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Real-time healthcare monitoring using smart systems: A step towards healthcare service orchestration

Smart systems for futuristic healthcare

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***Abstract*— With the modern technological innovations every industry is transforming itself to produce better goods and services for client satisfaction. Healthcare is also such an industry which is using modern technology for transforming the pattern of patient care and treatment. In the technological era, the aim of the healthcare ecosystem is not only disease management but an overall well being of patients. Sensor enabled IoT based smart healthcare systems along with integration of artificial intelligence creates orchestration of healthcare services and enables healthcare professionals to monitor the routine activities of patients in real-time enabling on time response for patients' healthcare needs. The study discusses how artificial intelligence and sensor enabled smart devices creates smart systems for continuous monitoring of patient's health and creates orchestrated services for the benefits of the patients. Study also creates the literature-based propositions which can be empirically validated in the future.**

Keywords—Artificial Intelligence, Internet of Things(IoT), Smart Healthcare Systems, Wearable Devices, Patient health monitoring.

I. INTRODUCTION

The world is moving towards the smart things. Like cities are not just cities, but now they are smart cities. Smart cities invest in novel ICT (Internet and Communication Technologies including IoT (Internet of Things), AI (Artificial Intelligence), cloud computing, mobile internet based services etc. for providing better governance and better services to the residents [1]. Providing better healthcare is equally important as providing better governance with smart gadgets and smart technology as with the aging population, chronic illness has become part of daily life [2]. Although with the slow adoption of smart devices, healthcare is slowly transforming itself towards digitization of services by slowly adopting the smart technologies [3].

People have started to adopt modern healthcare technological innovations not just for activity tracking but also for healthcare purposes [4]. People have started to use mHealth platforms for an online consultation with their physician in chronic as well as acute disease [5], and sensor enabled IoT based wearable devices for the purpose of exercise and fitness tracking as well as for continuous monitoring of vital physiological signs [6]. On the other end, healthcare service providers also adopted the smart devices and technology to create orchestrated services for enabling their flexibility and agility [7], [8].

With the increase in use of smart health gadgets like IoT, it is not only possible to monitor the health remotely, but also possible to run healthcare analytics for individual patients, as data can be obtained in real-time. With the integration of artificial intelligence and smart gadgets, it is possible to find the undesirable outcome and alert the patient at the correct time [9], enabling the right-time treatment for the patients. The study describes applications of AI when it is integrated and embedded with smart health systems and gadgets like IoT or IoMT (Internet of Medical Things) enabled devices responsible for real-time remote monitoring for individuals. The study also describes the opportunities and advantages of using such technologies into healthcare scenarios and gives a framework for orchestrated futuristic healthcare enabling the better service outputs.

The remaining floe of the study is presented as follows, section 2 represents the objective of the study and section 3. represents theoretical framework and literature review. Section 4 and 5 represent methodology and results respectively, whereas section 6 represents a hypothetical case study and section 7 represents the proposition development, where the proposed theoretical model has been established. At the end section 8 represents conclusion along with research limitations and future scope.

II. OBJECTIVE OF THE STUDY

The literature-based study aims to investigate the futuristic healthcare service scenario from the lenses of healthcare service orchestration where the network of healthcare professionals is seamlessly integrated and creates orchestrated services to serve healthcare needs of patients.

- To understand how artificial intelligence, when integrated with sensor enabled IoT based devices can create the smart systems.
- To analyze how smart systems enable remote-patient monitoring and create service orchestration by involving the network of healthcare professionals.

III. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

A. Temporal Displacement of Care

The premises of temporal displacement of care develops upon the place and time of treatment consumed by the patients of autoimmune and chronic disorders, mostly related to heart and kidneys (like arrhythmia, high blood pressure, diabetes, other cardiac related issues) [10]. As per temporal displacement of care, time of consuming the treatment can be replaced by an integration of modern and state-of-the-art sensor-enabled smart devices, which can share information in real-time with the networked healthcare professionals. Thereby, early intervention of a medical professional is desirable and possible during the fatal and emergency situations.

With the integration of AI with IoT enabled smart health trackers, doors of possibilities open where different types of data enable analytical operations are possible [7]. With the embedded analytics, which includes supervised and unsupervised learning, eventualities of emergency can be predicted with alarming to patient as well as physician. In this case, the temporality is originated, and value of healthcare services are created by healthcare organizations by enabling the use of modern infrastructure with smart systems created through integration of ICT and analytics at various levels.

For the healthcare operations to be run seamlessly, and to ensure the proper quality, a healthcare facility needs to be equipped with computer systems, software, embedded analytics along with the précised data etc. so that the time component, treatment class, expense, and implications can be quantified. Assimilation of information through current structures requires knowledge to be available, collected, and circulated distributed, which extends the cooperation among stakeholders [11].

B. Sensor enabled IoT based devices

Many smart devices are available in the market which tracks users' vitals and stores them in the cloud. Users can log in with the mobile app using their credentials and see the progress of exercises, steps, running, cycling, sleep monitoring etc. [12]. With some high variant smart devices users will get the notifications about female health status, stress conditions and guided meditation during stress conditions [13], fitness tracking and evening exercise based on day's calorie burnt [14], continuous heart rate and blood pressure monitoring including ECG in higher variants with fall detection alarms when vitals are changed significantly by finding irregular patterns [15], [16]. Not only heart, blood pressure, exercise, sleep and female health tracking but these smart devices could uninterruptedly measure oxygen saturation levels also and gives timely alarm when SpO_2 level decreased below 95% [17]. Smart devices serve for metabolic disorders also, like diabetes. For measurement of diabetes, daily routine tests are available where patients must prick daily and check the blood sugar level on a new strip every time. However, the procedure is costly and painful. But, with the help of smart systems the issue can be solved creatively. With the smart glucometer, patients just have to insert the sensor enabled machine on the skin once and then can regularly monitor the blood sugar level in real-time and there is no need for pricking every time or using a new needle or strip every time [18].

C. Artificial Intelligence

Since emergency room and doctor-patient contact is not often reliable due to the scarcity of required information on disease and medicines, the practitioner cannot be confident that the treatment would be effective on them. As half of the drugs and treatments used by the health care workers do not provide any efficacy or viability effects in the participants, since these trials involve poor sample figures as sample size, the studies are replicated, and the findings of the studies are regarded merely as averages. To say that doctors may not have enough details in their hands to give an accurate care plan for the patient suggests incompetence on the part of the doctors. Although, much of the health care they offer is improved with the futuristic aim of including artificial intelligence. The future of healthcare is to provide physicians with smart systems, smart technology and intelligence. Artificial intelligence would be allowing for technologies to be applied as a second set of eyes in the medical sector.

Healthcare sector generates huge amounts of data from EHR (electronic Health Records) and EMR (Electronic Medical Records) from the in-patient data. With the help of the smart healthcare systems and devices data for outpatients can also be collected in real-time to run machine learning algorithms and analytics based on artificial intelligence [19]. With the sophisticated, state-of-the-art smart systems, more detailed and holistic data obtained by the health sector can be used by numerous machine - learning algorithms to anticipate and understand the current and future needs of patients in health-care units. A medical professional would have difficulty analyzing the different number of tests from multiple patients as well as the symptoms of each person. As a consequence, a physician will have a hard time diagnosing illnesses with such a huge number of samples. Faced with a huge number of devices and deep learning algorithms that can manage effectively with lower error rate and higher accuracy than the Technicians of the laboratory, the decision of the optimal choice should be made [20]. Artificial Intelligence (AI) learning algorithms may manage vast quantities of documents collected from such IