7. INDIA SCENARIO :

The COVID-19 pandemic has affected billions of people across 187 nations around the world. Since the disease had no particular medication or vaccine it had created waves of panic especially in thickly populated countries like India. The healthcare resources and infrastructure were put into test during the outbreak of the pandemic.

The first case of COVID-19 was reported in India on the 30th of January, 2020, on the 14th of March 100th case was reported. The count of infected continued increasing exponentially and on the 13th of April, 2020 1000th case was reported. On the 18th of May, 2020, the total number of infected people reached 1 Lakhs. The count was doubled on the 12th of June, 2020. The count crossed 1 million on 16th July 2020 and became more than 5 million on 15th September 2020.

It crossed 1 crore on 18th December 2020. As of 22nd April 2021, 1,50,061805 people reported positive for COVID-19. The first COVID-19 fatality was reported on the 11th of March 2020, the 10th was reported on the 23rd March 2020 and the 100th death was reported on 6th April 2021. It crossed 10,000 on 16th June 2020 and 1 Lack on 2nd October 2020. As of 22nd April, 2021 total number of deaths reported in India is 1,78,768.

India responded appropriately and took every possible measure to contain the spread of the disease. Thermal screening of overseas passengers, isolation of COVID-19 infected people, quarantine of COVID-19 probable, observing social distancing, shutting down of schools and colleges, increasing the healthcare facilities, etc. were some of the measures taken. The Indian government took proactive measures and stringent actions to detect, treat and reduce the spread of the virus. To restraint the growing fright it distributed authentic information on the virus, preventive measures, guidelines, and accelerated the steps to develop a vaccine for the virus. The stringent actions taken by the government can be observed from the SI of India calculated by the OxCGRT. It delivers a clear representation of measures taken by the country to contain the spread of the disease.

In January 2020 the SI of India was 5.56. When COVID-19 cases were detected in some countries, preventive

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measures were taken and SI was 10.19 at the end of Jan 2020. On the 15th March 2020, it was 26.85 and it reached 50 on the 18th of March 2020. Between 25th March 2020 and 19th, April 2020 SI of India was at its threshold value that is 100. During this period the government of India imposed strict lockdown. When compared to the SI of the United States, the United Kingdom, France, Germany, and Italy the government response was more in India. It is observed that when SI is more, the spread of the disease is less.

Table 2 shows different parameters that are affected by the SI from the data recorded by the OxCGRT. As indicated in the table when the SI was more, the number of COVID-19 positive cases was less. When there are travel restrictions, restrictions on public gatherings, shut down of schools and colleges, etc. the value of SI was more.

It is found that the infection rate is growing exponentially during the post-lockdown period when compared to the lockdown period based on the value of SI. The positivity rate is used to measure the spread of infection. From Table 2 it is clear that the positivity rate was less when SI was high this means that when there are restrictions imposed by the government the spread of the disease was less. During the post-lockdown period, the value of positivity got increased as SI was less [17], [19].

Table 2: Impact of SI on positivity rate

Date	Stringency Index	Absolute Change	Relative Change	Total No. of COVID-19 Cases	New COVID-19 Cases Added	Positive Rate	No. of Deaths due to COVID-19	No. of New Deaths due to COVID-19
1/02/2020	10.19	-	-	1	1	-	0	-
1/03/2020	10.19	+0.00	+0%	3	2	-	0	0
1/04/2020	100	+89.81	+881%	1998	1995	0.69	58	58
1/05/2020	96.30	-3.70	-4%	37257	35259	0.035	1223	1165
1/06/2020	75.46	-20.84	-22%	198370	161113	0.066	5608	4385
1/07/2020	74.06	-1.39	-2%	604641	406271	0.089	17834	12226
1/08/2020	79.63	+5.56	+8%	1750723	1146082	0.104	37364	19530
1/09/2020	81.02	+1.39	+2%	3769523	2018800	0.084	66333	28969
1/10/2020	73.61	-7.41	-9%	6394068	2624545	0.07	99773	33440
1/11/2020	61.57	-12.04	-16%	8229313	1835245	0.043	122607	22834
1/12/2020	68.98	+7.41	+12%	9499413	1270100	0.036	138122	15515
1/01/2021	68.98	+0.00	+0%	10286709	787296	0.017	148994	10872
1/02/2021	61.57	-7.41	-11%	10766245	479536	0.019	154486	5492
1/03/2021	63.43	+1.86	+3%	11124527	358282	0.02	157248	2762
1/04/2021	57.87	-5.56	-9%	12303131	1178604	0.063	163396	6148
12/4/2021	69.91	+12.04	+2%	13689453	1386322	0.114	171058	7662

The positivity rate and mortality rate are not solely determined by the SI value. SI simply indicates that the government has implemented a specific policy or measure. It makes no mention of executing or complying with the law. The decrease in the number of promising cases, on the other hand, is indicative of the effectiveness of the measures undertaken. The GRI and CHI are the two indices identified by the OxCGRT which also affect the positivity rate. The GRI depends upon 16 key indicators including vaccination rate. The COVID-19 vaccination provides some sort of protection against the virus. The vaccine is strictly evaluated in different levels of clinical trials. Studies show that fully vaccinated people are less likely to get affected by the COVID-19 virus. Hence, they are potentially less likely to spread the disease. Immunity also reduces the risk of hospitalization and fatality rate. Table 3 lists different indices, positivity rate, count, and the percentage of people who are fully vaccinated in India between 1st March 2021 and 25th March 2021[17].

Table 3: Datasets showing different indices, positive rate, total cases and vaccination details for the month March 2021

Date	Total Cases	Positive Rate	Tests Per Case	People Fully Vaccinated	Vaccination %	Stringency index	Government Response Index	Containment Health Index

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01-03-21	11124527	0.02	49.1	2597799	1.08	63.43	69.64	72.44
02-03-21	11139516	0.02	49.3	2713978	1.13	63.43	69.64	72.44
03-03-21	11156923	0.02	48.8	2876927	1.2	63.43	69.64	72.44
04-03-21	11173761	0.021	48.5	3208668	1.3	63.43	69.64	72.44
05-03-21	11192045	0.021	47.1	3501021	1.41	63.43	69.64	72.44
06-03-21	11210799	0.022	46.1	3754041	1.52	63.43	69.64	72.44
07-03-21	11229398	0.023	44.4	3761107	1.52	63.43	69.64	72.44
08-03-21	11244786	0.023	43.4	4065450	1.67	63.43	69.64	72.44
09-03-21	11262707	0.024	41.4	4363679	1.77	57.87	66.51	68.87
10-03-21	11285561	0.025	39.5	4650530	1.86	57.87	66.51	68.87
11-03-21	11308846	0.027	37.6	4729079	1.9	57.87	66.51	68.87
12-03-21	11333728	0.028	35.7	5142953	2.04	57.87	66.51	68.87
13-03-21	11359048	0.029	34.7	5430774	2.15	57.87	66.51	68.87
14-03-21	11385339	0.03	33.8	5455653	2.17	57.87	66.51	68.87
15-03-21	11409831	0.031	32.3	5867948	2.39	57.87	66.51	68.87
16-03-21	11438734	0.032	31.6	6202499	2.54	57.87	66.51	68.87
17-03-21	11474605	0.033	30.5	6542468	2.69	57.87	66.51	68.87
18-03-21	11514331	0.034	29.5	6913587	2.85	57.87	66.51	68.87
19-03-21	11555284	0.035	28.8	7221362	3.05	57.87	66.51	68.87
20-03-21	11599130	0.036	27.5	7478654	3.23	57.87	66.51	68.87
21-03-21	11646081	0.039	25.8	7491696	3.27	57.87	66.51	68.87
22-03-21	11686796	0.039	25.4	7863441	3.51	57.87	66.51	68.87
23-03-21	11734058	0.041	24.2	8109334	3.68	57.87	66.51	68.87
24-03-21	11787534	0.044	23	8299171	3.85	57.87	66.51	68.87
25-03-21	11846652	0.046	21.6	8502968	4.02	57.87	66.51	68.87
26-03-21	11908910	0.049	20.5	8683155	4.21	57.87	66.51	68.87
27-03-21	11971624	0.051	19.7	8828346	4.37	57.87	66.51	68.87
28-03-21	12039644	0.052	19.1	8870201	4.39	57.87	66.51	68.87

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29-03-21	12095855	0.055	18.1	8901956	4.43	57.87	66.51	68.87
30-03-21	12149335	0.057	17.4	9065318	4.57	57.87	66.51	68.87
31-03-21	12221665	0.06	16.7	9334695	4.72	57.87	66.51	68.87

Studies show that when more and more people get vaccinated, their immunity level against the virus will get increased. But there is still a possibility that the vaccinated person may become the carrier of the virus and pass it to someone else. Experts recommend the use of sanitizers, observation of social distance, and wearing of masks is to be continued even after getting vaccinated. When 70% of the total population develops immunity, it is a good sign of progress for any country.

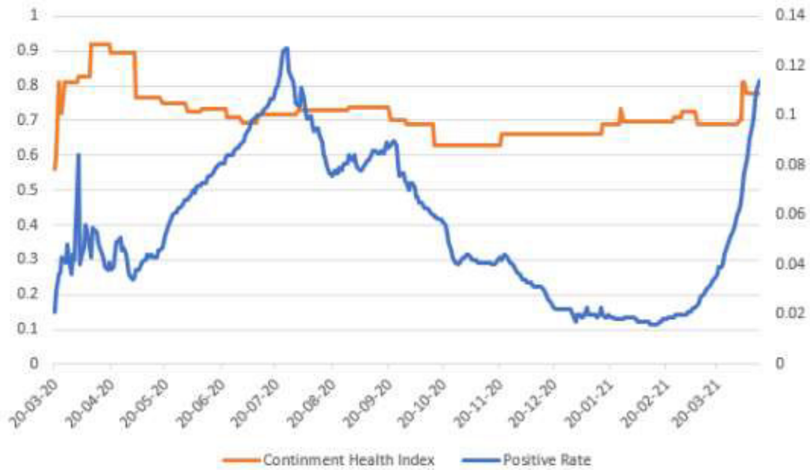

Fig. 5: Stringency Level and COVID-19 Positive cases between 20th March 2020 and 20th March 2021

SI is considered as the key product of the OxCGRT. It depends upon 14 different key indicators and ranges from 0 to 100. Between 25th March 2020 and 19th April 2020, the government imposed a strict lockdown. Hence during that period, the value of SI was 100. As indicated in Figure 5, when the Stringency Index was more the positive rate was less. There were a smaller number of positive cases between 20th June 2020 and 20th March 2021. When the SI value dropped, there is a sudden surge in the number of positive cases. At the end of March 2021, there is a spike in the number of positive cases [20].

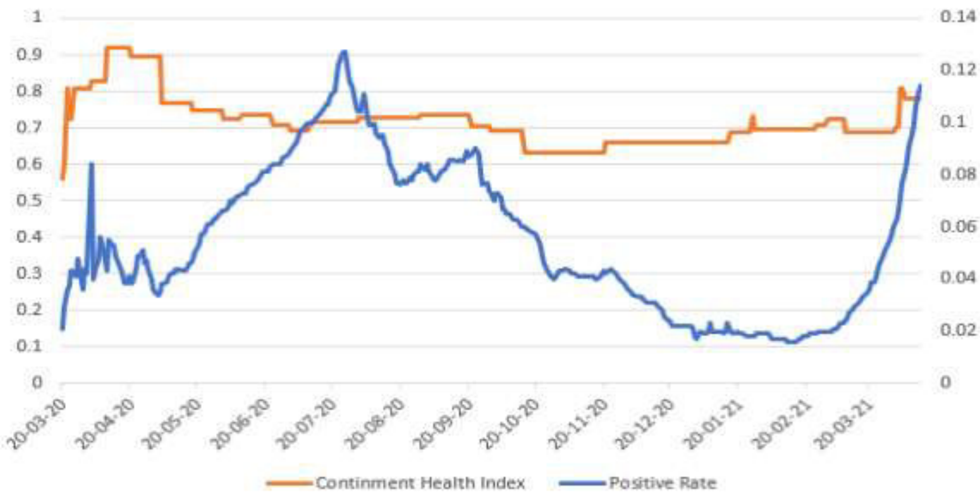

Fig. 6: Government Response Level and COVID-19 Positive cases between 20th March 2020 and 20th March 2021.

Figure 6 indicates the relationship between GRI and COVID-19 positive cases between 20th March 2020 and

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20th March 2021. The GRI depends upon 16 different key indicators. When the GRI value was dropped, there is a sudden surge in the number of positive cases. The positive rate was more in July 2020 and it was dropped was the GRI was almost steady between April 2020 and March 2021. At the end of March 2021, there is a surge in the number of positive cases [21].

Fig. 7: Containment and Health Level and COVID-19 Positive cases between 20th March 2020 and 20th March 2021.

Containment measures are implemented by a country to stop the spread of the virus. Figure 7 indicates the relationship between CHI and COVID-19 positive cases between 20th March 2020 and 20th March 2021. The CHI depends upon 14 different key indicators. When the CHI value was dropped, there is a sudden surge in the number of positive cases. The positive rate was more in July 2020 and it was dropped was the CHI was almost steady between April 2020 and March 2021. These results indicate that the measures followed by the country are found to be effective in flattening the curve of positive rate. As a result of the decrease in the CHI at the end of March 2021, there is a gush in the number of positive cases [22].

8. COVID-19 INFECTION FORECASTING :

According to Buzrul *et al.* [model1] in some countries, the total number of cases at a given time 't' shows sigmoid behavior. The statistical model is indicated by using the formula

$$y(t) = \frac{a^m.t^m}{b^m + t^n}$$

Equation (1)

In equation (1) y(t) is the total number of cases, a, b, m, and n are parameters whose value can be adjustable. At time t=0 y(t) is also 0 which indicates that to begin with the total number of cases was zero. When the value of m is greater than that of n as $t \to \infty$, $y(t) \to \infty$ which means that the total number of cases increases continuously. When m is less than n as $t \to \infty$, $y(t) \to 0$ this means that when the value of the adjustable parameter m is less than that of n, the total number of cases decreases as time passes and will reach zero. The formula takes a special value when m is equal to n as

$$y(t) = \frac{a^m.t^m}{b^m + t^m}$$

Equation (2)

Equation (2) shows the same value as that of Equation (1) when t is 0. When $t \to \infty$, the total number of cases converges at a given value after a certain point of time.

Jayatilleke *et al.* [Model2] used the SIRD (susceptible, infected, recovered, dead) model to predict the number of cases in the near future. The model uses a sliding window with equal intervals and the method of least squares to estimate the accuracy of predictions. N represents the total number of populations at a given time t, which is the sum of susceptible, infected, recovered, and dead as mentioned in Equation (3).

$$N = S(t) + I(t) + R(t) + D(t)$$ Equation (3)

If α, β, and γ denote the projected rate of infection, rate of recovery, and death rate respectively then to

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calculate the probability of susceptibility the equation (4) can be used.

$$S(t)= S(t-1) - \frac{\alpha}{N} . S(t-1). I(t-1) \quad \text{Equation (4)}$$

The number of infected at time t is calculated using the equation (5)

$$I(t)= I(t-1) + \frac{\alpha}{N} .S(t-1). I(t-1) \quad \text{Equation (5)}$$

The total number of recovered cases at time t is calculated using the equation (6)

$$R(t)= R(t-1) +\beta . I(t-1) \quad \text{Equation (6)}$$

The number of deaths can be estimated using the equation (7)

$$D(t)= D(t-1) + \gamma . I(t-1) \quad \text{Equation (7)}$$

This model also requires another parameter R_0 which is the basic reproduction rate. It is calculated using equation (8)

$$R_0= \frac{\alpha}{\beta + \gamma} \quad \text{Equation (8) [18] [23][24]}$$

9. PROCASE MODEL FOR FORECASTING :

The statistical models mentioned in section 7 do not consider the percentage of vaccination. The rate of infection is found to be dependent on several factors. It is low where protective measures such as social distancing, disinfectant use, and sanitization have properly adhered. Other than the intensity of the virus's replication rate, numerous factors influence fatality, recovery, and rates of infection. It also depends on demographic data, a person's disease risk, co-morbidities, and the availability of services in the emergency care departments, such as oxygen cylinders and ventilators. It is also observed that the severity of the disease is very low if a person is vaccinated.

A new mathematical model, ProCase (Project Case) was developed using the models listed above to forecast COVID-19 cases daily. This is seen as an equation (9) below.

$$C_d = C_{d-1} + C_{d-1}\left(\frac{(vpt)^2}{GCS}\right) \quad \text{Equation (9)}$$

Based on the statistics of the day, this model can be used to forecast COVID-19 cases that will be registered tomorrow. Where *Cd* is the total cases forecasted, Cd-1 is the total cases reported today, *v* is the vaccination percent, *p* is the positive rate, *t* is the number of tests performed per case, *G* is the Government Response Index, C is the Containment and Health Index, and *S* is the Stringency Index. Using ten pre-recorded data sets, the equation's operation is investigated. The accuracy of the analysis is ≥98 percent, with a ≤2% error rate and same is produced below as Table 4 [17].

Table 4: Datasets used for the verification of the model and its result

Date	Positive Rate	Tests Per Case	Vaccination %	Stringency index	Government Response Index	Containment Health Index	Projected Cases	Actual Cases of the Day	% of Error
01-04-21	0.063	16	4.98	57.87	66.51	70.3	12222803	12303131	0.65
02-04-21	0.066	15.1	5.29	57.87	66.51	70.3	12304394	12392260	0.70
03-04-21	0.071	14	5.51	74.54	70.89	81.01	12393128	12485509	0.74
04-04-21	0.077	13.1	5.73	74.54	70.89	81.01	12486483	12589067	0.81
05-04-21	0.082	12.1	6.02	69.91	68.28	78.04	12590272	12686049	0.75

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06-04-21	0.086	11.6	6.31	69.91	68.28	78.04	12687398	12801785	0.89
07-04-21	0.091	11	6.54	69.91	68.28	78.04	12803257	12928574	0.97
08-04-21	0.096	10.4	6.84	69.91	68.28	78.04	12930193	13060542	1.00
09-04-21	0.1	10	7.11	69.91	68.28	78.04	13062316	13205926	1.09
10-04-21	0.106	9.5	7.36	69.91	68.28	78.04	13207874	13358805	1.12

10. DISCUSSION :

AI-based Predictive Analytics tools may also be used to forecast or predict COVID-19-related statistics. We used Datapine's online Data Analytics tool to forecast COVID-19 incidents, Stringency Index, and deaths for the next three months, i.e., May, June, and July 2021. A different group of data has been used to predict different parameters.

Prediction of Stringency Index: index of date and stringency extracted from the above-mentioned dataset was used to map the Stringency Index from February 1, 2020, to April 12, 2021, and to forecast the same for the next three months. To find the future value, it was asked to measure aggregate data using median values accumulated over time. Set a parameter to use a power line to display the trend. The month has been used to establish data points as the interval of time. All data points were used in the projection, with more recent periods being given higher weights. The 95 percent confidence interval for model quality was chosen.

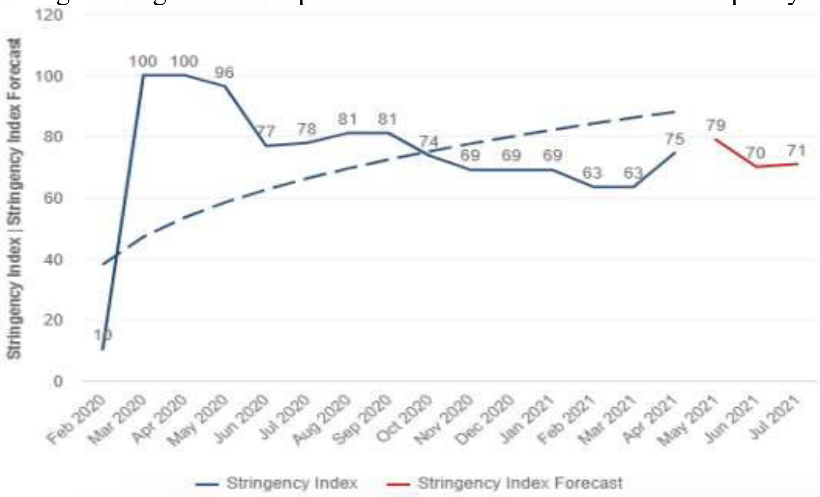

Fig. 8: Predicted Stringency Index for May, June, and July 2021

As seen in the Figure 8 above, the aggregate median stringency index for May, June, and July is expected to be 79, 70, and 71. That means the degree of strictness will be reduced after May, as the establishment may relax a few restrictions.

Prediction of COVID-19 cases: index of date and total cases extracted from the above-mentioned dataset was used to map the COVID-19 cases from April 1, 2021, to April 28, 2021, and to forecast the same for the next three months. To find the future value, it was asked to measure aggregate data using median values accumulated over time. Set a parameter to use a power line to display the trend. The days have been used to establish data points as the interval of time. All data points were used in the projection, with more recent periods being given higher weights. The 95 percent confidence interval for model quality was chosen.

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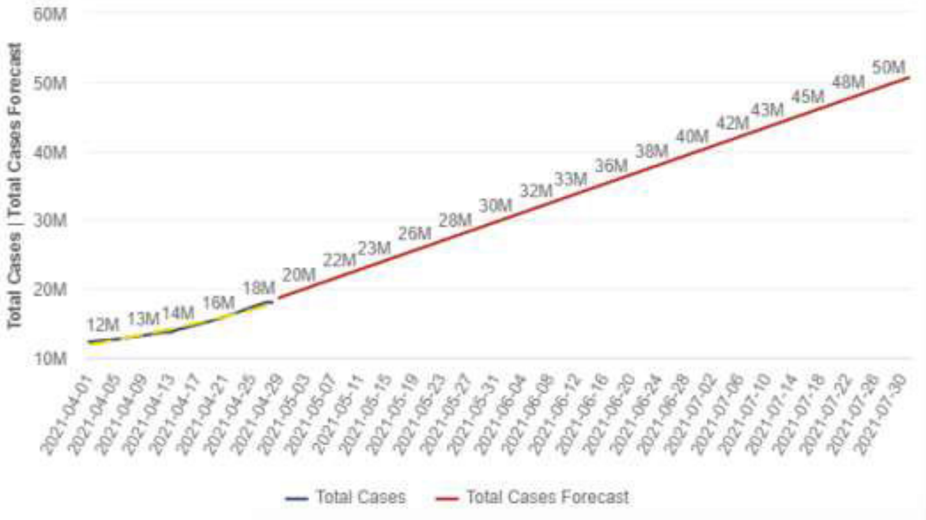

Fig. 9: Predicted COVID-19 cases in India for May, June, and July 2021

As shown in Figure 9 above, by the end of July 2021, the aggregate median cumulative cases are projected to reach 50 million. In April 2021, the total number of cases reported is expected to be about 18 million. It will reach 20 million in the first week of May, 30 million in the second, 40 million in the third week of July, and 50 million in the fourth.

Prediction of Total deaths: index of date and total deaths due to COVID-19 extracted from the above-mentioned dataset was used to map the COVID-19 cases from April 1, 2021, to April 28, 2021, and to forecast the same for the next three months. To find the future value, it was asked to measure aggregate data using median values accumulated over time. Set a parameter to use a power line to display the trend. The days have been used to establish data points as the interval of time. All data points were used in the projection, with more recent periods being given higher weights. The 95 percent confidence interval for model quality was chosen

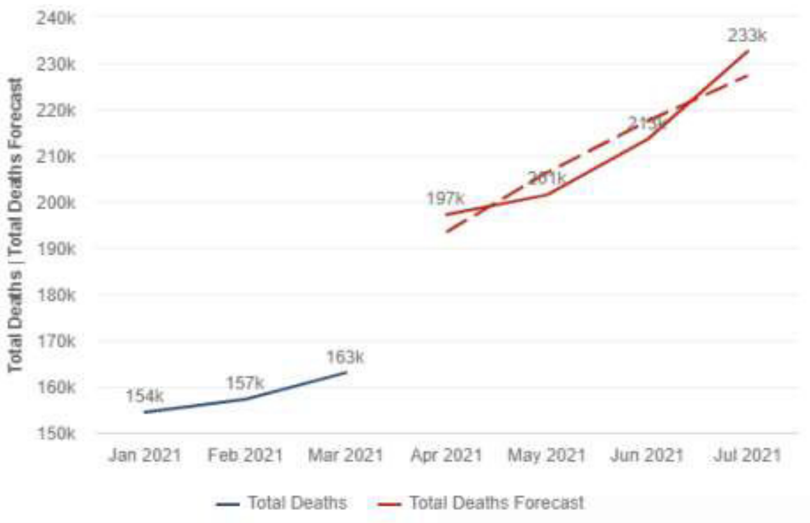

Fig. 10: Predicted deaths due to COVID-19 for May, June, and July 2021

As shown in Figure 10 above, the total number of deaths in India due to COVID-19 is projected to reach 2.33 lakhs by the end of July 2021. It is expected to be around 1.97 lakhs at the end of April 2021, 2.0 lakhs in May, and 2.13 lakhs in June. There is a possibility of the deterioration of the number of COVID-19 infections after July as the vaccination will be made available to more people [24-26].

11. CONCLUSION :

The Oxford COVID-19 Government Response Tracker tracks the level of rigor with which a government implements COVID-19 prevention and suppression measures. These indexes take into account all steps that

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governments around the world have adopted and are thus applicable to India as well. It was observed that in India, as in other countries, there is a close association between Stringency Level and COVID-19 cases. The higher the degree of stringency, the lower the cases, and vice versa. The same can be said about the government's role and degree of containment & health. In this paper, we analyzed various mathematical models for predicting the total number of COVID-19 cases and deaths due to COVID-19 in India. We also examined the relationship between total cases and the Government's Response Index, Containment & Health Index, and Stringency Index indicators. The model we proposed to predict COVID-19 cases on a day-by-day basis had a 98 percent accuracy rate and a 2% error rate.

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Literature Review of Applications of ICT on Solar Cold Chain

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ABSTRACT
The Cold Chain (CC) is a system containing a range of processes like shipping 'temperature-sensitive' items by special kind of packaging along a supply chain, and strategic planning to ensure the safety and integrity of items that are shipped. The items of CC are transported in many ways, such as refrigerated vehicles and railcars, cargo ships, reefers, and air freight. For many years, the 'Cold' element of the system, that is, refrigerators, powered by gas or kerosene was considered the most appropriate option in areas without reliable energy sources like electricity. Nevertheless, numerous problems with these tools have made it both difficult and costly to maintain temperatures within the safe range. In the 1980s, solar refrigerators powered by batteries were introduced as a solution to those problems. But the batteries they relied on required regular maintenance, had a lifespan of only three to five years, and replacements of quality were costly and sometimes hard to get. A new solution has emerged in recent years, the design of a solar refrigerator, removing the need for costly and unreliable energy storage batteries used to power solar refrigerators. This technology uses solar energy to freeze cold storage material directly and then uses the energy stored in the frozen bank to keep the refrigerator cool at night and on cloudy days. The new ICT technology offers greater visibility and control over the entire CC network operated by the solar. Using data in real-time, ICT component Technology called the Internet of Things (IoT) will allow quicker, more appropriate reactions as well as much more informed decisions. This literature analysis is created by revising a good number of papers published in peer-reviewed journals and online sources making use of secondary data obtained. The goal of the study is to explain the use of applications of ICT in the CC System and find research gaps.
Keywords: Solar Energy, Cold Chain, ICT, Cloud Computing, AI, Big Data, Cloud Storage, Smart Sensors, Energy Grid, Bluetooth, WiFi.

1. INTRODUCTION :

Because of 'globalization', the logical distance between two parts of the world has decreased; the reality is that the physical distance between them remains the same. When items are shipped using CC, they may get damaged because of vibration or improper temperature. During transport time, the quality of a range of products considered to be perishable objects, such as good products, maybe reduced because they sustain chemical reactions that can often be mitigated under unstable temperature conditions. Reliable freight management involves effective time-consuming planning which has invariably negative effects, particularly if such a shipment is perishable. To mitigate these consequences, CC is extensively used by the food industry, healthcare sector, and pharmaceutical sectors. They depend upon the CC mainly to ensure that the items shipped are not harmed or tampered during the process of transportation. To ensure the safety and integrity of items shipped using CC, a sort of systematization or planning is very much needed. "The cold chain is a process of transportation of temperature-sensitive products along a supply chain through thermal and refrigerated packaging methods and the logistical planning to protect the integrity of these shipments. The modes of transportation are of items using CC include refrigerated trucks and railcars, refrigerated cargo ships, reefers as well as air cargo" [1].
The CC technology includes the element of science; because the items shipped using it will undergo

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chemical reaction or develop pathogens as the time progresses. The product perishability and integrity depend solely on physical means to guarantee the necessary temperature conditions along the transport chain and the process element comprising a variety of transport chain issues. This system has four main factors: Cooling Systems, Cold Storage, Cold Transport, and Cold Processing and Distribution.

The success of an effective 'Cold Chain' system solely depends on the performance of the critical element 'Cold'. That is 'what mechanism is used to ship the items under controlled temperature? The type of container being used for shipment and the cooling technology adopted will ensure that the items remain within the specified temperature range for a prolonged period. Approximately 20 percent of all energy used in CC logistics requires container cooling [1]. Factors such as transit time, shipment size, and observed ambient or external temperatures are critical when determining what form of packaging is needed and the related energy consumption level. These can vary from small isolated boxes containing dry ice or gel packs, rolling containers, to a large reefer with an electric cooling unit.

For many years, the 'Cold' element of the system, that is, refrigerators, powered by kerosene, gas or diesel was considered the most appropriate option in areas without reliable energy sources like electricity. Nevertheless, numerous problems with these tools have made it both difficult and costly to maintain temperatures within the safe range [2].

In the 1980s, solar refrigerators powered by batteries were introduced as a solution to those problems. But the batteries they relied on required regular maintenance, had a lifespan of only three to five years, and replacements of quality were costly and sometimes hard to get. A new solution has emerged in recent years, the design of a solar refrigerator, removing the need for costly and unreliable energy storage batteries used to power solar refrigerators. This technology uses solar energy to freeze cold storage material directly and then uses the energy stored in the frozen bank to keep the refrigerator cool at night and on cloudy days [3].

The ICT offers greater visibility and control over the entire solar-operated cold-chain system. ICT's use of data in real-time would allow quicker, more effective reactions as well as much more informed decisions. Recent technologies such as smart sensors, cloud platforms, GPS devices, network gateways, big data analytics tools, wireless networking solutions, and customized user interfaces [4] can simplify the system's integrated operation such as tracking, aggregating, monitoring, delivery, reporting, analytics and sharing [5].

The typical integrated Solar Powered CC Portfolio Management System includes - Smart Sensors such as chemical, automotive, moisture, flow, sound, weather, and humidity, the temperature that detects physical environmental conditions, processes and converts them into the signal. They contain a built-in microcontroller with wireless transmission capabilities. It performs an automated collection of data, pre-processing as well as transmission. Sensors generated data is collected by different IoT devices [6]. IoT Devices include different development boards such as Arduino, ARM, RaspberryPi, Beagle Bone, Intel Edison, Intel Galileo, etc. The IoT device communicates with the gateway using protocols such as ZigBee, Z-wave, Bluetooth, BLE &Wi-Fi, Wireless Sensor & Actuator Networks, GPS and Cellular Gateways. The data from the gateway to the cloud is communicated usually using protocols like MQTT, CoAP, and XMPP [7], [8]. Cloud infrastructure provides a platform for quick, easy and complex processing of events in real-time needed to perform advanced sensor data analytics. Cloud computing technology harnesses a Big Data platform which allows large amounts of data to be stored in a decentralized site, ensuring easy access to data, high protection, and reduced storage costs. Notable cloud platforms are Amazon Web Services, Microsoft Azure, VMWare, and Google Cloud. Each Cloud Platform offers a suite of tools that make it easy to gather, process and store data[9].Machine Learning and Artificial Intelligence tools such as Google Cloud ML Engine, Amazon Machine Learning (AML), Apache Mahout, Google ML Kit for Mobile Azure Machine Learning Studio, Eclipse Deep-learning facilitate the discovery of information and the generation of insights to provide empirical solutions. These include Energy Forecasting, Operational Intelligence, and Predictive Maintenance. They are considered key factors for improving the efficiency and profitability of power plants.

The system would increase the quality and effectiveness of food, pharmaceutical, and other perishable supply chains over long distances. The "cold chain" or 'temperature-controlled' supply chain, is now gradually integrating digital technological systems, stable cloud infrastructure, and open architecture rather than pure freezers and freight trains. Besides, the integration of eco-friendly renewable solar energy instead of non-renewable eco-unfriendly fossil energy controlled and managed by ICT results in a more intelligent solar-powered CC system that provides managers with live temperature and location data, minimizing any

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problems along the chain before they occur [10].

2. RESEARCH AIM AND METHODOLOGY :

This paper mainly focuses on Applications of Information and Communication Technology (ICT) in Solar Cold Chain Portfolio management. The main objectives of this research article are mentioned below:

- To familiarize the application of ICT in solar cold chain
- To identify the Research Gap based on the existing literature study
- To construct the Research Agenda

In this literature review paper, applications of ICT in Solar CC are reviewed and studied. The ICT system consists of many recent technologies such as smart sensors, cloud platforms, GPS devices, network gateways, big data analytics tools, wireless networking solutions, and customized user interfaces. This literature analysis is created by revising a good number of papers published in peer-reviewed journals and online sources using the secondary data obtained. The paper finds the research gap.

3. LITERATURE REVIEW :

In recent years a considerable extent of growth and development had been established in the field of CC, Solar-powered CC, and ICT. A significant number of published papers on the Solar CC perspective have been reviewed and examined in this paper in the peer-reviewed Journals and on the Internet for the last 15 years (2005-2020). Based on the analysis, the literature section has been logically classified into three subdivisions. This review outlines the different investigations on ICT technology and how it affects the Solar Energy-powered CC Portfolio Management.

CC managers used electronic temperature loggers that provided accurate data on the temperature of products delivered using the CC. The quality of temperature-sensitive items depends on a variety of unpredictable variables. Therefore, recording only the temperature data was not necessary. They indicated the need for an efficient monitoring system that would take care of several variables such as time, temperature, humidity and vibration (Bishra, 2006) [11].

"The system is a set of elements that interact over a while to create a coherent whole. Dynamics means that it is continuously changing. In the case of CC temperature, humidity and time are continuously changing parameters. To ensure the quality of items delivered using CC, these parameters must be controlled effectively. The model used RFID tags to generate temperature logs and, before unloading items, these logs were reviewed and only items that met the pre-determined temperature conditions were unloaded. It saved a lot of time and money (Oliva & Revetria, 2008) [12].

CC Information, hybrid technology produces huge data that is stored in the database, evaluated for resource development and fair use using modern technologies such as sensors, networking, network, and database. These integrated approach guarantees cost savings in CC logistics and product quality & safety of goods (Zhang *et al*., 2018) [13].

The success of any CC Portfolio Management system solely depends on the management of its core requirements of maintaining a suitable temperature environment to guard the reliability and quality of temperature-sensitive goods and perishable products (Yan & Lee, 2009) [14].

The requirements of such a system are generally higher compare to the regular supply chain system or managing the logistics system at room temperature. The process involves a large number of critical issues starting from production to last-mile delivery. It includes a temperature-sensitive logistics management process at every stage of the system such as production, storage, package, transport, delivery, and sales (Rodrigue & Notteboom, 2020) [15].

Lots of risks involved in it. To minimize the risk factor, manufacturers & producers of such goods and the companies involved in managing the logistics implement various devices that operate, monitor, track and automate the management process (Atzire & Yamaura, 2016) [16].

The incipient technologies such as the Internet, Smart Sensors, Mobile Technology, Wireless Connecting options, Cloud Computing, BigData Analytics, Artificial Intelligence and Machine Learning opens-up a plethora of opportunities to assure quality and efficacy of the CC goods. The use of technologies in the evolution of intelligent Solar CC systems is analyzed here in the chronological order.

Shivakumar & Deavours (2008) [17] introduced a microstrip-like antenna to address the technical shortcomings of deploying RFID in the CC. RFID (Radio Frequency Identification), an automated

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identification technology has the potential to serialize each container and provide accurate and automatic tracking inside the supply chain, greatly enhancing precision, speed, and cost while improving product quality.

As RFID's performance degrades when it is used with objects contains water fields, a new microstrip antenna was introduced. The antenna was proposed in two forms: i) To encourage a low cost and no effective profile, the cardboard itself is proposed as a substratum of the microstrip antenna, which has the advantage of protecting the antenna from the contents of the package and ii) two-element array and feed structure for providing a steady level of performance over a broad range of humidity conditions. By implementing new low-cost innovations such as these, authors believed off to overcome RFID's technological limitations and promote its use within the CC and the quality of items.

In their work Fu *et al.* (2008) [18] proposed integration of relatively new technology Wireless Sensor Network with RFID to make RFID more intelligent on its operational environment such as temperature, humidity, etc. WSN consists of several small tools that are capable of processing and sensing. Tracking and tracking operations with product position and quality perspective are enhanced if RFID systems are combined with condition monitoring systems such as WSN.

Moreover, the historical data so derived will enable the system to take decisions. The proposed system was developed using the Nano-Qplus platform-based sensing system which consists of NANO HAL to abstract the sensing and actuation of the hardware component, task management, power management, and message handling module. It also includes the ATmega128 MCU and the IEEE802.15.4 RF communication module, CC2420 Zigbee. And it was implemented using LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) and VISA tools.

In 2009, Carullo and his team proposed a measurement device for calculating container temperature along the supply chain logistics route to verify product integrity. It has been developed using Wireless Network Sensor technology. This was able to track the temperature inside a refrigerated vehicle with the packed goods. The layout consisted of a base station and several temperature measurement nodes that communicate with the base station through wireless communication options. Two types of nodes were used for measuring -One for measuring the temperature inside the vehicle's container, and the other for determining the temperature of the product. The nodes enclosed with the circuitry to track and acquire sensor data, data storage memory and transmitter for transmitting data to access point. The base station is designed to gather transmitted node data, store it in its memory, process it and make decisions. The base station sends an alarm signal to the cell phone when an abnormal situation occurs which compromises the product's integrity. The solution provided improved calculation and control of temperature measurement processes in the refrigerated vehicle. The center of the circuit is the CC2510F32RSPR system-on-chip provided by Texas Instruments that integrates both a microcontroller unit identical to the integrated circuit 8051 and a 2.4-GHz radio transmitter CC2510. As temperature sensors, three T-type thermocouples are used (Carullo*et al.,* 2009) [19].

RFID is a radio-signal-based technology that uses the Radiofrequency (RF) signal for the detection of stagnant or moving objects and the sharing of digital information. The RFID system comprises of three parts, namely tags, readers and antennas. The reader sends a fixed-frequency RF signal to the antenna. The tags create faradic impulses whenever they enter the working region of the antenna. Tags are triggered by electricity, and automatically transmit the coded messages via the built-in antenna of the cards. Carrier impulses sent by RF cards are received by the receiving antenna system, sent by the reader to the reader via the antenna controller, regulated and decoded, and then forwarded to the Backend Management System for disposal. Yan & Lee (2009) [20] developed a system using RFID technology to analyze the current location and measure the temperature to assure the quality of supply chain products. The system includes hardware such as RFID tags with 915MHZ ISO18000-6/EPC standards, Temperature sensors, that are pasted into a fixed product location, EPC Globe standard Double-standard network interface readers, fixed scanners, portable terminals, real-time data analyzing software framework, site computer terminals, and wireless networking devices. The device was able to monitor and process products for temperature and tracking & positioning.

Abad *et al.* (2009) [21] introduced the prototype of an RFID-based smart tag for object traceability in real-time and food-specific monitoring of CC systems. a Smart RFID tag and a card reader/writer. The tag attached to the product to be tracked and monitored includes photosensors, temperature and humidity, a microcontroller, a memory module, low-power electronics, and a communication RFID antenna.

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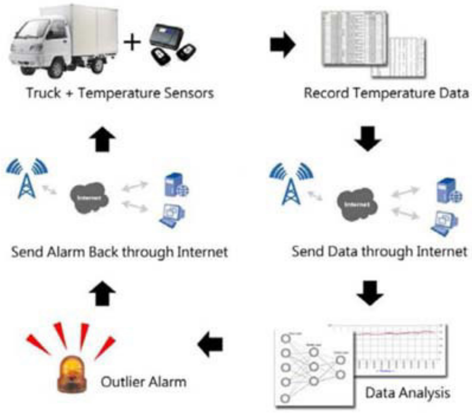

Fig.1: System Architecture (Abad *et al.*, 2009) [21]

The data collected from the sensor and the traceability information are stored in the memory module. The card reader / writer was used for interpreting tag data and for inserting data into log. Compared to traditional traceability tools and widely used temperature data loggers, the system shows major advantages, such as enhanced memory, reusability, minimal human involvement, zero tag exposure needed for reading, ability to read multiple tags at the same time, and greater tolerance to humidity and weather.

A power-efficient WSN for CC monitoring was proposed in 2009 by Kaucimi and his team. Their model was based on self-organizing protocols for monitoring energy consumption by the sensors resultantly increases in sensor lifetime and network longevity. Several plans seek to automate network operations at different levels to reduce energy usage. Protocols operating in the MAC layer such as S-MAC, T-MAC, B-MAC, and WiseMAC have been shown to save energy and are commonly used when a large number of sensors are operating under a process. Protocols based on IEEE802.15.4 MAC & PHY layers were used to distinguish various phases of operations: i) Initialization protocol -where the sensors begin a process of mutual recognition to determine the topology of the chain, ii) Addition protocol - when the introduction of other pallets, add one or more sensing devices to the network throughout the trip, iii) Protocol for reported/unforeseen loss of sensors-manage the absence of sensors when they are low in the battery or when the pallets are unloaded; iv) Steady-state protocol - for timing the regular waking of nodes to share and collect their alarms, v) Data collection protocol - to give the entire collected data to the operator during transport (Kacimi*et al.,*2009*)* [22].

In their research, Guanpeng Lv and his team described a real-time web-based CC monitoring system. The system had been broken down into three tasks. 1) Wireless sensors, sensing and relaying data to the database server through an outdoor network via the outdoor network using GSM (Global System for Mobile Communication) set-up and internal intranet, 2) Web application reviews sensed data stored in the database and 3) Alarm mechanism which fires alarm there is a deviation in the temperature or humidity. In four separate methods, an alarm is shot – email, SMS, dialing, and pup-up. The hardware/software of the system consists of *Sensors* - indoor sensors are used to sense the temperature or humidity of the surrounding air and outdoor sensors transmit data via GSM network to GSM base station, *Repeater* – Two types of repeaters are used, actual repeaters obtain data packets from wireless sensors and transmit data via the intranet to the network and virtual repeater in ta way of mobile sensors transmit data to the base station of GSM which acts as a repeater for sending data to the network, *GSM Base Station* - GSM base station has GSM MODEM and receives GSM network sensing data, *Software* - the framework is architecturally based on J2EE MVC (Model-View-Controller). Ajax, JSP, SERVLET, Java Bean, ADO, and MySQL were the tools used (Lv *et al.,* 2009) [23].

Liu &Jia (2010) [24] suggested a business model for CC management using IoT. IoT is a world of interconnected objects that are uniquely identifiable. These objects can interact with one another. The model uses Sensors, RFIDs and Smart Technology. The CC now consists of network operators, providers of terminal equipment, developers of software, manufacturers, inspection department, suppliers, distributors, buyers and finally consumers. There are two variants of the pattern. One is called the Terminal

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Equipment Provider-centered model where the terminal equipment provider conducts as many activities as possible. The service charges are fixed by terminal equipment provider along with network operator, manufacturer and application developer. In-network operator-centric model, the service charges are fixed by the network equipment provider.

Wang *et al.* (2010) [25] are proposed a multi-level instrumented physical monitoring using RFID, ZigBee, 3G networks and grid computing technology. The temperature of the products delivered is tested at each Critical Control Point (CCP) in the conventional CC. Since temperature is the most significant factor in maximizing the shelf-life of the shipped goods using CC, it must be controlled continuously. RFID tags are incorporated into goods which are shipped using the CC. The core of the model is the Electronic Product Code (EPC) which uses RFID to uniquely identify the object. Temperature sensors placed on the product can continuously transmit information about the temperature. The RFID reader reads the data and sends it to the ZigBee system which, by using the 3G network, sends it to the computer. Grid computing is used to regulate the temperature of products delivered using the CC, effectively. The tracking process starts at the production stage and lasts until the commodity reaches the buyer's doorway.

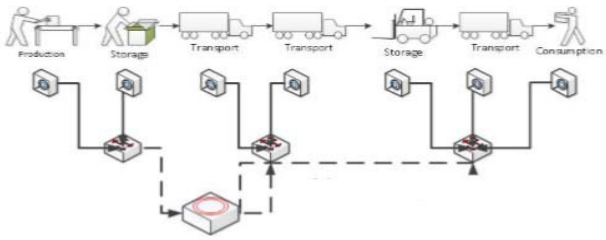

Fig.2: Multi-level instrumented physical monitoring (Wang *et al.,* 2010) [23]

Provided that the sensors connected to CC's logistics move with the goods from their origin to the final destination together with the transportation in heterogeneous network environments. Some protocols are more appropriate than others depending on the situation prevailing. The system expects to be able to turn to appropriate protocols and adapt it according to its requirements. In their research, Nicolas and his team are proposing these methods. The proposed system enables a sensor to adjust to the situation to suit the best protocol. A hybrid synchronization system is introduced to ensure that nodes are synchronized with power efficiency and context adaptability. The system also dynamically chose routing protocols, based on their access to the network available. (Nicolas *et al.* 2011) [26].

The CC logistics includes a wide variety of processes such as production, packaging, warehousing, transportation, distribution, feedback, etc, involving contributions of different departments of enterprise-wide players. There is a demand for a collaborative business process between different entities related to business and expects greater and viable support for the IT system. Cloud computing is used to make CC logistics more efficient with minimal investment as the cloud is owned by a third-party. With the help of cloud technology, entire CC management can be integrated and optimized to form a single unit although there are several entities are involved. The CC logistics system based on cloud technology is will contain a database. The CC infrastructure should be structured to guarantee that the services are paid for by all consumers who have access to them. To do this, the framework must have functions such as real time CC logistics control, calculation of data, logbook recording, querying the database, generating reports, etc. (Li *et al.* 2011) [27].

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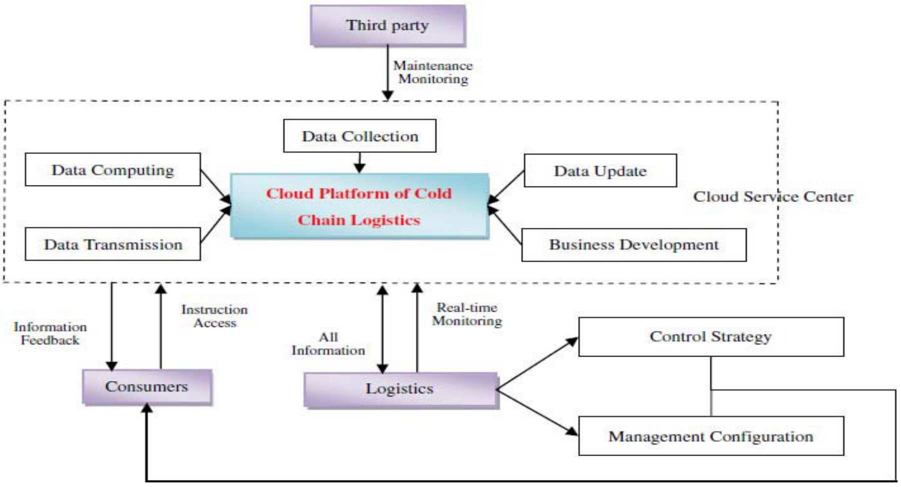

Fig. 3: The CC logistics system using Cloud Technology (Li *et al.,* 2011) [27].

As demand for the CC logistics increases, more researches are conducted to make the CC more effective. Cloud storage technology helps the CC framework to deliver high-quality services with limited investment because a third party owns the cloud. Accessing and analyzing the data can be done seamlessly with the ubiquitous availability of data. With the support of any portable device with Internet connectivity, data can be accessed anywhere at any time. The requirement for IT resources and equipment is reduced as pay for use policies are implemented. CC data can be accessed via the Cloud platform in real-time. Cloud computing is more useful when security and privacy problems that are associated with it are addressed effectively (Adhianto *et al*., 2011) [28].
Service-Oriented Architecture (SAO) has enabled supply chain organizations to exchange information to improve the supply chain network, which is fairly important for e-commerce requiring a single forum for information sharing. IoT can incorporate technologies such as RFID, Sensors, GPS, Laser Scanners, etc. to create a Global Network with the Internet. The ultimate goal is to provide a single network such that the SC elements can be easily defined and controlled. Through a case study, Sun and his team showed utility. The product framework includes storage reader, position reader, handheld reader, RFID tags, etc. The self-developed app uses a wireless network to communicate with readers. The system identifies the goods during loading & unloading for transport, records cargo inventory, storage records and out-store information (Sun *et al.,* 2011*)* [29].

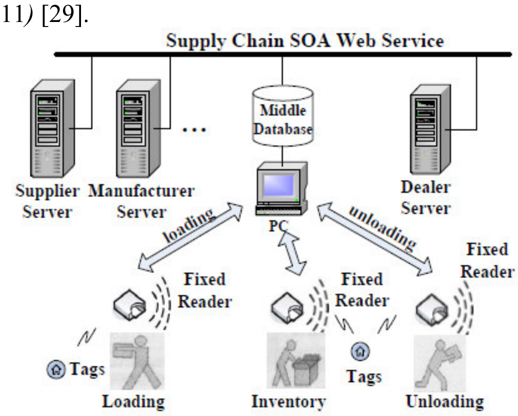

Fig. 4: Construction and implementation of IoT-based manufacturing enterprise knowledge transformation system (Sun *et al.* 2011*)* [29].

Aung *et al.* (2011) [30] demonstrated the design of the Intelligent CC Management model by using RFID & WSN to track temperature-sensitive objects during their life cycle, such as production, shipping,

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warehousing, and quality support, thereby improving the operation of the CC. A Nano-Qplus platform based sensor network framework was implemented in tandem with Nano Hardware Abstraction Layer (HAL) for sensing & actuating. It also takes care of some other tasks like energy management, and message handling. Besides the communication module ATmega128 MCU and CC2420 Zigbee, IEEE802.15.4 Radio Frequency (RF) was also used.

Over the years, efficient management of CC is becoming increasingly popular because of the high demand for the 'Cold items'. Kim *et al.* (2012) [31] proposes RFID/USN (Ubiquitous Sensor Network) based CC for the efficient shipping of temperature-sensitive items. CC management ensures that high-quality items are delivered effectively to the customer. If the entire process is carried out by using technology, this can be achieved effortlessly.

While packing, the manufacturer has to indicate the materials used, ideal temperature, shelf-life, etc on every unit being shipped using CC. The data is stored in the cloud automatically as RFID tags are deployed on the product. At every Critical Check Point (CCP) the details can be verified automatically because of RFID tags and temperature sensors on the items. If the item fails to satisfy the desired quality criteria, the consumer will specify the same and reverse chain starts. At each CCP status can be updated automatically. The process gets terminated at the manufacturer-end where the manufacturer disposes the items and updates the inventory. At every level, confirmation of distribution, confirmation of product quality and confirmation transportation is done using RFID/USN technology.

Li *et al.* (2012) [32] suggested the use of a Wireless Sensor Module (WSM) implemented using the wireless microcontroller JENNIC5418 and the thermocouple converter MAX31855. Automation is employed to increase the CC's performance. The WSM is embedded. Data is sent from each sensor to the access point. If the temperature detected is more than the temperature specified, then the alarm will be turned on. The access point is incorporated with GPS and a 3G communication network. Thus, monitoring can be performed at remote points periodically.

To address the limitations associated with RFID, Chou *et al.* (2013) [33] developed a model called Intelligent Insulating Shipping Containers with low power consuming Bluetooth 4.0 Low Energy Devices (BLE). BLE sensors are implanted on each container and are continuously monitoring the interior temperature and sending the same to PDA using BLE. This also uses geo-coordinate stamped GPRS to map the location of the item that is shipped using CC.

Thoma *et al.* (2013) [34] introduced a model that monitors the whole CC and even the retail sector effectively. The transportation of 'cold objects' in their system is 'smartened' by technology sensor-enabled technology. Sensors are mounted on every pallet or container delivered using CC. The sensors transmit information related to temperature and location to other connected devices. If any temperature difference is observed, the warning message is sent to the authority concerned for further action. Studies show that more than 20% of perishable products shipped through CC are not reaching the customer. They will either be damaged during shipping or discarded by the retailer. Sensor-based quality control is used to fix the price of items sold in retail stores. This is used to determine the future quality of perishable items based on the brightness, temperature, and humidity of the atmosphere rather than based on data on their shelf-life retrieved from the database. The use of sensor-driven quality control and dynamic pricing guarantees that products are delivered before their deterioration occurs.

Ding *et al* (2013) [35] proposed a model called Multidimensional Information Sensing Surveillance for the identification of suspicious events occurring during the shipment of products using CC. The model uses Computational RFID tags known as CRFID, due to the inherent shortcomings of GPS and RFID tags. It also uses the entropy and the AVC algorithm to track the movement patterns of things and conveyances. The model uses WISP, a passive CRFID unit with numerous sensors like temperature sensor, photo-sensor, etc. The model can effectively monitor the temperature of the objects inside the vehicle as the sensors track the data and send it to the control center in real-time. Besides, irregular circumstances such as stealing, leaning and dropping of items may also be detected during transport. Minimum entropy is calculated using the Naïve Baye classification, and a theft alarm can be produced if there is a difference between the measured value and the calculated value. GPS fails as the vehicle passes through tunnels. CRFID is used to solve this problem. The CRFID tracking module is only enabled when the vehicle leaves for its destination. The model can, therefore, be used to identify multiple irregular circumstances.

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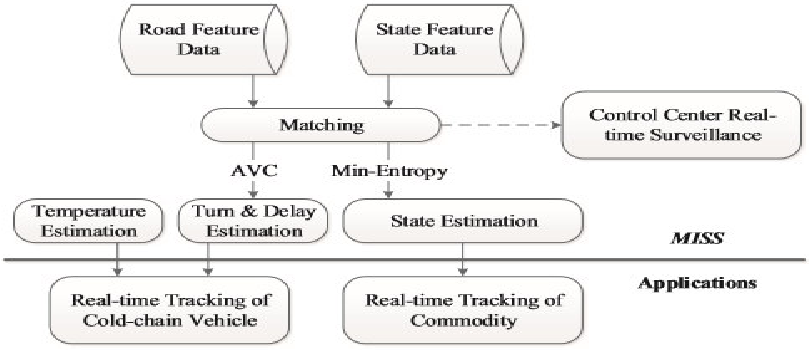

Fig. 5: The MISS framework for CC (Ding *et al.,* 2013) [35]

When the demand for 'cold products' grows, demands for quality are growing in several ways. To satisfy this requirement, Lee *et al*. (2013) [36] recommend a model that uses sensors and ZigBee to track local data and GPS to track location-sensitive data for successful CC monitoring. Real-time monitoring of empirical data like temperature, humidity, etc. is carried out by employing a network of sensors. This network is developed using ZigBee technology that is cost-effective and energy-efficient. The data will be sent to the smart device. In addition to local data, the location of specific data is sent through GPS. This data is used by the central administrative system, which controls the efficient management of the CC.

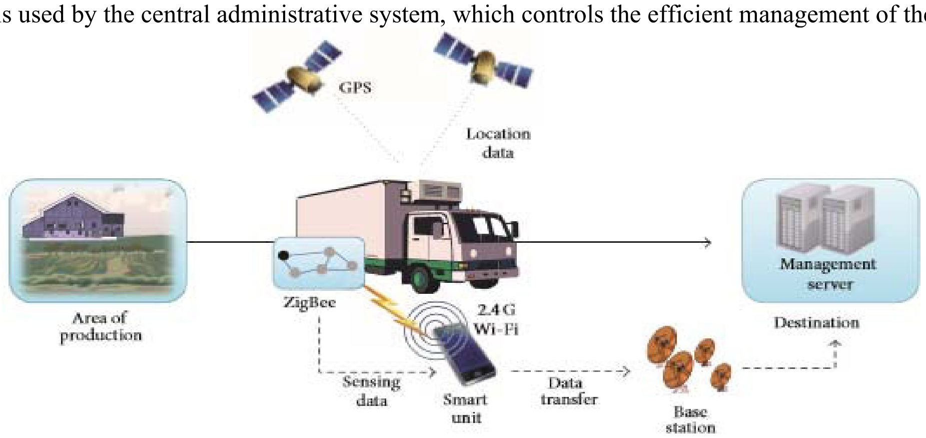

Fig. 6: Monitoring of CC using ZigBee (Lee *et al*., 2013) [34]

Engel & Supangkat (2014) [37] suggest a model that uses temperature sensors, RFID tags, humidity sensors, gas sensors, GPS, time sensors, tilting sensors, congestion sensors to effectively track the CC. The data obtained from various sensors is analyzed for correctness and accuracy. If the data is incomplete or bad, the data will be filtered out. The model provides a knowledge base that stores the domain-specific information required to understand the context. Data from different sensors is stored in the reference engine. In this Context-Aware Inference model, artificial neural networks, vector support machines, and machine learning are used to turn sensor data into useful information.

Chen (2015) [38] proposed a model used to ensure the traceability and safety of products delivered using CC. It uses fog technology that uses a local database or private cloud, sensing equipment and uses an artificial neural network or fuzzy logic to perform local-level computing and data transfer. Fog Computing-based intelligent analysis is the performance measurement framework for the CC. The fog computing network will meet the specifications of the CC, such as flexibility, protection, location recognition, and low power consumption.

Đorđević *et al*. (2016) [39] recommend a method used to measure the remaining shelf-life of products delivered using CC and suggest corrective steps to be taken to maximize shelf-life. The conventional CC system focuses on temperature management over single CC logistics rather than over-viewing the

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transportation cycle throughout logistics. To overcome this limitation, Shih and Wang have proposed a Time-Temperature Indication (TTI) model based on IoT that uses Wireless Sensors to monitor data through logistics distribution semantics (Shih & Wang, 2016) [40].

Lu and Wang proposed a cloud based IoT system to provide unprecedented transparency for frozen item delivery in a cost-effective manner. Sensing devices and RFID tags are combined to form an all-encompassing computing framework to create context-sensitivity for perishable goods. For certain applications, every perishable product is attached with a sensor-controlled UHF RFID tag for collecting atmospheric identity and environmental data. Every perishable product holds a passive RFID tag in some other affordable but less reliable applications and the sensors are housed within the storage area at various sites. Frozen Transportation Management System The system includes modules like i) refrigerated transportation – where a cold truck is fitted with sensors that send data on 'cold items' and the status related to door through a Zigbee coordinator and a GPRS/3G / LTE module, ii) warehouse management – through established WSN to observe the temperature and humidity, iii) traceability - Electronic Product Code Information Services and IoT to track the perishable products throughout the CC, iv) business intelligence – to deal with more complex jobs Through incorporating IoT with the Internet to exchange essential data, analyze data and provide decision-making capabilities, such as load planning, vehicle scheduling and coordination of the entire CC, and v) web-based platform. (Lu & Wang, 2016) [41].

Controlling the temperature remains the essential function of any CC Management System. In most use cases, the monitors attached to the packaging containers perform the task of monitoring temperature. New self-powered time-temperature tracking has attracted designers because it can be configured with passive RFID tags. The advantage is that no external power is used to monitor time-temperature by these devices, in turn, they are self-powered. The sensors used in the model by applying the physical theory Fowler-Nordheim (FN) tunneling monitor the air temperature over the entire life-cycle of the CC (Zhou & Chakrabartty, 2017) [42]

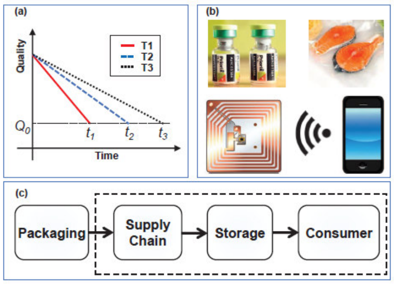

Fig. 7: Time-Temperature monitoring in the CC [41]

The above model represents a) how the product quality relies on time-temperature constituents (b) the use of the innovative sensor for auto-powered time and temperature management, and (c) the supply chain management. Zhang *et al.* (2018) [13] presented a prototype of the CC logistics model "New Food Sensory Perception Framework," based on IoT, RFID, Planar Bar Code, BigData and Cloud Computing technologies. It is made up of three parts – (i) information awareness, (ii) real-time monitoring and data collection and (iii) information dissemination. Real-time data collection, data analysis, the transmission of data, early warning, remote monitoring, etc. significantly increase the level of intelligence on the CC logistics and increase functional efficiency.

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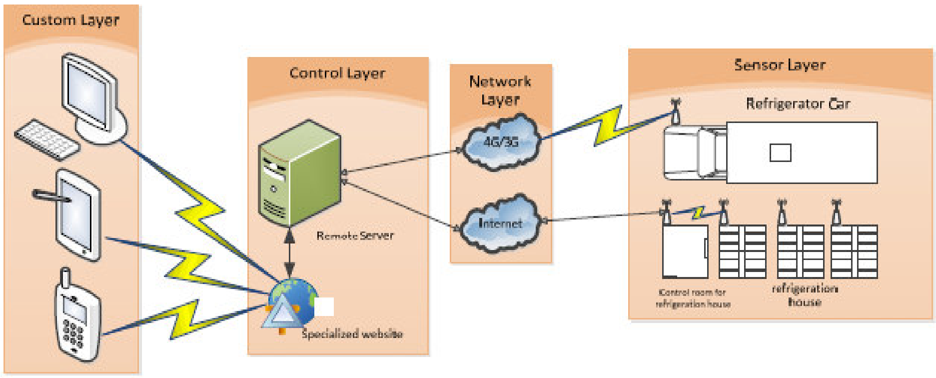

Fig. 8: The block diagram of food sensory-perceptual system (Zhang *et al.,* 2018) [13]

The system consists of four layers: (i) Sensor Layer – is tasked to acquire and process environmental elements like temperature.(ii) Network Layer – to collect and store real-time information received from the sensor layer with the help of 4G/3G network and GPS communication, (iii) Control Layer – analyze stored data and perform decision-making activities such as forecasting, warning, query processing and keeping track on the quality and safety of goods, and iv) Customer Layer – consists of applications with GUI to view transmission status, track, monitor and aware of goods under logistics process.

Zhang & Liu (2019) [43] introduced an "Intelligent CC Transportation Terminal System" to handle and control the temperature of CC logistics mainly integrating Narrow Bound IoT communication and GPS/Beidou position technologies along with other similar technologies. The core components of the system are the smart terminal, data transmission, and remote-control system.

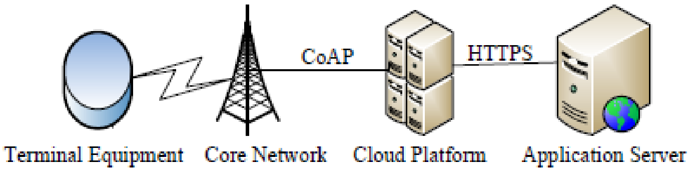

Fig. 9: Architecture of the intelligent terminal (Zhang & Liu, 2019) [42].

Intelligent Terminal is a 'data center' positioned on a refrigerated container and is responsible for gathering its geographical location, temperature and humidity level, and so on. Wireless Communication acts as a bridge between smart terminals and remote monitoring platforms for data exchange. The Advanced Surveillance system extracts from the server the original data submitted by the smart terminal and shows the data collected to the user within a framework

LEVERAGE used Google Cloud Platform (GCP) to deliver a solution for CC Management. GCP was chosen by the company because it comes with a set of tools that are used to safely capture process and store data from vehicle sensors. A robust approach from data collection to user interface display built using a range of available resources such as Cloud IoT Core, Cloud Pub / Sub, Cloud Functions, BigQuery, Firebase and Google Cloud Storage (Gifford, 2019) [44].

Management of the CC product transit is simplified by the use of sensors that ensure live visibility of the logistics movement through the supply chain. IoT sensors monitor temperature, friction, humidity, manipulation, position and product identification at the point of its transit through the wireless networking options like NFC, WiFi, and Bluetooth, these sensors record data that are available to the managers. Mobile devices act as display terminals, data scanners, warning modules, and local data aggregation hub and provide a convenient Cloud gateway. Cloud provides a convenient way for logistics companies to control supply chain events. (Sreeremya, 2019) [45].

In his web article Joshi (2020) [46] summarized how ICT is useful for CC logistics operations. He has highlighted numerous areas where ICT can play its part. Implementing IoT solutions helps companies to track the food product temperature, which is probably the most important parameter in CC logistics. Sensors may be used to track the temperature of the food products on transport modes such as trucks, rail freight, or air freight. The sensors gather these data and share them in real-time. Accordingly, businesses

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have full control over temperature management and process monitoring. Everything obtained by IoT devices is evaluated and shared with other users in regular intervals. This means businesses can have control of the logistics process as they can be alerted as soon as they occur of any issues occurring in the transportation process. IoT applications interact with the machine as much as they do with devices. The data obtained by the IoT devices can be used by advanced artificial intelligence applications running on those devices to auto-generate reports.CC logistics processes can be enhanced with artificial intelligence and machine learning by analyzing the data obtained from IoT devices. Businesses must have complete knowledge of their shipments. This is the aim of using IoT for CC logistics. Companies may track their shipment with IoT devices 24 * 7. When the chain is running at a slower pace than expected, they can make some changes to the logistics schedule easily.

Table1: Use of ICT in CC/Solar CC process management (2005-2020)

SN	Authors	Year	Inventions/Findings/Results
1	Shivakumar & Deavours	2008	Introduced an antenna that resembles amicrostrip-like which is used to address the technical limitations of deploying RFID in the CC.
2	Fu *et al.*	2008	Integration Nano-Qplus platform-based Wireless Sensor Network with RFID to make RFID more intelligent on its operational environment such as temperature, humidity, etc.
3	Barullo *et al.*	2009	A measuring system to measure the containers' temperature throughout the CC logistics path to verify the integrity of the product using WSN
4	Yan & Lee	2009	RFID technology to monitor location-related real-time data and to measure the temperature for the assurance of quality and integrity of items shipped using CC
5	Abad *et al.*	2009	Introduced the prototype of an RFID-based smart tag for object traceability and food-specific tracking of CC systems. The machine consisted of an RFID smart tag and a commercial card reader/writer.
6	Kacimi *et al.*	2009	An energy-efficient WSN based on self-organizing protocols to monitor energy consumption by the sensors
7	Lv *et al.*	2009	Introduced a real-time CC monitoring method based on the web using Wireless sensors and GSM communication network.
8	Liu & Jia	2010	Proposed business models for the effective management of CC using IoT.
9	Wang *et al.*	2010	Introduced a multi-level-instrumented physical monitoring system for the CC using RFID, ZigBee, 3G network and grid computing.
10	Nicolas *et al.*	2011	Proposed a cloud computing-based CC logistics system for continuous monitoring of items shipped. The system maintains a logbook and generates reports based on the logs
11	Li *et al.*	2011	Cloud-based CC logistics framework with functionality like continuous monitoring, data estimation, logbook processing, query, report generation etc.
12	Sun *et al.*	2011	IoT can incorporate technologies such as RFID, Sensors, GPS, Laser Scanners, Internet, etc. to create a unified network to provide a single network wherein SC elements can be easily defined and controlled.
13	Aung *et al.*	2011	Intelligent CC Management System based on RFID & WSN to track temperature-sensitive objects during their

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			life cycle, such as production, shipping, warehousing, and quality support, thereby improving the operation of the CC.
14	Adhianto *et al.*	2011	Cloud storage technology is applied to the CC to enable secure access to real-time data.
15	Kim *et al.*	2012	Use of RFID/USN for the efficient management of CC that contains quality check mechanism at every CCP
16	Li *et al.*	2012	Introduced a Wireless Sensing Module that contains a microcontroller, thermocouple converter, GPS for the effective monitoring of temperature at remote destinations
17	Chou *et al.*	2013	Designed a special type of container called IISC which is used to deliver temperature-related alerts using BLE to the smartphones
18	Thoma *et al.*	2013	Proposed a model that manages the CC and the conventional retail environment efficiently by making use of dynamic price tags which are shown on the perishable products
19	Ding *et al.*	2013	Introduced Multi-Dimensional Information Sensing Surveillance using CRFID tags to identify irregular circumstances when transporting objects using CC
20	Lee *et al.*	2013	Suggested a conceptual model for the continuous tracking of CC using sensors and ZigBee network
21	Engel & Supangkat	2014	Proposed context-aware inference model that uses multiple sensors that detect the environment and emerging technologies for decision-making.
22	Chen	2016	Recommended Fog Computing Intelligent Model to ensure traceability of items shipped using CC
23	Đorđević *et al.*	2016	Recommend a method used to measure the remaining shelf-life of products delivered using CC and suggest corrective steps to be taken to maximize shelf-life.
24	Shih & Wang	2016	Proposed a Time-Temperature Indication (TTI) model based on IoT that uses Wireless Sensors to monitor data through logistics distribution semantics
25	Lu & Wang	2016	A cloud-based IoT platform where sensors and RFID tags are combined to create an all-encompassing computing framework to establish context awareness for perishable goods
26	Zhou &Chakrabartty	2017	Proposed a new self-powered time-temperature monitoring embedded into passive RFID tags. The advantage is that no external power is used to monitor time-temperature by these devices, in turn, they are self-powered.
27	Zhang *et al.*	2018	Presented a prototype of the CC logistics model "New Food Sensory Perception Framework" based on IoT and Cloud platform along with RFID and Planar Bar Code
28	Zhang & Liu	2019	Introduced Intelligent CC Transportation Terminal System that controls and manages the temperature of CC logistics mainly integrating NarrowBound IoT communication and GPS/Beidou position technologies along with other similar technologies.
29	Gifford	2019	CC Management solution using Google Cloud Platform (GCP)

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30	Sreeremya	2019	Proposed IoT Transit Medication Management (ITMM) for the live visibility of the logistics movement through the supply chain
31	Joshi	2020	Narrated how ICT is useful for CC logistics operation and pinpointed the different areas where ICT may be applied.

4. RESEARCH GAP :

Our analysis reveals that the CC data do not only correspond to Factors to the atmosphere, such as humidity levels and temperature of the products being delivered. It also includes other useful details such as vibration, the temperature during packaging time, shifting time from packing to cold storage, etc. The study also implies that the implementation of automated traceability systems to promote the food supply chain was not as swift as expected. The development of temperature monitoring and ensuring traceability throughout the CC will be required before the data collected from these systems can be monitored and scrutinized continuously for accurate perception in the CC. Suitable technology solutions for networking, middleware, and applications that can be used in different CCs, for example in the dairy segment, that has minimum research on the technology infrastructure required to collect data need to be identified. In order to guarantee traceability, effective technical procedures must also be implemented to collect data from earlier phases of the CC, i.e. pre-packaging and manufacturing. It is also necessary to understand how persistent monitoring of temperatures and other atmospheric measurements can be turned into an assessment of the quality of the items in full detail, the calculation of the real shelf-life of the objects, and the use of those for decision taking in CCs, such as product rerouting. Assessment of such data over a prolonged period of time may also give indications of product degradation under various transport conditions that can lead to a transportation system redesign to reduce quality losses or take steps to avoid unfavourable travel circumstances. There is very little discussion on how these analytics capabilities can affect the CC's overall performance in terms of efficiency, cost-effectiveness, impact on the environment, and productivity. Via the CC process, some relevant variables for the capture of commodity parameters and also transaction data for temperature-sensitive products can be defined and these factors can be used to improve the planning of procurement, development and production schedules, transport and storage schedules and even the pricing of such goods in retail stores based on production. Attempting to resolve any of the above research gaps will involve interdisciplinary collaborative research work comprising researchers in food technology and engineering, information technology and computer science and logistics, and supply chain management.

5. RECOMMENDATION BASED ON THE EXISTING STUDY :

CC administrators need to handle more than dry stock. The highest energy users are inventory refrigeration systems and distribution centers frozen items equipped with freezers and requiring strict design and construction specifications. Devices must work for 24 hours a day for a wide variety of materials while maintaining the appropriate temperature levels. CC administrators will also tackle issues such as energy conservation; temperature regulation and smooth functioning of the CC. Cold storage providers implement ICT-enabled monitoring technologies, such as built-in sensors, to avoid disruption. The sensing devices deployed in the CC plants, refrigerators as well as containers of 'cold items', collect data related to temperature and humidity. They send aggregated data to CC management systems which use the same to track the items. The collected data is used to provide timely alerts. Undoubtedly, the introduction of ICT-based solutions entails ongoing restructuring of the CC. The conventional CC elements will be converted from obsolete cooling packages into smart shipping deliveries ensuring better temperature control and pervasive data monitoring. Intelligent shipping packages will also contain additional features such as automatic reporting and predictive analysis of data. Off late, ICT has been used actively used to provide user-friendly CC management solutions. Ultimately, CC needs to consider the application of ICT use cases for untapped ICT applications, e.g. container tracking can aid both in freight and fleet management.
CCs will make the most use of ICT given that an intelligent network of assets is established. To achieve this objective, a range of main factors have been suggested:

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- Establishment of coherent and transparent policies for the application of asset identifiers throughout the CC
- Establishing a smooth data-sharing framework among sensors; proposing roles for data ownership
- Creation of privacy and security policies to resolve major risks

6. CONCLUSION :

The CC has always been a challenging logistical sector because of its capital-intensive machinery, strict temperature specifications, and energy dependence. In recent years, the sector has faced additional challenges, from increasing vulnerability, quality requirements and the volume of many of its goods to still-increasing restrictions. CC also faces many of the same challenges that affect the entire conventional supply chain: targeting the global market, driving out prices, becoming more competitive, overcoming power and resource constraints, and at the same time meeting the challenging needs of the essential cargo sector — primarily food and pharmaceuticals. The data collected from self-powered sensors, apart from the monitoring of real-time properties, enables participants to further know the risks associated, to increase efficiency and productivity and delivery timelines. At the end of the day, it results in good retention of customers as CC management becomes more organized and transparent. When IoT-based solutions are adopted, the need for checking cold storage period or environmental conditions manually is not at all necessary. However, even the freshness of the products can be checked without human assistance. One solution deploys IoT sensing devices inside palettes to continuously monitor the temperature and analyze their quality and predict the expiry dates. Such a system makes it possible to handle supplies more effectively as ripe pallets can be detected and used on time to avoid unnecessary waste. Another solution is to automate the monitoring of inventories with fewer wireless devices. Earlier, any item on stock needed manual scanning at checkpoints with a device. Failure to do so may result in inconsistent data obtained operators leading to audit anomalies. ICT does make a difference, reducing the possibility of shipping delays. Similarly, earlier managers of CC had to be present in -person at cold storage facility to check the deliverables and ensure their integrity. Efficient management has to take into account the large geography of dispersed distribution centers, which puts a lot of constraints on the functioning of CC. With the implementation of smart sensing tools and cloud-based data aggregation technology, CC partners will remain aware, irrespective of their remote location. They can now track shipments, storage, and even last-mile deliveries through mobile applications. Such examples are just evidence of ICT's effectiveness in CC Management. The sector is open to innovation and entrepreneurial ventures. This paper attempted to shed light on the growth of the Solar CC field and to conclude with the hope that there would be more and more research work will follow.

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An Integrated Solution for Solar Cold Chain Portfolio Management using Internet of Things

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ABSTRACT

The Cold Chain system includes a range of systems, such as 'thermal' and 'refrigerated packaging' strategies for moving temperature-sensitive goods along a supply chain, and logistical preparation to ensure shipment integrity. Cold Chain products, including refrigerated trucks and railcars, container ships, reefers, and air freight, are shipped in many different ways. The basic elements of the system are Cooling Systems, Cold, Cold Transport and Cold Processing and Distribution. The 'cold' element of the system, i.e. refrigerators powered by gas or kerosene, has been considered the most suitable choice in areas without reliable energy sources such as electricity. Nevertheless, numerous problems with these tools have made it both difficult and costly to maintain temperatures within the safe range. In the 1980s, solar refrigerators powered by batteries were introduced as a solution to those problems. But the batteries they relied on required regular maintenance, had a lifespan of only three to five years, and replacements of quality were costly and sometimes hard to get. A new solution with solar power has emerged in recent years by avoiding unreliable energy storage which is also expensive. This new solar-powered system freezes the material and keeps the tank frozen when there is no sunlight. The new IoT technology offers greater visibility and control over the entire cold chain network operated by the solar. Using data in real-time, IoT will allow quicker, more appropriate reactions as well as much more informed decisions. Nonetheless, the issue is that most IoT solutions aren't considered primetime ready. IoT has tremendous potential to play a pivotal role in turning the Solar Cold Chain System into Smarter one. This literature analysis is created by revising a good number of papers published in peer-reviewed journals and online sources using the secondary data obtained. The goal of the study is to explain the use of IoT in the Solar-powered Cold Chain System, the future of IoT in this area, find research gaps and finally list the research agenda.

Keywords: Solar Energy, Cold Chain, IoT, Cloud Computing, AI, Big Data, Cloud Storage, Smart Sensors, Energy Grid, Bluetooth, WiFi.

1. INTRODUCTION :

With technology, the distance between the two parts of the world is being reduced even if the physical distance is kept the same. The shock or vibrations may cause damage to the items that were delivered using the cold chain, but excessive temperature sometimes broke them too. During transport time, the quality of a range of products considered to be perishable objects, such as good products, maybe reduced because they sustain chemical reactions that can often be mitigated under unstable temperature conditions. Reliable freight management involves effective time-consuming planning which has invariably negative effects, particularly if such a shipment is perishable. Depending on the cold chain, food, pharmaceutical and medical industries deliver an unacceptable cargo service guarantee. The transport of goods requiring sensitivity for temperature through a supply chain with methods of packaging such as thermal and cooling is referred to as cold chain. In order to safeguard products in shipping, it needs a good logistic planning of shipments. There are various modes of transport, such as refrigerated freight ships, air, rail and trucks, with the cold chain [1].

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The success of an effective 'Cold Chain' system solely depends on the performance of the critical element 'Cold'. The type of container and the cooling system used on shipments for a long period of time are therefore important. 20% of energy is used for container cooling only in most of the cold chain logistics operation [1]. Factors such as transit time, shipment size, and observed ambient or external temperatures are critical when determining what form of packaging is needed and the related energy consumption level. These may vary from a tiny box that requires dry ice or spray, rolling containers to an electrically refreshing big reefer. For many years, the 'Cold' element of the system, that is, refrigerators, powered by kerosene, gas or diesel was considered the most suitable choice for areas with no stable energy sources such as electricity. Nevertheless, numerous problems with these tools have made it both difficult and costly to maintain temperatures within the safe range [2]. In the 1980s, solar refrigerators powered by batteries were introduced as a solution to those problems. But the batteries they relied on required regular maintenance, had a lifespan of only three to five years, and replacements of quality were costly and sometimes hard to get. A new solution has emerged in recent years, the design of a solar refrigerator, deleting the energy storage battery requirement used for power solar refrigerators for expensive and unreliable. This model uses solar energy for directly freeze storage materials to keep the refrigerator cold at night and rainy days afterward the power in the frozen bank [3].

The ICT offers greater visibility and control over the entire solar-operated cold-chain system. ICT's use of data in real-time would allow quicker, more effective reactions as well as much more informed decisions. Recent technologies such as smart sensors, cloud platforms, GPS devices, network gateways, big data analytics tools, wireless networking solutions, and customized user interfaces [4] can simplify the system's integrated operation such as tracking, aggregating, monitoring, delivery, reporting, analytics and sharing [5].

The typical integrated Solar Powered Cold Chain Portfolio Management System includes - Smart Sensors such as automotive, chemical, moisture, flow, weather, humidity, sound, temperature, that detects physical environmental conditions, procedure and changes them into the signal. They have integrated microcontrollers and broadcasting capabilities to automatically capture, pre-process and transmit data. For the collection of data obtained by these sensors, different IoT devices are used [6].

IoT Systems includes numerous boards of developers including Arduino, Beagle Bone, ARM, RaspberryPi, Intel Edison, Intel Galileo, etc. The gateway is used to communicate with the IoT node through protocols like ZigBee, BLE, Z-wave, GPS, Bluetooth, Wi-Fi and mobile portals. Usually, protocols like CoAP, MQTT, and XMPP communicate the data from the gateway to the cloud [7], [8]. Cloud infrastructure provides a platform for quick, easy and complex processing of events in real-time needed to perform advanced sensor data analytics. Cloud computing technology harnesses a Big Data platform which allows large amounts of data to be stored in a decentralized location, ensuring easy data access, data protection, and reduced storage costs. Notable cloud platforms are Amazon Web Services, Microsoft Azure, VMWare, and Google Cloud. The Cloud Platform offers a suite of tools for collecting, processing and storing data [9].Machine learning and artificial intelligence software, such as Google Cloud ML, Amazon Machine Learning (AML) and Google ML Kit for Mobile Azure Machine Learning Lab, make it possible to discover knowledge and to create insights to provide analytical solutions that are essential to enhance the efficiency and profit of energy plants.

The system would increase the quality and effectiveness of food, pharmaceutical, and other perishable supply chains over long distances. The "cold chain" or temperature-controlled supply chain, is now gradually integrating digital technological systems, stable cloud infrastructure, and open architecture rather than pure freezers and freight trains. Besides, the integration of eco-friendly renewable solar energy instead of non-renewable eco-unfriendly fossil energy controlled and managed by ICT results in a more intelligent solar-powered cold chain system that provides managers with live temperature and location data, minimizing any problems along the chain before they occur [10].

2. RESEARCH AIM AND METHODOLOGY :

This paper mainly focuses on the role of Information and Communication Technology (ICT) in improving and finding integrated solutions for Solar Cold Chain Portfolio management. The main objectives of this research article are listed below:

- To know the development in Cold Chain operation and Management.

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- To understand the role of Solar Energy for the Cold element of the Cold Chain.
- To envision the future of ICT in Solar Cold Chain.
- To draw a review model on ICT in Solar Cold Chain.

This paper makes use of secondary data from journal articles, magazines, and some official websites. In this paper, a real attempt is made to know the research carried out in the area of Solar Cold Chain Operation and management. The role of Solar Energy for the Cold element of the Cold Chain also reviewed. The applications of ICT in Solar Cold Chain also studied. The ICT system consists of many recent technologies such as smart sensors, cloud platforms, GPS devices, network gateways, big data analytics tools, wireless networking solutions, and customized user interfaces. This literature analysis is created by revising a good number of papers published in peer-reviewed journals and online sources using the secondary data obtained. The paper also analyses the research agenda. Finally, this paper tries to put forward some suggestions to implement Research Activities according to the proposal.

3. LITERATURE REVIEW :

In recent years a considerable extent of growth and development had been established in the field of Cold Chain, Solar-powered Cold Chain, and ICT. A significant number of published papers on the Solar Cold Chain perspective have been reviewed and examined in this paper in the peer-reviewed Journals and on the Internet for the last 15 years (2005-2020). The analysis, made the literature section classified into three subdivisions. Primarily, the emphasis is on finding development in the Cold Chain sector Operation and its Management. This later discusses the role of Solar Energy in managing the 'Cold' element of the Cold Chain. This also outlines the different investigations on ICT technology and how it affects the Solar Energy-powered Cold Chain Portfolio Management.

3.1 DEVELOPMENT IN COLD CHAIN OPERATION & MANAGEMENT :

Manufacturers use ‘Cold Chain' to deliver environmentally sensitive goods. Frozen items require the regulated temperature to ensure that the same 'quality' product is supplied to the customer from the manufacturer. According to WHO, "a drug should be evaluated under storage conditions its thermal stability". Before 1987, "manufacturers are responsible for shipping and maintaining the required temperature in the supply chain" as per the Food and Drug Distribution Act (FDA). The act was amended in 1897 as "for the effective distribution of temperature-sensitive products, all producers and distributors will work together"

Management of supply chain involves packaging, labeling, determining the mode of transportation (air, road or ship), shipping the product and maintaining shipping evidence. The entire shipping cycle is done at a controlled temperature. The temperature-critical items can be checked for quality and stability at any time or any given location if necessary (Bishra, 2006) [11].

Oliva & Revetria (2008) [12] developed a model for efficient transportation of temperature-sensitive items. According to them, some items such as food are facing a major loss of quality as they have a very short shelf-life. To maintain quality, they are to be frozen. The frozen elements get contaminated due to inadequate packaging and transportation. Despite the Hazard Analysis of Critical Control Point (HACCP), which is the formulation of food and health regulations, food-borne diseases are most prevalent in Europe. Cold Chain Management (CCM) is implemented for effective control of the supply chain. This means that the heat is to be maintained in the supply chain. Protection to ‘cold items’ must be assured from manufacturer to customer.

Good cold chain management involves cross-docking to reduce inventory rates, consolidating for efficient delivery and temperature assessment to ensure quality. The authors suggest a model for CCM that would replace an outdated conventional FIFO. The item which is manufactured first in the FIFO system will be packed first. The new model is called Safety Monitoring and Assurance System (SMAS) with Time Temperature Integrators (TTI) are small, inexpensive devices for measuring time-temperature-dependent changes in the quality of items. In this model, instead of FIFO, items are graded as First Grade, Second Grade, etc. To ensure high quality the ideal temperature condition and shelf-life must be recorded on every pack of food.

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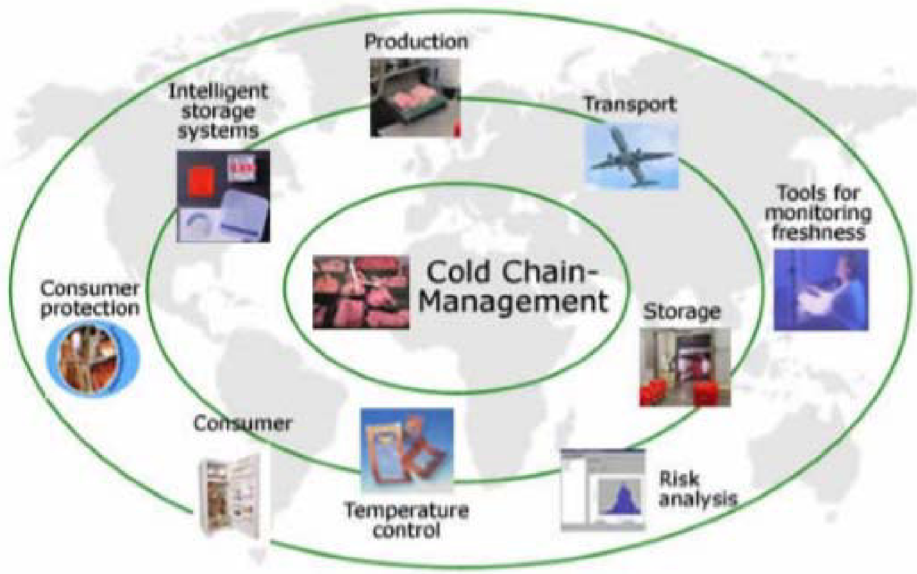

Fig.1: Cold Chain Management (Oliva & Revetria, 2008) [12].

The HACCP Act ensures quality, hygiene, and safety of the cold items. The act is necessary to recognize hazards and risks associated with the distribution of items using the cold chain, to evaluate critical points, to create quality assurance monitoring and controls, to take action if quality requirements are not met, to check cold chain operations and to maintain records necessary. Food, beverages, and cosmetics have a very short life span. Efficient monitoring and tracking should, therefore, be done to mitigate the possible losses. On every single packet of the product, the manufacturer must record the raw materials used, ideal temperature condition and shelf-life. To ensure maximum profit effective supply chain planning and execution are proposed (Fu *et al.,* 2008) [13].

Products supplied using Clod Chain experience transit conditions during the loading and unloading process. The required temperature cannot be preserved if the transport vehicle doors are open for long periods during the loading or unloading process. The heat produced inside the vehicle during the transportation process can also be the reason for the variation in the temperature. During the transportation process, a sudden interruption can occur in the refrigeration system. A model is proposed to manage such circumstances. The model proposed uses temperature control technology and produces alert messages if the temperature drops (Carullo *et al.,* 2009) [14].

Rollo & Gnoni (2010) [15] propose a CCM model. This includes four parties, namely production, management of inventories, distribution, and end-consumer. "Intelligent packaging" is to be performed during manufacturing to ensure that the product quality is not compromised due to the packaging. When shipping different items using the cold chain it is important to maintain different temperatures. If the proper temperature is not preserved, the shelf-life of 'cold products' can be reduced. Therefore "intelligent shipping" is required. First Expired First Out is the strategy that is more successful than FIFO. Distribution is achieved in most cases by the outsourcing of the cold chain. At this point, the performance depends on things, containers, transit time, etc. The end customer is the last party in the Cold Chain. Temperature regulation at this point is very difficult because it depends on the performance of the consumer's refrigerator. In the case of reverse flow, which is from the customer to the cold chain, precaution must be taken to ensure the quality of products.

Not only does the cold chain include 'Cold materials on wheels.' People are a vital part of the chain for the proper execution of all required procedures. In the case of any problem or unforeseen circumstance, people need to take appropriate measures (Vesper *et al.,* 2010) [16].

Liu & Gia (2010) [17] developed the e^3-V approach for effective cold chain management. It involves actors, value activity, and value object value port and value interface. The key actors are buyers and sellers. The value operation is the use of technology to manage the Cold Chain effectively. The object of interest is the

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one that is exchanged between the producer and the consumer; it may be in terms of goods, services or money. The port of value is where goods are traded. The value system ensures Cold Chain is handled properly. The customer gets shipped goods or services only when he pays for the same. Value activity means that the seller uses technology to ensure goods are delivered properly, and the buyer uses technology to ensure payment.

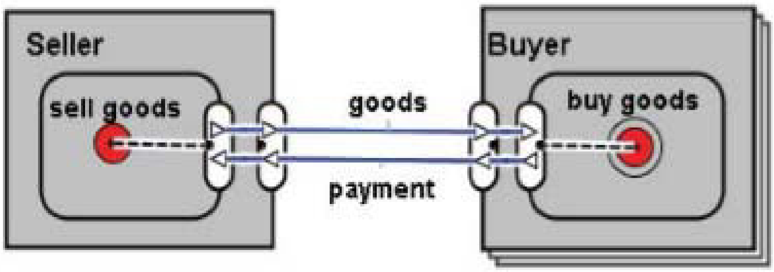

Fig. 2: Example of the e3-Value model (Liu &Gia, 2010) [17].

Gui *et al.* (2010) [18] introduced a model called the Multi-Echelon stochastic inventory model to satisfy customers 'unpredictable demands and maintain optimal inventory levels. In general, the cold chain comprises three stages, namely production delivery, and distribution. This model is perfect for getting maximum gain and overcoming the loss due to surplus stock. For the three cold storage units, it assumes a convergence branch structure as shown in figure-3. The first level includes cold storage at the manufacturing plant, processing unit, and packaging unit, the second level is cold storage on wheels and the third level is cold storage at various distortion units. The stock levels are determined by demand.

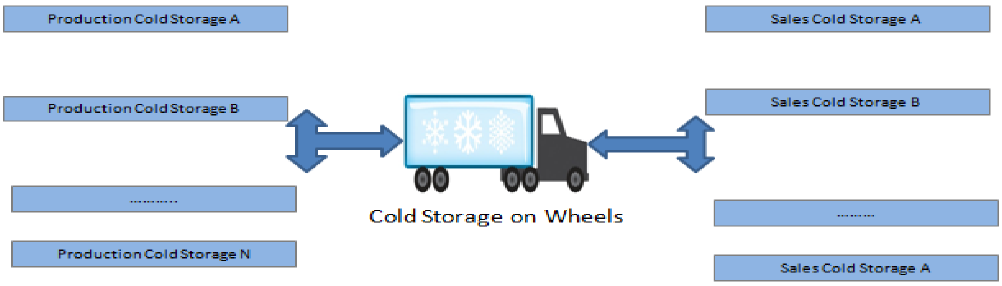

Fig. 3: Multi-echelon stochastic model (Gue *et al.,* 2010) [18]

Ying *et al.* (2010) [19] suggested a model called Optimum Distribution System for the efficient distribution of Cold Chain products. Carrying and storage are seen as two of the Cold Chain's main components. 'Cold material' is supplied to the user without wasting resources. Since the quality of the 'Cold items' degrades due to temperature change, the ship of the goods is to be performed with the utmost care.

Continuous electricity supply is needed for maintaining the desired temperature in the cold chain. Previously, battery-powered refrigerators were used. Such batteries have a very short lifespan of 3-5 years. That would then result in enormous replacement costs. Solar refrigerators that use flat-plate evacuated tubes are used to overcome this situation (Kurian 2012) [20].

Many products delivered using the Cold Chain are consumables. The ideal temperature required for these products should be maintained, from production to consumption. By shipping goods using Cold Chain, care must be taken on the 'quality' and 'safety' of the goods delivered across the supply chain is maintained. To ensure maximum benefit, it is necessary to forecast the demand for the items to store the items on high demand in adequate quantities. Likewise, to mitigate the potential loss, the stock of non-moving objects must be reduced. In CCM this approach is called 'demand forecasting.' It is primarily used by warehouse owners to overcome out of stock and surplus stock situations (Lan & Tialn, 2013) [21].

When thermal sensitive items that get perished easily are shipped through the cold chain, care must be taken to maintain the required temperature from the manufacturer to the distributor or consumer. The Perishable Product Export Control Board (PPECCB) suggests the use of reefers to transport the items. When 'cold items' are transported, there is a possibility of container rain. When the container is cooled

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before loading of 'cold items', due to hot air outside the container, moisture gets condensed on the roof walls. As quickly perishing thermally sensitive products are transported via the cold chain, care must be taken to keep the appropriate temperature from the supplier to the distributor or user. The Perishable Product Export Control Board (PPECB) recommends that the products be transported using reefers. When the 'cold objects' are transported, container rain is likely. Once the container is cooled before loading 'cold products,' due to hot atmosphere outside the container, humidity is condensed on the walls of the roof. That would then result in enormous replacement costs. Solar refrigerators that use flat- evacuated tubes are used to overcome this situation. This is called container rain. It will harm the quality of shipped goods. To avoid this continuous electricity is to be supplied to the containers once loaded with items. The aim here is to hold the ideal temperature during adverse weather, such as hot summer (Freiboth *et al.,* 2013) [22].
Liu & Liu (2013) [23] introduce a 2-hub cold supply chain model. There are three forms of information flow between various nodes within a cold supply chain, namely logistic information, business information, and capital flow. Cold supply chain 2-hub model is implemented to bridge the gap related to the flow of information between different nodes. For transportation, the cold supply chain uses third-party logistics (TPL), but it uses technology to control information flow between various nodes.

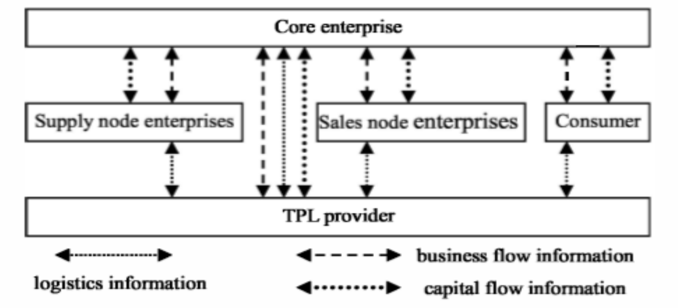

Fig. 4: 2-Hub model for cold supply chain using TPL (Liu &Liu 2013) [23].

Yang *et al.* (2013) [24] demonstrate how the cold supply chain progresses from third-party logistics (3PL) to fourth-party logistics (4PL) using technology. Full cold supply chain automation is realized using 4PL technology.
Using the Cold Supply Chain, utmost care must be taken when transporting temperature and vibration-sensitive objects. Many of the abnormal incidents happen during the process of transportation. Therefore, complete monitoring of the cold supply chain is much needed. The entire supply chain is monitored for detecting temperature anomalies, detecting theft and detecting any obstacles during transport or detecting the location. Multidimensional Cold Chain Logistics Information Sensing Surveillance (MISS) uses technology to track the entire cold supply chain, thus ensuring the protection of shipped products (Ding *et al*., 2013) [25].
Safety and reliability are the two quantitative elements that are to be handled to optimize the cold supply chain. To minimize loss during transportation, using a heuristic algorithm, the safety and reliability of items to be delivered are measured. The cost of transportation of items using the cold chain also involves a cost to ensure the safety and reliability of items to be delivered (Zou *et al.,*2013) [26].
The efficient transport of thermally sensitive items is a worldwide challenge. The cold supply chain covers production, processing, shipping, and sales. The continuous flow of information will occur among the four. The use of 3PL breaks the connection as the services of third parties are used for the transport. Using ubiquitous technology, real-time monitoring is used to bridge that gap. It ensures the safety and quality of shipped goods using the Cold Chain (Zang & Chen, 2014) [27].
Liolissia (2015) [28] developed a new paradigm to ensure that products are distributed effectively using the Cold Supply Chain. This paradigm is called an Integrated Cold Supply Network consisting of goods, origin/destination, distribution, conditional demand, the integrity of the load and integrity of the transport. The product must be delivered according to conditional demand. When the product is packed, ideal temperature and humidity levels are to be recorded on each unit needed to maintain its quality. Source and destination are critical aspects of measuring temperature-sensitive object quality. The ideal temperature should be preserved during transport. The integrity of transport ensures the specified temperature of the

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products is preserved during the shipping process. Load integrity ensures that every unit is kept at the required temperature.

Singh *et al.* (2017) [29] proposed a conceptual model for the assessment of Cold Chain sustainability. Sustainability is a key factor in any business. The model analyzes the sustainability contributing factors. The factors ensuring the sustainability of the cold chain are a selection of manufacturer/supplier, knowledge of environmental conditions, the close association among various Cold Chain stakeholders. The Cold Chain should be measured based on production costs, distribution costs, waste rate, energy use and performance in transport. The obstacles to sustainability are insufficient facilities, inefficient mechanisms, and inappropriate deployment of Cold Chain centers and lack of expertise. Reduced risks and costs, optimal inventory levels, increased flexibility, and improved quality are the supporting factors.

To delay the biological deterioration of perishable goods transported using the Cold Chain, time-temperature constraints need to be critically evaluated at each significant stage of the cold chain. Failure to maintain the desired temperature condition reduces cold chain performance. Depending on time and temperature the shelf-life of products delivered using cold chains should be determined. The objects will perish before the specified time if the appropriate temperature is not maintained. Therefore, the time-temperature history of the products should be used to evaluate the quality (Mercier *et al.,* 2017) [30].

Low-temperature conditions, unreliable shelf-life printed on the pack of goods are the key cause of the wastage of temperature-sensitive products delivered using cold chain. The cold chain will not stop with the convenience store. It goes on until the consumer. But on the customer side, the refrigeration level would be different compared to the manufacturing stage. 'Intelligent packing' is achieved using 'smart technology' to ensure the quality of the items. Intelligent packaging is "a packaging system capable of performing smart functions to promote decision-making to extend shelf life, improve safety, improve quality, provide details and warn about possible problems." The quality check can be done by using Time Temperature Indicators (TTI) and smart devices (Stergiou, 2018) [31].

A reliable way to confirm and verify that goods have been stored within a permitted range of temperature is needed at any node of the cold chain. To check the consistency of items supplied, a distributed ledger system is used in cold chain management. This uses intelligent devices to test the quality of products delivered using a cold chain (Hulea & Miron, 2018) [32].

The use of solar refrigerators, innovations in transportations, real-time monitoring and temperature maintenance throughout the cold chain are factors that have a major impact on the performance of the cold chain. There are several Critical Control Points (CCPs) between producer and customer on the cold chain. The quality and temperature of the products must be tested at any critical point using real-time technology (Compos & Villa, 2018) [33].

Table 1: Development in Cold Chain Operation & Management (2005-2020).

Sl.No	Authors	Year	Inventions/Findings/Results
1	Bishra [11]	2006	Manufacturers and retailers alike and not just the manufacturer take responsibility for the successful management of the cold chain.
2	Oliva & Revetria [12]	2008	Instead of conventional FIFO, SAMS model is proposed for CCM. SAMS model includes TTI for measuring the quality of the shipped products.
3	Fu *et al.* [13]	2008	For effective CCM, supply chain planning and execution is a must. For effective tracking of items can be done by using technology
4	Carullo *et al.* [14]	2009	For efficient CCM, an alert mechanism using some technology is implemented in unexpected circumstances where the temperature cannot be maintained
5	Rollo & Gnoni [15]	2010	“Intelligent packing”, “intelligent shipping”, FEFO strategies make CCM more effective
6	Vesper *et al.* [16]	2010	People are an essential part of the cold chain.
7	Liu & Gia [17]	2010	e^3 V methodology for CCM

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8	Gui *et al.* [18]	2010	Multi-echelon stochastic model for CCM is developed to meet the ransom demands of customers
9	Ying *et al.* [19]	2010	Model is developed for effective transportation of 'Cold things'
10	Kurian [20]	2012	Use of Solar Cold Chain
11	Lan & Tialn [21]	2013	The demand must be forecasted when maintaining cold products stock to ensure maximum gain
12	Freiboth *et al.* [22]	2013	The quality of products should not be deteriorated when they are distributed using the cold chain during adverse weather conditions such as Summer
13	Liu & Liu [23]	2013	Two hub model for the effective flow of information using technology
14	Yang *et al.* [24]	2013	Use of technology to create 4PL
15	Ding *et al.* [25]	2013	Multi-dimensional Information Sensing Surveillance for Cold Chain Logistics using technology to ensure the safety of items shipped using Cold Supply Chain
16	Zou *et al.* [26]	2013	Heuristic algorithm to ensure safety and reliability of items delivered using Cold Supply Chain
17	Zang & Chen [27]	2014	Real-time monitoring of Cold chain to guarantee the quality and safety of items
18	Liolissa [28]	2015	Design of a new paradigm called integrated cold chain to make sure the quality of items delivered
19	Singh *et al.* [29]	2017	Main reasons for achieving the sustainability of the cold supply chain, activities to be adopted to ensure sustainability and main performance metrics for sustainability evaluation are identified
20	Mercier *et al.* [30]	2017	Quality and stability of items depends not only on temperature but also on time-temperature conditions
21	Stergiou [31]	2018	To ensure the better shelf-life of items, 'intelligent packing' is done using 'smart devices and TTI
22	Hulea & Miron [32]	2018	Use of distributed ledger technologies to verify the quality of items delivered using Cold Chain
23	Compos & Villa [33]	2018	At every Critical Control Point (CCP) temperature is to be checked using technology to ensure the quality of items

3.2 SOLAR ENERGY FOR THE 'COLD' ELEMENT OF THE COLD CHAIN :

Solar cooling includes two forms in theory. One is the use of photovoltaic technology-translation of solar energy into electricity first, and then this produced electric energy is used for cooling and refrigeration, such as photovoltaic refrigeration and thermoelectric refrigeration. The use of solar collectors is another technique. First, solar energy is transformed to heat, and heat is used to drive cooling energy, such as absorption cooling, adsorption cooling, and jet cooling. 2 key factors are driving the implementation of the solar cooling technology, one being the solar cooling capacity and the other being the high solar energy costs. Solar refrigerator costs are based solely on the technology employed. Costs will range from $1,200 US to $7,000 US (Liu, 2010) [17].

A current alternative to raising the peak of energy use is the potential use of renewable energies such as wind, biogas, hydro, ocean waves, and solar radiation, etc., have played a major role in reforming the natural balance and creating increasing demand for the population. Clean and renewable energy, solar energy, is today one of the most distributed sources of energy in the world. Likely, the availability of the excessive amount of solar radiation provides the opportunity to use solar thermal technology for summer cooling and summer cooling. The challenge is to choose effective and sufficient technologies to take advantage of the full heat from the sun to meet the demand for electricity. Solar energy is the most environmentally sustainable choice for cooling from any angle including potential for Ozone depletion, the potential for global warming and primary energy use.

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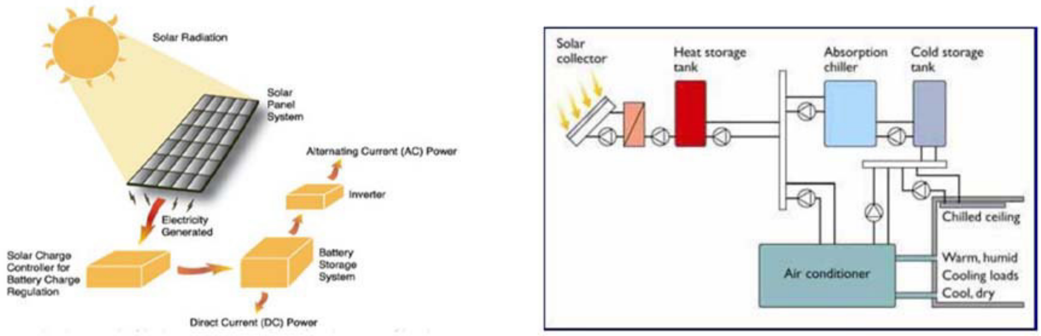

(a) (b)

Fig. 5: Basic principles of (a) Solar light - electricity conversion refrigeration and (b) Solar absorption refrigeration [34].

Balaras *et al.* (2007) [34], in Europe, surveyed more than50 projects on solar-powered cooling systems to determine the potential needs of solar refrigeration technology. In the US state of Indiana, the world's first solar-powered single-effect Lithium Bromide refrigerator was placed into commercial service, and this created widespread interest in the solar refrigeration market. Coefficient of Performance (COP) is used to calculate the efficacy of the refrigeration system. This is the ratio of useful work to energy input. The system's efficiency will be calculated with a high COP value.

The refrigerator with solar adsorption consists primarily of a collector holding the adsorbent, an evaporator, and a condenser. It uses the performance of the adsorbent – refrigerant pair in the refrigerator process during adsorption and desorption. Performances in 14 consecutive days are assessed. Also, on cloudy and rainy days, the device generates cold air. The COP (cooling energy / solar energy) contained in average ambient temperature between 14 and 18°C for irradiation between 12,000 and 27,000 kJ/m^{2}was 5 to 8 percent. COP was small, but it was noiseless and polite to the environment (Lemmini & Errougani, 2005) [35].

With wireless sensor nodes, photodiodes and storage capacitors implemented using 0.35 µm CMOS logic process, solar energy can be used as a power source for harvesting and storage. Integrated vertical plate condensers allow for dense energy storage without restricting optical efficiency. It is possible to generate power of 225 µW / mm^2 as output by a 20k LUX light with intensity. Photodiodes convert light energy into electrical energy while electromechanical transducers convert vibrations into electrical energy. A digital-analog converter (ADC) sampling the sensor data, an RF transceiver and a DSP core, are the major parts of the sensor node (Guilar *et al*. 2006) [36].

In the Faculty of Sciences, Rabat, Laboratory of Solar experimented with solar adsorption refrigerator using pairs of activated carbon-methanol fluids. It was composed of an adsorbent (collector), an evaporator, and a condenser. Even at rainy and cloudy weather temperatures, with very high irradiation, it can produce cold less than -11^{0}C during days. For irradiation with range 12,000 and 28,000 kJm^{-2} and each day ambient surrounding heat around 20°C, the COP was ranging from 0.05 to 0.08. The results show that the unit performs well in Rabat, Mediterranean climate (Lemmin & Errougani, 2007) [37].

Ogueke & Anyanwu (2008) [38] analyzed the solid adsorption refrigerator performance. They were observed and tested during the collector's cool down and evaporation processes. They found that if the initial concentration of adsorbents decreased from 0.29 to 0.21 kg/kg, then the adsorbed concentration rose from 55 to 98%. For the same difference in the initial adsorbent concentration, the mass of ice produced is increased from 0 kg of ice/kg of adsorbent to 0.4 kg of ice/kg of the same.

Peltier effect (the principles of a thermoelectric module) can be used to design the solar-powered refrigerator, to store and transport perishable items, medicines, and biological materials at low temperatures. By producing temperature 5°C from 27°C in approximately 44mins, it had proven its performance, and calculated COP would be 0.16. The refrigerator's main aim is to be ideal for use by Bedouins living in remote areas of Oman where electricity is a dream (Wahab *et al.*, 2009) [39].

A new model named solar adsorption refrigerator was developed using fuzzy clustering techniques based on the ANFIS architecture. They used it for commercial as well as domestic purposes. The evaporating, condensing and generating temperatures are 0^0C, 35^0C and 107^0C respectively are used here to produce a COP of 0.616 (Tashtoush *et al*., 2011) [40].

Activated carbon prepared by coconut shell is considered better to provide the lowest temperature than palm seed and charcoal as an adsorber. It has been proven to inflate plate cooling powered by sunlight energy during daytime and night temperatures (Tashtoush *et al.,* 2012) [41].

Chien *et al.* (2013) [42] found that after 160 minutes, the increase in solar irradiance from 550 to 700W / m^2 and 500ml ambient temperature water as the cooling load would hold the cooling at 5–8^0C. The working fluids used here are NH_3-H_2O which produces around 0.25 COPs. This may be used in transportation to desert areas for vaccination or food cooling. One way of cooling is by using solar power to compress the vapor.

Sunlight, Photovoltaic panel transforms the source of energy into DC. A DC drives a compressor to extract heat from the insulated field, and extracted heat acts as a heat sink in the absence of sunlight to preserve the insulation temperature. Inside the insulated region, the thermal reservoir also includes a substance for phase shift. (Ewert *et al.*, 2013) [43].

An alternative to the fuel-driven movers was developed using solar panels as a transport refrigeration system. It consisted of a compressor (electric motor to provide the compressor with motive force), fans, solar PV electrical power source and a power management controller to supply electrical power to the two motors (Blasko *et al.,* 2013) [44].

The solar adsorption ice makers are invented in sustaining the cold chain in third world countries. They are also used for the storage of vaccines. To develop these ice makers, the activated carbon/methanol pair were used. They could produce 5 kg of ice and COP of about 0.08 with the whole next day. At dimension 1.7 x 1.5 x 0.95 m the prototype has experimented. A solar collector with a 1.2m^2 exposed area was used to gather solar radiation (Santori *et al*., 2014) [45].

The model uses heat coupled with thermo-acoustic cooler to generate an acoustic function that was developed to turn the acoustic energy into cooling power. The solar-driven thermo-acoustic cooler is built with PCM. This PCM is rapidly crystallized throughout the day with high solar irradiation to achieve a low temperature of approximately -35 ° C was possible. (Muzet *et al.*, 2014) [46].

Throughout the daytime, the solar PV panel mounted on the top of the roof can be used to prepare cold storage. This design could reach a minimum temperature of 2-3 degrees during the daytime and slowly rise to a maximum temperature of 7-8 degrees at night. This cold storage system has made it ideal for growers of vegetables and fruits to store products for 2 weeks. It avoided costs and rotting by at least 10 to 15 percent. (Khan &Iqbal, 2014) [47].

The project includes solar panels for charging a Lead Acid Battery (12V, 1.2Amp hrs), and a Peltier thermoelectric device for cooling on one side and heat dissipation on the other. Heat dissipation from the sink is cooled by a fan. The system creates quick chilling in just a few seconds as the plate heats up. They are the alternatives to the regular refrigerators that emit CFC and HCFC, making the environment free from pollution (Reddy & Basha, 2015) [48].

The need for electricity can be reduced by using photovoltaic, renewable sources. Depending on the building's position, construction and load, 21 to 70 percent of the electricity requirement can be saved by the solar thermal refrigeration. (Eicker *et al.*, 2015) [49].

The process called Ocean Thermal Energy Conversion used solar energy absorbed in the upper layer of the water. It is a device for producing electricity, and its power is based on OTEC solar assistance. This provided electricity used for electricity and fish storage. (Yuan *et al.*, 2015) [50].

The new design of a solar refrigerator has the irreversibility effect on the performance of the machines. The fall in heat source temperature causes the COP value to decrease. (Betouche *et al.*, 2016) [51].

Tracking is done primarily through the use of electric motors, sensors, microcontrollers, PLC and many other methods where some input is given to it. This paper takes an approach to the use as a source of a refrigerant such as R744 (CO_2), FREON 12, Ammonia, FREON 22, and FREON 135. An automatic machine is designed and fabricated based on the pressure variation of the refrigerants. The tracking system is used as the working medium with a refrigerant to rotate the device concerning rotation from the sun. Energy output power generation increases as a result of continuous extraction and minimal light utilization (Kumar 2016) [52].

The invention is the portable refrigerator that can transition between a functional mode for use in food and drink cold storage and a collapsed mode of transport. A chiller circuit cooled the food storage space, which

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can be powered by one or more solar panels (Trotter *et al.,*2016) [53].
The 109 m^3 cold room is refrigerated with an ammonia-absorbing machine. A cold room is driven by a solar absorption system intended for storing fruit and vegetables, especially dates in southern Tunisia. It is important to pay attention to the cooling load, moisture, and ventilation in the room to avoid the perishability of the food and to preserve the nutritional value, quality, and color. Authors propose a model that uses vacuum tube collectors, to provide the required heat thermally from the sun. To accomplish the solar cold room work, at least 21m^2 of solar collectors are required. Several technologies are available such as copper absorber vacuum collectors, and glass absorber vacuum collectors. The fruits are first pre-cooled in an adjacent space at 6°C indoor temperature, and then processed at 2°C in the cold room to avoid product shock. The Solar collector area calculation depends on the global radiation available. Solar collector design requires either a numerical model like the Eufrat model, the Capderou model or the Brichambaut model or direct data from stations in the region (Hmida *et al.,* 2017) [54].
A solar adsorption refrigerator is designed to conserve pharmaceutical products, using the zeolite/water pair. The test was to calculate solar radiation on the collector-adsorber, the temperature of all collector-adsorber, condenser, evaporator, and storage tank components. The SCOP value and total energy obtained by refrigeration with solar adsorption range from 0.09 to 0.185 and 15 to19 MJ respectively. (Tubreoumya *et al.,* 2017) [55].
When using solar arrays in Solar Direct Drive systems, the decreased solar irradiance during rainy weather has surmounted. The energy harvesting system aims to determine the priority of the electricity demand before supplying it to the needy. Consequently, once the basic needs are met and excess energy is allocated to other devices, such as health facility lighting, appliance data loggers, diagnostic equipment and cell phone chargers, etc (Myers *et al*., 2017) [56].
Simulation of the solar air conditioning system was performed and tested with $LiNO_3$-NH_3working fluids to achieve optimum COP performance. Here the energy was saved over other commercial air conditioning by up over 98.95 percent. (Sutikno *et al*., 2018) [57].
Vapor absorption cooling system gives scope to use low-grade energy source i.e. solar panel to generate cooling effect dominated by compression technology driven by high-grade energy. The absorption refrigeration system offers great potential to reduce environmental heat pollution (Narale *et al.*, 2018) [58].
The cooler was designed and powered by a solar hybrid wind system. The photovoltaic solar array is installed at the top of the truck to transform DC output alternating with Current using an inverter. A charge controller is mounted to track the charge stored on the battery. To observe its efficiency, AI is implemented too. As the vehicle is moving, this wind energy is used for amplification by wind turbines installed at the truck's speed. Now, this energy is combined with the photovoltaic solar system and is used for cooling purposes. (Njoroge *et al*., 2018) [59].
Coefficient of Performance (COP) is used to calculate the efficacy of the refrigeration system. The system's efficiency will be calculated with a high COP value. Comparisons of some COP with varieties of solar-powered refrigerators are shown below:

Table 2: Comparisons of some COP with varieties of solar-powered refrigerators

Author(s)	Year	Type	Working Fluids	COP
Lemmini & Errougani [35]	2005	Solar Adsorption Refrigerator	carbon AC35-methanol	0.05-0.08
Lemmini & Errougani [37]	2007	Solar Adsorption Refrigerator	Methanol-Carbon (AC35)	0.05-0.08
Wahab *et al.* [39]	2009	Thermoelectric Refrigerator	Crystalline silicon solar cell	0.16
Tashtoush *et al.* [41]	2012	Solar Adsorption Refrigerator	Carbon (coconut shell)-methanol	0.31
Chien*et al.* [42]	2013	Solar Adsorption Refrigerator	NH_3-H_2O	0.25
Santori *et. al.* [45]	2014	Solar Adsorption Refrigerator	Carbon-methanol	0.08
Muzet *et al.* [46]	2014	Solar Thermoacoustic refrigerator	-	0.21

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Yuan *et al.* [50]	2015	Solar-assisted combined cycle	Ammonia-water	0.18
Tubreoumya *et al.* [55]	2017	Solar Adsorption Refrigerator	zeolite-water	*0.09 to 0.185*
Sutikno *et al.* [57]	2018	Solar Adsorption Refrigerator	NH_3-$LiNO_3$	0.743 to 0.824
Narale *et al.* [58]	2018	Solar Adsorption Refrigerator	R-717 - water	0.74

4. INTEGRATED SOLUTION FOR SOLAR COLD CHAIN MANAGEMENT :

The term integration means "the making up or composition of a whole by adding together or combining the separate parts or elements". A Cold Chain usually consisting of a chain of activities from supplier to seller, or from producer to customer, describing a business process that links supplier/manufacturer, transport logistics service provider, and consumers. Since the process viewpoint is the main component, the addition or combination of activities and processes can be seen as an overall element for the integration of the supply chain. Functionally a solar cold chain can be seen as the close association between four technologies:

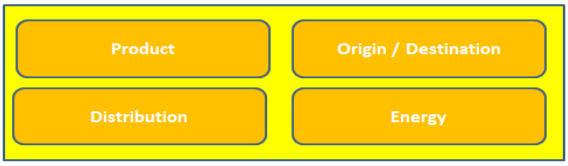

Fig. 6: Technologies associated with the Solar Cold Chain System.

- **Product-** A product has physical attributes that require different conditions of temperature and humidity. Such requirements govern its movement, which must take place in a way that does not compromise its physical integrity to a degree considered unacceptable. Such physical characteristics include how fresh and delicate a product can be; how it manages the cycle of the cold chain. Otherwise, the commodity may be completely or partially losing its market value.
- **Origin / Destination** - The respective locations where they produce and consume a temperature-sensitive commodity. This illustrates the complexity of making a product accessible at a market from where it is made, which can be a major restriction. Because of developments in cold chain logistics, the use of increasingly distant procurement techniques, some of which span the globe, became possible.
- **Distribution-** The available methods and facilities for transporting a commodity inside a temperature-controlled climate. They can include temperature controlled containers (refers), trucks, and equipment for warehousing.
- **Energy -** Control of temperature is a function of almost every stage of the cold chain. By utilizing low-energy technology, the sector will become less dependent on fossil fuels. In cold-chain systems, renewable energies such as wind, bio-energy, solar, hydro and geothermal can be used as a replacement for fossil fuels to produce electricity for use in refrigerating and supply chain operations. Solar power is one of the best solutions in tropical countries for running small, cold storage systems. (Rodriguez, 2019) [60].

5. THE RESEARCH MODEL :

A research model is built based on an analysis of literature inside solar cold chain integration and the effects of ICT. The model is shown below in Figure 6. The purpose of this model is to dynamically integrate the relationship between ICT and control of the solar cold chain. It will be the starting point for empirical analysis. Besides, it suggests a collection of areas considered important to consider when discussing the effect of ICT on process integration. The model advocates predominantly an overall exploratory approach and is mostly applicable to rigorous qualitative studies.

1. Intelligent Packaging: Cold chain products such as food or pharmaceuticals are fabricated or processed in explicit services. When a manufactured good is ready for shipping, various types of packaging techniques

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are available to help preserve the quality of its temperature as well as protect it from damage. Most versatile among them is Intelligent Packaging. It is primarily used during transport and storage to track the condition of a packaged product and to collect and provide information about the nature of the packaged goods quality. The system consists of hardware components such as time-temperature indicators, gas detection systems, freshness and/or ripening indicators, and radio frequency indicators. It is capable of monitoring and acting upon changes in a product or its environment. This can track and manage a package's environment actively, and interact with an external interface. Intelligent packaging with smart sensors can monitor time and temperature and can include a product's background of partial or complete temperature. In the supply chain, sensor-based RFID technology can be incorporated into the product packaging to monitor and trace the origin of the product and any sources of contamination or interference.

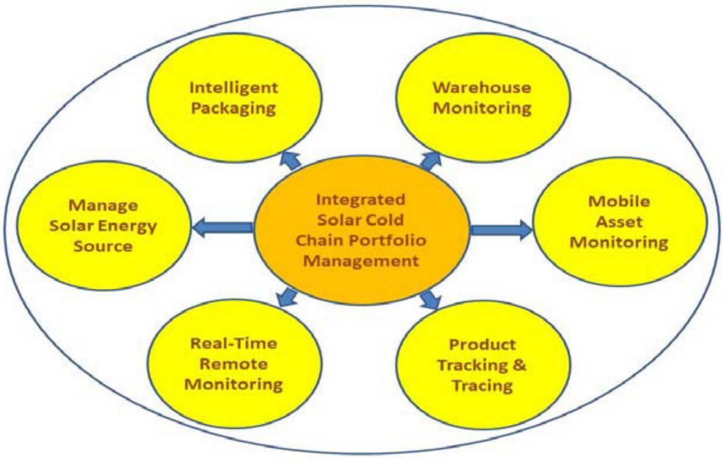

Fig. 7: Integrated Solar Cold Chain Portfolio Management Model

2. Warehouse Monitoring: While the most vulnerable process of end-to-end cold chain management is cooled container transport in cold chain logistics. The important components of this logistics are the security monitoring, refrigerated storehouse distribution conditions and other cold storage facilities. Better temperature control in refrigerated warehouses may help to minimize waste as temperatures that are either too high or too low can lead to loss as it is generally accepted that temperature is an essential environmental attribute regarding product spoilage. RFID sensors are capable of collecting location and temperature and transmitting this information back to a more computationally driven device that can measure parameters such as approximate remaining shelf life. Usually, WSN systems have more sensors than RFID and have incorporated members but are also more costly. RFID and WSN systems are typically limited to one per pallet, but fairly extensive data collection may be involved. Thermal imaging may be used to decrease the number of specific sensors used inside a storage system (RFID or WSN). Computational fluid dynamics technique used to study airflow during the cooling process which can be used to determine the optimal ventilation for containers, pallet distribution, and other variables within the cold storage.

3. Mobile Asset Monitoring: Provides tracking and monitoring of temperature-controlled vehicles used in the Cold Chain in real-time. It keeps track of the cargo temperature and humidity in the truck, reporting shocks and tracking the fuel level and location of the vehicle. The data collected is sent to the cloud application regularly to record, monitor, evaluate and produce various alerts based on alarm conditions and help cold-sensitive products manufacturers enhance operational efficiency and ensure compliance with legal safety initiatives. The system addresses out of band temperature inside the container, stealing/siphoning/adulteration of goods from the carrier, unauthorized stops or routes of the carrier, deviation in fuel consumption & schedule adherence and driving patterns of the driver.

4. Product Tracking & Tracing: Tracking and tracing systems are very useful in the design or setup of a cold chain passive cooling system where thermal or insulated packaging systems are used to maintain the temperature of sensitive time-temperature items. A tracking and tracing system can be introduced to monitor the location and service status of the thermal packaging device at any time, and the tracking system can be used to establish a product quality management system for the packaged product. The combination

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of IoT and Blockchain provides mechanisms to collect, store and share data with all of the partners in the Cold Chain – securely and in real-time. In Cold Chain, IoT linked sensors help to evaluate and verify the source of the component materials and their compliance with regulations. It stores output metrics for tracking and recording deviations in process efficiency. Embedded goods sensors track items and alert supply chain stakeholders to issues such as temperature anomalies or harm to the products. Smart sensors provide data at each point of the Cold Chain that draws a complete image of a product from raw materials to final distribution and with appropriate granularity to perform root-cause analysis, assess liability in the event of an accident and obtain any number or form of insight.

5. Real-Time Remote Monitoring refers to devices and systems capable of tracking the Cold Chain's environmental state in all of the stages involved, such as temperature, humidity, gas, voltage, vibration, etc. It will provide an account of the Cold Chain's integrity, and help recognize possible vulnerabilities. Wireless smart sensors, such as temperature sensors, moisture sensors, thermocouple sensors, water rope sensors, water detectors, door open/close sensors, accelerometers, current detectors, etc., continuously and automatically monitor environmental conditions around the clock, perform mobility gages, track moisture levels to ensure proper storage, identify coolant leakage or other potential issues.

6. Manage Solar Energy Source: While, with advancements in conversion technology, solar power generation becomes cheaper, the need for the hour is to make the device open to monitoring at the customer level. The Solar PV system consistently generates enough electricity, and its output needs to be tracked in real-time. Smart sensors including voltage sensors, current sensors, and temperature sensor are sensing the essential solar photovoltaic device parameters. Such sensors are integrated with the Solar System sense environmental conditions and transmit generated data with the help of wireless communication medium to the Cloud. The data so accumulated and collected and evaluated for automated decision-making by the Manage and Control applications.

6. DISCUSSION & FUTURE WORK :

In this work, an analysis of the growth of Cold Chain logistics and development in Solar Energy as the cause of energy to the 'Cold' element of Cold Chain in the last 15 years was carried out. The contributions of various authors in the field were discussed in chronological order with a view of recording milestones achieved. The Cold Chain has been found to include many processes such as cold storage, cold transportation, packing, cold warehouse, inventory monitoring & tracing, and distribution. Authors viewed the need to incorporate ICT with the Cold Chain System to simplify processes and make the system more efficient. With the introduction of new technology with diversified uses and functionalities, everything can be leveraged to make the Cold Chain System flexible and competitive. There is also significant progress in the field of Solar as the source energy to meet the Cold Chain's power requirements for both – providing current to refrigeration systems, and making them self-reliable. Solar driven Cold Chain has a bright future and the sector is in its nascent stage. Authors expect researchers to explore the potential and build heterogeneous solutions that address all of the Solar Cold Chain's requirements. Prospective is widely accessible integrating cloud computing, Bigdata, Blockchain, Artificial Intelligence, Machine Learning with powerful cross-platform sensors and unique actuators.

This article introduced the Integrated Solar Cold Chain Portfolio Management Conceptual Model. The model contains six major processes that only provided the theoretical analysis. The model was created by uniting the ideas that various contributors put forward in the field. Future research to be built in the Solar Cold Chain will combine these processes with emerging technologies. We can also use predictive control models to assess perishable products' temperature and relative moisture sharing. They may also contribute to the knowledge of the time of delivery of perishable goods along the chain and their expiry in case of a cold loss or disruption of the system. Another important thing would be measuring the energy costs required to maintain the fresh product's proper temperature at each point of the cold chain.

7. CONCLUSION :

IoT has emerged as a revolutionary technology, capable of enhancing the process flow of the Cold Chain. However, the impact of IoT on system integration and the output, in turn, is not yet empirically explored. The cross-sectional literature review analysis shows a strong and powerful relationship between IoT adoption and the impact it can have on manufacturers, suppliers, logistics managers, retailers, and customers. It is perceived that the coexistence of IoT capabilities in conjunction with ICT technology has

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substantial process change as well as sustainable service efficiency. This study leads to the integration of processes in the Solar Cold Chain. The adoption of IoT from an organizational capability theory perspective helps to attain the potential for organizational integration.

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FORM 1 THE PATENTS ACT, 1970 (39 of 1970) & THE PATENTS RULES, 2003 APPLICATION FOR GRANT OF PATENT [See sections 7,54 & 135 and rule 20(1)]	(FOR OFFICE USE ONLY) Application No.: .... Filing Date: .... Amount of Fee Paid: .... CBR No.: .... Signature: ....

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9	Dr. T.P Latchoumi	India	Assistant Professor, Department of Computer Science and Engineering, VFSTR (Deemed to be University), Guntur District, Andhra Pradesh, India	India	Andhra Pradesh

2. INVENTOR(S):

Sr.No.	Name	Nationality	Address	Country	State
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3	Dr. Raju Dindigala	India	Professor of Mathematics, Humanities and Sciences, Vidya Jyothi Institute of Technology (A) Hyderabad, Telangana, India	India	Telangana
4	V.Sridhar	India	Assistant Professor, Department of Electronics & Communication Engineering, Vidya Jyothi Institute of Technology, Telangana, India	India	Telangana
5	Dr.I.Sivakumar	India	Post Doctoral Fellow	India	Tamil Nadu

			(RUSA 2.0), Department of Women's Studies, Alagappa University, Karaikudi, Tamil Nadu, India		
6	Dr. Krishna Prasad K	India	Associate Professor & Director- College Research Council, College of Computer Science and Information Science, Srinivas University, Karnataka, India	India	Karnataka
7	Udit Mamodiya	India	Assistant Professor, Department of Electrical Engineering, Poornima Institute of Engineering & Technology, Jaipur, Rajasthan, India	India	Rajasthan
8	Dr. A. Jayanthiladevi	India	Professor & Director-Industry Relations & International Research Collaborations, College of Computer Science and Information Science, Srinivas University, Karnataka, India	India	Karnataka
9	Dr. T.P Latchoumi	India	Assistant Professor, Department of Computer Science and Engineering, VFSTR (Deemed to be University), Guntur District, Andhra Pradesh, India	India	Andhra Pradesh

3. TITLE OF THE INVENTION: METHOD FOR DIAGNOSE MEDICAL PROBLEM THROUGH MEDICAL IMAGE PROCESSING USING BIG DATA AND MACHINE LEARNING

4. ADDRESS FOR CORRESPONDENCE OF APPLICANT / AUTHORISED PATENT AGENT IN INDIA:
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5. PRIORITY PARTICULARS OF THE APPLICATION(S) FILED IN CONVENTION COUNTRY:

Sr.No.	Country	Application Number	Filing Date	Name of the Applicant	Tilte of the Invention

6. PARTICULARS FOR FILING PATENT COOPERATION TREATY (PCT) NATIONAL PHASE APPLICATION:

International Application Number	International Filing Date as Allotted by the Receiving Office
PCT//	

7. PARTICULARS FOR FILING DIVISIONAL APPLICATION

Original (first) Application Number	Date of Filing of Original (first) Application

8. PARTICULARS FOR FILING PATENT OF ADDITION:

Main Application / Patent Number:	Date of Filing of Main Application

9. DECLARATIONS:

(i) Declaration by the inventor(s)

I/We ,Dr. Achyuth Sarkar,Dr. E Laxmi Lydia,Dr. Raju Dindigala,V.Sridhar,Dr.I.Sivakumar,Dr. Krishna Prasad K,Udit Mamodiya,Dr. A. Jayanthiladevi,Dr. T.P Latchoumi, is/are the true & first inventor(s) for this invention and declare that the applicant(s) herein is/are my/our assignee or legal representative.

(a) Date: -----

(b) Signature(s) of the inventor(s): ....

(c) Name(s): Dr. Achyuth Sarkar,Dr. E Laxmi Lydia,Dr. Raju Dindigala,V.Sridhar,Dr.I.Sivakumar,Dr. Krishna Prasad K,Udit Mamodiya,Dr. A. Jayanthiladevi,Dr. T.P Latchoumi

(ii) Declaration by the applicant(s) in the convention country

I/We, the applicant(s) in the convention country declare that the applicant(s) herein is/are my/our assignee or legal representative.

(a) Date: -----

(b) Signature(s) : ....

(c) Name(s) of the singnatory: Dr. Achyuth Sarkar,Dr. E Laxmi Lydia,Dr. Raju Dindigala,V.Sridhar,Dr.I.Sivakumar,Dr. Krishna Prasad K,Udit Mamodiya,Dr. A. Jayanthiladevi,Dr. T.P Latchoumi

(iii) Declaration by the applicant(s)

- **The Complete specification relationg to the invention is filed with this application.**
- **I am/We are, in the possession of the above mentioned invention.**
- **There is no lawful ground of objection to the grant of the Patent to me/us.**

10. FOLLOWING ARE THE ATTACHMENTS WITH THE APPLICATION:

Sr.	Document Description	FileName
1	REQUEST FOR EARLY PUBLICATION(FORM-9)	Form 9..pdf
2	COMPLETE SPECIFICATION	FORM-2.pdf
3	DRAWINGS	Drawings.pdf
4	STATEMENT OF UNDERTAKING (FORM 3)	Form 3.pdf
5	DECLARATION OF INVENTORSHIP (FORM 5)	Form 5.pdf

I/We hereby declare that to the best of my/our knowledge, information and belief the fact and matters stated hering are correct and I/We request that a patent may be granted to me/us for the said invention.

Dated this(Final Payment Date): ------------

Signature: ....

Name: Balram Singh Yadav

To The Controller of Patents

The Patent office at KOLKATA

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Print

FORM 2

THE PATENTS ACT, 1970

(39 of 1970)&

THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(See section 10, rule 13)

1. TITLE OF THE INVENTION:

METHOD FOR DIAGNOSE MEDICAL PROBLEM THROUGH MEDICAL IMAGE PROCESSING USING BIG DATA AND MACHINE LEARNING

2. APPLICANTS

Sr.No.	Name	Nationality	Address
1	Dr. Achyuth Sarkar	India	Assistant Professor, Department of Computer Science Engineering,National Institute of Technology, Arunachal Pradesh, India
2	Dr. E Laxmi Lydia	India	Professor, Computer Science and Engineering, Vignan's Institute of Information Technology, Visakhapatnam, India
3	Dr. Raju Dindigala	India	Professor of Mathematics, Humanities and Sciences, Vidya Jyothi Institute of Technology (A) Hyderabad, Telangana, India
4	V.Sridhar	India	Assistant Professor, Department of Electronics & Communication Engineering, Vidya Jyothi Institute of Technology, Telangana, India
5	Dr.I.Sivakumar	India	Post Doctoral Fellow (RUSA 2.0), Department of Women's Studies, Alagappa University, Karaikudi, Tamil Nadu, India
6	Dr. Krishna Prasad K	India	Associate Professor & Director- College Research Council, College of Computer Science and Information Science, Srinivas University, Karnataka, India
7	Udit Mamodiya	India	Assistant Professor, Department of Electrical Engineering, Poornima Institute of Engineering & Technology, Jaipur, Rajasthan, India
8	Dr. A. Jayanthiladevi	India	Professor & Director- Industry Relations & International Research Collaborations, College of Computer Science and Information Science, Srinivas University, Karnataka, India
9	Dr. T.P Latchoumi	India	Assistant Professor, Department of Computer Science and Engineering, VFSTR (Deemed to be University), Guntur District, Andhra Pradesh, India

3. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is to be performed.

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METHOD FOR DIAGNOSE MEDICAL PROBLEM THROUGH MEDICAL IMAGE PROCESSING USING BIG DATA AND MACHINE LEARNING

FIELD OF INVENTION

The present invention relates to the technical field of biomedical image processing.

Particularly, the present invention relates to biomedical image processing method for the diagnose disease of the patient.

More particularly, the present invention is related to a computer implemented method for diagnose medical problem through medical image processing using big data and machine learning.

BACKGROUND & PRIOR ART

The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in-and-of-themselves may also be inventions.

Some of the work listed in the prior art is as follows:

US20150310301A1 - *Analyzing or resolving ambiguities in an image for object or pattern recognition* presents "methods, and systems for artificial intelligence, soft computing, and deep learning/recognition, e.g., image recognition (e.g., for action, gesture, emotion, expression, biometrics, fingerprint, facial, OCR (text), background, relationship, position, pattern, and object), large number of images ("Big Data") analytics, machine learning, training schemes, crowd-sourcing (using experts or humans), feature space, clustering, classification, similarity measures, optimization, search engine, ranking, question-answering system, soft (fuzzy or unsharp) boundaries/impreciseness/ambiguities/fuzziness in language, Natural Language Processing (NLP), Computing-with-Words (CWW), parsing, machine translation, sound and speech recognition, video search and analysis (e.g. tracking), image annotation, geometrical abstraction, image correction, semantic web, context analysis, data reliability (e.g., using Z-number (e.g., "About 45 minutes; Very sure")), rules engine, control system, autonomous vehicle, self-diagnosis and self-repair robots, system diagnosis, medical diagnosis"

CN106066934A - *Alzheimer disease early-stage auxiliary diagnosing system based on Spark platform* presents "an Alzheimer disease early-stage auxiliary diagnosing system based on a Spark platform, and belongs to the medical big data application field. The system comprises an image storage module, an image preprocessor module, a model training module, and a predictive diagnosing module. An original sMRI image database is established on a cluster through the image storage module, and HDFS distributed storage is employed. The image preprocessor module preprocesses original images to obtain effective data which are sent to the model training module. The model training module calls MLlib machine learning algorithm to effectively reduce dimension and classify the effective data and obtain an optimal classification model. The predictive diagnosing module processes sMRI images of subjects on a real-time basis through Spark Streaming, conducts classification through a classification module and provides a diagnosing result. The auxiliary diagnosing system combines big data and sMRI technologies, and automatically and effectively provides an objective diagnosing result for sMRI image data of subjects on basis of massive image data processing. ”

WO2017069596A1 - *system for automatic diagnosis and prognosis of tuberculosis by cad-based digital x-ray* presents “ a system for automatic diagnosis and prognosis of tuberculosis by a CAD-based digital X-ray, and more particularly, to a system for automatically diagnosing and predicting whether a patient has been infected with tuberculosis, by applying a deep learning algorithm to big data associated with a tuberculosis X-ray image. The system for automatic diagnosis and prognosis of tuberculosis by the CAD-based digital X-ray according to the present invention supports a general-purpose approach through a digital X-ray and picture archiving & communication system (PACS) through an appropriate technology-based approach for export to developing countries, and thus, improves efficiency of diagnosis. Also, the system for automatic diagnosis and prognosis of tuberculosis by the CAD-based digital X-ray according to the present invention pushes forward supporting big data-based prognosis and customized diagnosis of tuberculosis on the basis of development and trends of tuberculosis patients through CAD-based pre-screening."

CN107016665A - *Deep-convolution-neural-network-based CT pulmonary nodule detectionmethod* presents "a deep-convolution-neural-network-based CT pulmonary nodule detection method. The method comprises: (1), CT image pretreatment is carried out, so that the pixel spacing becomes unified and image comparison is unified; (2), a two-dimensional convolution neural network U-net is trained, a pulmonary nodule segmentation image is predicted, and a candidate nodule is recommended based on the pulmonary nodule segmentation image; and (3), a three-dimensional deep residual neural network Resnet3D is trained, a true-false positive probability of the pulmonary nodule is predicted, and a false positive nodule is screened out. According to the detection method disclosed by the invention, the deep learning advantages are utilized fully, so that the pulmonary nodule can be detected in a CT image automatically, efficiently and accurately; and the adaptability to medical big data is high"

KR101884609B1 - *system for diagnosing disease through modularized reinforcement learnin*G presents " a disease diagnosing system through modularized reinforcement learning, capable of performing machine learning by maximally securing learning data with high quality in a process of generating and refining the learning data by refining the initial learning data generated through simple learning based on medical information such as medical images, medical history, health values, family history, sex, race, etc., by reflecting opinions of doctors, and performing the machine learning based on final learning data which is refined to generate a prediction model, thereby improving the prediction performance of the generated prediction model."

KR101929965B1 - *method for diagnosis of alzheimer's disease based on structural mri images using relm and pca features and the apparatus thereof* presents "a method for diagnosing Alzheimer′s disease based on a structural MRI image using principle component analysis (PCA) features and a regularized extreme learning machine, and to an apparatus thereof. According to the present invention, an early diagnosis for a patient of with Alzheimer′s disease can be performed so as to quickly treat the patient and activate an associated research based on the early diagnosis. To this end, features to be analyzed in the structural MRI image can be measured by a PCA scheme, and each of the measured features are learned through a regularized extreme learning machine (RELM) learning model generated based on big data associated with Alzheimer′s disease collected in hospitals,"

US20180204111A1 - *System and Method for Extremely Efficient Image and Pattern Recognition and Artificial Intelligence Platform* presents " systems for: Artificial Intelligence; the first application of General-AI (versus Specific, Vertical, or Narrow-AI) (as humans can do); addition of reasoning, inference, and cognitive layers/engines to learning module/engine/layer; soft computing; Information Principle; Stratification; Incremental Enlargement Principle; deep-level/detailed recognition, e.g., image recognition (e.g., for action, gesture, emotion, expression, biometrics, fingerprint, tilted or partial-face. OCR, relationship, position, pattern, and object); Big Data analytics; machine learning; crowd-sourcing; classification; clustering; SVM; similarity measures; Enhanced Boltzmann Machines; Enhanced Convolutional Neural Networks; optimization; search engine; ranking; semantic web; context analysis; question-answering system; soft, fuzzy, or un-sharp boundaries/impreciseness/ambiguities/fuzziness in class or set, e.g., for language analysis; Natural Language Processing (NLP); Computing-with-Words (CWW); parsing; machine translation; music, sound, speech, or speaker recognition; video search and analysis (e.g. tracking); image annotation; image or color correction; data reliability; "

CN109872814A - *Deep-learning based intelligent auxiliary diagnosis system for cholelithiasis* presents "a deep-learning based intelligent auxiliary diagnosis system for cholelithiasis, and relates to the fields of image processing, medical big data and deep learning. The deep-learning based intelligent auxiliary diagnosis system for cholelithiasis is characterized in that 1) a patient user uses a CT scanner and other equipment to collect data so as to obtain the own CT medical image of cholelithiasis of the patient; 2) the data is transmitted to a data analysis unit of the system for pre-processing the CT medical image data of cholelithiasis; 3) the pre-processed data istransmitted to an intelligent auxiliary diagnosis unit, and an image-marking algorithm based on the deep convolutional neural network is used to mark the CT medical image data of cholelithiasis, andthe convolutional neural network after dimension reduction is used to perform automatic feature extraction and identification on the marked CT medical image data of cholelithiasis, and analyze the condition; 4) the diagnosis result is fed back to the patient user in the form of electronic medical report, and at the same time the diagnostic record is transmitted to a cloud server through the network for storage and documentation, so as to provide the diagnostic record to the relevant institution and the designated hospital as clinical medical history reference for cholelithiasis; ”

CN109961446A - *CT/MR three-dimensional image segmentation processing method and device, equipment and medium* presents “a CT/MR three-dimensional image segmentation processing method and device, equipment and a medium. Based on a big data deep learning algorithm, the method comprises the following steps: obtaining a CT/MR three-dimensional image, carrying out resampling processing on the CT/MR three-dimensional image to obtain an image block with a preset size, and obtaining an optimal critical bounding box of the image block; through a pre-stored detection and segmentation integrated three-dimensional convolutional neural network model, detecting and segmenting the optimal critical bounding box to obtain a segmentation tag for marking the required target region in the CT-MR three-dimensional image; wherein the three-dimensional convolutional neural network model comprises a residualerror block, the residual error block comprises a batch normalization layer and an alternating structure with alternating convolutional layers, and the residual error block further comprises a jump connection layer"

Groupings of alternative elements or embodiments of the invention disclosed herein are not to be construed as limitations. Each group member can be referred to and claimed individually or in any combination with other members of the group or other elements found herein. One or more members of a group can be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is herein deemed to contain the group as modified thus fulfilling the written description of all Markush groups used in the appended claims.

As used in the description herein and throughout the claims that follow, the meaning of "a," "an," and "the" includes plural reference unless the context clearly dictates otherwise. Also, as used in the description herein, the meaning of "in" includes "in" and "on" unless the context clearly dictates otherwise.

The recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

The use of any and all examples, or exemplary language (e.g. "such as") provided with respect to certain embodiments herein is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the invention.

The above information disclosed in this Background section is only for enhancement of understanding of the background of the invention and therefore it may contain information that does not form the prior art that is already known in this country to a person of ordinary skill in the art.

SUMMARY

Before the present systems and methods, are described, it is to be understood that this application is not limited to the particular systems, and methodologies described, as there can be multiple possible embodiments which are not expressly illustrated in the present disclosure. It is also to be understood that the terminology used in the description is for the purpose of describing the particular versions or embodiments only and is not intended to limit the scope of the present application. This summary is provided to introduce concepts related to systems and methods for producing sugarcane juice using a vending machine and the concepts are further described below in the detailed description. This summary is not intended to identify essential features of the claimed subject matter nor is it intended for use in determining or limiting the scope of the claimed subject matter.

The present invention mainly cures and solves the technical problems existing in the prior art. In response to these problems, the present invention a computer implemented method for diagnose medical problem through medical image processing using big data and machine learning.

An aspect of the present disclosure relates to a method for diagnose a medical problem using medical images of the patient, wherein the medical images are the set of medical images from a biomedical diagnostic medical instrument, wherein the steps of method is characterized of : collecting at least one medical image of the patient from the biomedical diagnostic medical instrument by an image acquisition module , wherein the biomedical diagnostic medical instrument is connected to the image acquisition module via wireless communication module; receiving the medical data, patient history and patient information of the patient, from a patient data storage of a server associated with the biomedical diagnostic medical instrument; prepossessing of the collect image using image processing tools by an image filtering module , wherein the image filtering module is used to filter , normalize and combine the collect image of the patient for a particular type of biomedical diagnostic medical instrument; storing the collected medical data, patient history and patient information of the patient, with the collected image to a central server , wherein the central server is connected to a cloud computation module , the cloud computation module comprises an artificial and machine learning module, which learnt from a large training set data of patients, their medical data, patient history and patient information with their associated medical images of various biomedical diagnostic medical instrument, with the current and resulted health and treatment of the patients; and diagnosing the medical problem using medical images of the patient by the artificial and machine learning module based on the large data analysis and comparing the data from their medical data, patient history and patient information with their associated medical images of various biomedical diagnostic medical instrument, with the current and resulted health and treatment of the patients, to the data of the patient. ..

OBJECTIVE OF THE INVENTION

The principle objective of the present invention is to provide a computer implemented method for diagnose medical problem through medical image processing using big data and machine learning.

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BRIEF DESCRIPTION OF DRAWINGS

To clarify various aspects of some example embodiments of the present invention, a more particular description of the invention will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. It is appreciated that these drawings depict only illustrated embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail through the use of the accompanying drawings.

In order that the advantages of the present invention will be easily understood, a detail description of the invention is discussed below in conjunction with the appended drawings, which, however, should not be considered to limit the scope of the invention to the accompanying drawings, in which:

Figure 1 shows a block-diagram representation of an exemplary system for the method of diagnose medical problem through medical image processing using big data and machine learning, according to the present invention

Figure 2 shows a flow-diagram representation of computer implemented method for diagnose medical problem through medical image processing using big data and machine learning, according to the present invention.

DETAIL DESCRIPTION

The present invention is related to a computer implemented method for identification and classification of brain tumors based on magnetic resonance imaging (MRI) images of the patient using machine learning.

Figure 1 shows a block-diagram representation of an exemplary system for the method of diagnose medical problem through medical image processing using big data and machine learning, according to the present invention

Although the present disclosure has been described with the purpose of a computer implemented method for diagnose medical problem through medical image processing using big data and machine learning, it should be appreciated that the same has been done merely to illustrate the invention in an exemplary manner and to highlight any other purpose or function for which explained structures or configurations could be used and is covered within the scope of the present disclosure.

Some embodiments of this disclosure, illustrating all its features, will now be discussed in detail. The words and other forms thereof, are intended to be open ended in that an item or items following any one of these words is not meant to be an exhaustive listing of such item or items, or meant to be limited to only the listed item or items. It must also be noted that as used herein and in the appended claims, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Although any systems and methods similar or equivalent to those described herein can be used in the practice or testing of embodiments of the present disclosure, the exemplary systems and methods are now described. The disclosed embodiments are merely exemplary of the disclosure, which may be embodied in various forms.

Various modifications to the embodiment will be readily apparent to those skilled in the art and the generic principles herein may be applied to other embodiments. However, one of ordinary skill in the art will readily recognize that the present disclosure is not intended to be limited to the embodiments illustrated, but is to be accorded the widest scope consistent with the principles and features described herein.

Figure 2 shows a flow-diagram representation of computer implemented method for diagnose medical problem through medical image processing using big data and machine learning, according to the present invention.

The method for diagnose a medical problem using medical images of the patient is presented in this disclosure. In an exemplary embodiment , the medical problem is tumor or pulmonary disease.

The steps of method is characterized of collecting at least one medical image of the patient from the biomedical diagnostic medical instrument by an image acquisition module.

The biomedical diagnostic medical instrument is connected to the image acquisition module via wireless communication module. The medical images are the set of medical images from a biomedical diagnostic medical instrument.

In an exemplary embodiment, the biomedical diagnostic medical instrument is selected from , but not limited to an MRI diagnostic machine or. CT scans Machine OR Radiograph Machine.

The medical data, patient history and patient information of the patient is received from a patient data storage of a server associated with the biomedical diagnostic medical instrument.

The collected image is processed using image processing tools by an image filtering module. in the step of prepossessing of the collect image using image processing tools by an image filtering module comprises processing of the medical image with all of the medical image pixel interval unified, Image contrast unity; predicting medical disease based on the segmentation Image two-dimensional convolutional neural network training, based on Image recommend the candidate plexus; training three-dimensional depth residual neural network. The artificial and machine learning module recognizing a medical image , from a medical image database, using a first feature of said first portion with respect to said first set of data, based on said Z-valuation for said parameter for said first portion with respect to said first set of data..

The image filtering module is used to filter , normalize and combine the collect image of the patient for a particular type of biomedical diagnostic medical instrument;

The collected medical data, patient history and patient information of the patient, with the collected image is stored to a central server.

The central server is connected to a cloud computation module , the cloud computation module comprises an artificial and machine learning module, which learnt from a large training set data of patients, their medical data, patient history and patient information with their associated medical images of various

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biomedical diagnostic medical instruments, with the current and resulted health and treatment of the patients.

The medical problem is diagnosed by using input medical images of the patient by the artificial and machine learning module based on the large data analysis and comparing the data from their medical data, patient history and patient information with their associated medical images of various biomedical diagnostic medical instrument, with the current and resulted health and treatment of the patients, to the data of the patient. The diagnosing the medical problem using medical images of the patient by the artificial and machine learning module comprises determining Z-valuation for a portion with respect to each medical image; wherein the Z-valuation for the parameter for the first portion with respect to the first image is based on un sharp or soft class boundary or fuzzy membership function.

The artificial intelligence and machine learning module comprises learning model to store the medical images with a real-time analysis , storing the said learning results with a model of the machine learning.

The figures and the foregoing description give examples of embodiments. Those skilled in the art will appreciate that one or more of the described elements may well be combined into a single functional element. Alternatively, certain elements may be split into multiple functional elements. Elements from one embodiment may be added to another embodiment. For example, order of processes described herein may be changed and are not limited to the manner described herein. Moreover, the actions of any flow diagram need not be implemented in the order shown; nor do all of the acts need to be necessarily performed. Also, those acts that are not dependent on other acts may be performed in parallel with the other acts. The scope of embodiments is by no means limited by these specific examples.

Although implementations for invention have been described in a language specific to structural features and/or methods, it is to be understood that the appended claims are not necessarily limited to the specific features or methods described. Rather, the specific features and methods are disclosed as examples of implementations for the invention.

Dated 8th Day of May, 2020

Balram Singh

IN/PA/2661

. CLAIMS

We claim:

1. A method for diagnose a medical problem using medical images of the patient, wherein the medical images are the set of medical images from a biomedical diagnostic medical instrument, wherein the steps of method is characterized of :

   Collecting at least one medical image of the patient from the biomedical diagnostic medical instrument by an image acquisition module , wherein the biomedical diagnostic medical instrument is connected to the image acquisition module via wireless communication module;

   Receiving the medical data, patient history and patient information of the patient, from a patient data storage of a server associated with the biomedical diagnostic medical instrument;

   Prepossessing of the collect image using image processing tools by an image filtering module , wherein the image filtering module is used to filter , normalize and combine the collect image of the patient for a particular type of biomedical diagnostic medical instrument;

   Storing the collected medical data, patient history and patient information of the patient, with the collected image to a central server , wherein the central server is connected to a cloud computation module , the cloud computation module comprises an artificial and machine learning module, which learnt from a large training set data of patients, their medical data, patient history and patient information with their associated medical images of various biomedical diagnostic medical instrument, with the current and resulted health and treatment of the patients; and

Diagnosing the medical problem using medical images of the patient by the artificial and machine learning module based on the large data analysis and comparing the data from their medical data, patient history and patient information with their associated medical images of various biomedical diagnostic medical instrument, with the current and resulted health and treatment of the patients, to the data of the patient.

2. The method for diagnose a medical problem using medical images of the patient as claimed in claim 1, the biomedical diagnostic medical instrument is selected from , but not limited to an MRI diagnostic machine or. CT scans Machine OR Radiograph Machine.

3. The method for diagnose a medical problem using medical images of the patient as claimed in claim 1, the medical problem is tumor or pulmonary disease.

4. The method for diagnose a medical problem using medical images of the patient as claimed in claim 1, wherein diagnosing the medical problem using medical images of the patient by the artificial and machine learning module comprises determining Z-valuation for a portion with respect to each medical image; wherein the Z-valuation for the parameter for the first portion with respect to the first image is based on un sharp or soft class boundary or fuzzy membership function.

5. The method for diagnose a medical problem using medical images of the patient as claimed in claim 1, in the step of prepossessing of the collect image using image processing tools by an image filtering module comprises processing of the medical image with all of the medical image pixel interval unified, Image contrast unity; predicting medical disease based on the segmentation Image two-dimensional convolutional neural network training, based on Image recommend the candidate plexus; training three-dimensional depth residual neural network.

6. The method for diagnose a medical problem using medical images of the patient as claimed in claim 1, the artificial intelligence and machine learning module comprises learning model to store the medical images with a real-time analysis , storing the said learning results with a model of the machine learning.

7. The method for diagnose a medical problem using medical images of the patient as claimed in claim 1& 4, said artificial and machine learning module recognizing a medical image , from a medical image database, using a first feature of said first portion with respect to said first set of data, based on said Z-valuation for said parameter for said first portion with respect to said first set of data.

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Dated 8th Day of May, 2020

Balram Singh

IN/PA/2661

METHOD FOR IDENTIFICATION AND CLASSIFICATION OF BRAIN TUMORS BASED ON MRI IMAGES USING MACHINE LEARNING

ABSTRACT

The present invention is related to a computer implemented method for diagnose medical problem through medical image processing using big data and machine learning. The objective of the present invention is to solve the problems in the prior art related to adequacies in technologies for diagnose medical problem using medical image processing.

Dated 8th Day of May, 2020

Balram Singh

IN/PA/2661

DRAWINGS

Applicants**: Dr. Achyuth Sarkar & Others** Sheet No. 1 Total 2

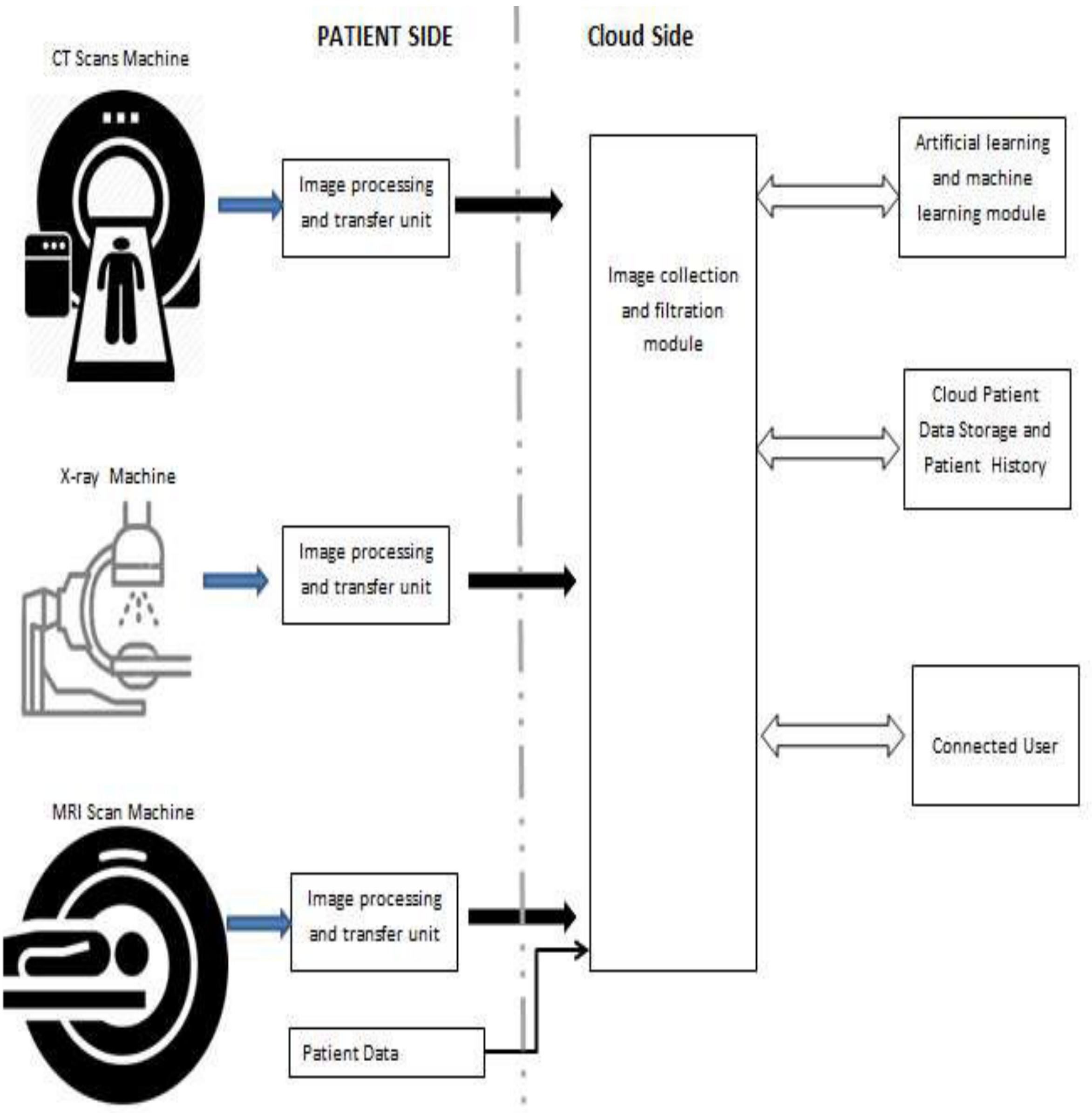

FIGURE 1

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Dated 08th Day of May.., 2020

Applicants**: Dr. Achyuth Sarkar & Others** Sheet No. 2 Total 2

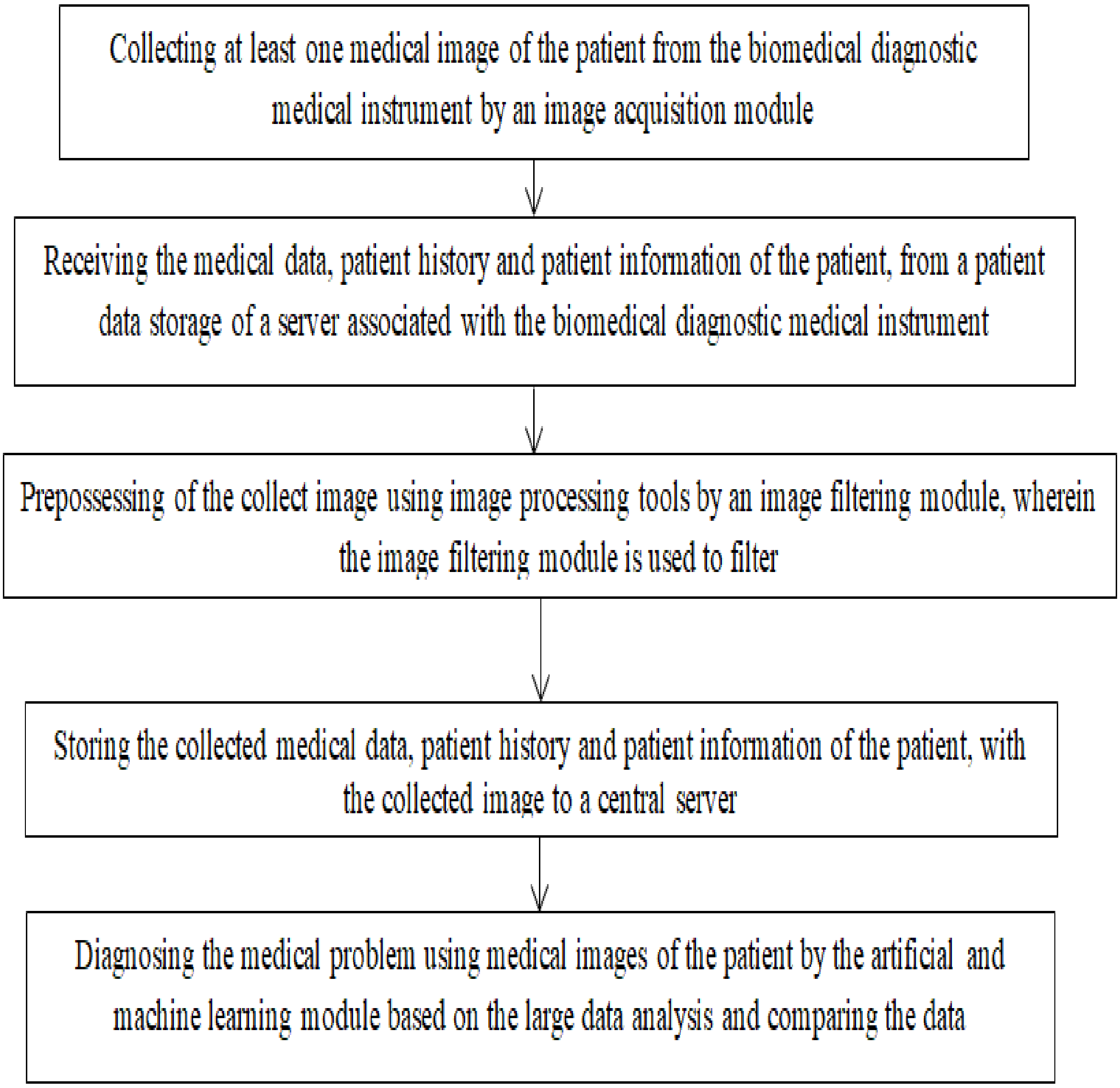

FIGURE 2

Balram Singh

Patent Agent **IN/PA/2661**

Dated 08th Day of May.., 2020

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Conclusion

The anticipated model for healthcare system is to offer privacy over the data stored in cloud environment with the use of IoT technologies. The requirements for maintaining the privacy with healthcare data is secrecy, energy efficiency, transmission rate and cost. This healthcare model provides superior QoS requirements like lesser overhead and lesser bandwidth utilization, reduced delay and service availability. The anticipated model helps to enhance the multi-cast communication over the network environment with diverse privacy providing factors and reduces the packet drops by constantly monitoring the layers of communication environment. This model offers secure healthcare communication. In recent times, it is generally surgical processes that are monitored by the physicians remotely. With this condition may harm the patients under treatment, when it moves to distributed environment. Therefore, the anticipated model is more compatible with the available layer monitoring and offers a faster and secure accessibility over patients‟ data with higher reliability and accuracy with healthcare and information system. In future, the process optimization is considered for validating the global solutions for measuring data transmission with IoT.

Fusion Based Learning Approach for Predicting Diseases in Earlier Stage utilizes potential competency for using fusion concept and learning model to improve healthcare analytics, therefore this process may be done with effectual computation. In machine learning process, complex functionality has been done for enhancing analytical performance. With this learning process, it may facilitate risks to identify prediction in more appropriate manner. Here, network model has the ability to improve analysis for training accuracy. This specification has enormous training sets. This is because of analytical components and workflow. The architectural model is based on anticipated framework to organize components of analytical system to acquire fusion.

An Integration of Cardiovascular Event Data and Machine Learning Models for Cardiac Arrest Predictions paper made the evaluation of cardiovascular disease using popular machine learning algorithms, data. The dataset used in this study are from famous Cleveland datasets of US, Statlog Dataset of UK, and Hungarian dataset of Hungary, Switzerland. The dataset collected is then verified for the changes by splitting into training and test set. Data are then given for feature extraction; this phase extracts 7 features, which contribute to the event. In addition, extracted features are used to train the selected machine learning classifier models, and results are obtained and obtained results are then evaluated using test data and final results are drawn. Extra Tree Classifier has the highest value of 0.957 for average area under the curve (AUC).

Tracking and Monitoring Fitness of Athletes Using IoT Enabled Wearables for Activity Recognition and Random Forest Algorithm for Performance Prediction explains different types of Physical activities to gain fitness and optimize their performance. Monitoring the Physical activities of athletes makes the coaches learn their strengths, weaknesses, habits and behavioral patterns. The data captured using IoT-enabled wearable devices can be evaluated and analyzed so that the coaches can guide the athletes to perform to the best of their ability. The building blocks of an intelligent sports framework arewearable devices or smart objects. PAs make a bigger difference in physical and mental health of athletes. Athletes and health enthusiasts can benefit from wearable sports equipment in many ways. These systems arelow-cost and have revolutionized the way sports are played. To automate the data collection process, smart devices can be linked together. When several devices are connected in order to simplify the data collection process, protocols must ensure safe data transfer while data from these devices is used. Smart devices can be used to actively track events and gain more insights into them.

An AI-based Analysis of the effect of COVID-19 Stringency Index on Infection rates: A case of India paper tries to represent COVID-19 India's cases using appropriate statistical models. The Oxford COVID-19 Government Response Tracker tracks the level of rigor with which a government implements COVID-19 prevention and suppression measures. These indexes take into account all steps that governments around the world have adopted and are thus applicable to India as well. It was observed that in India, as in other countries, there is a close association between Stringency Level and COVID-19 cases. The higher the degree of stringency the lower the cases, and vice versa. The same can be said about the government's role and degree of containment & health. In this paper, we analyzed various mathematical models for predicting the total number of COVID-19 cases and deaths due to COVID-19 in India. We also examined the relationship between total cases and the Government's Response Index, Containment & Health Index, and Stringency Index indicators. The model we proposed to predict COVID-19 cases on a day-by-day basis had a 98 percent accuracy rate and a 2% error rate.

Method for Identification and Classification of Brain Tumors based on MRI Images using Machine Learning patent invention is related to a computer implemented method for diagnose medical problem through medical image processing using big data and machine learning. The objective of the present invention is to solve the problems in the prior art related to adequacies in technologies for diagnose medical problem using medical image processing.

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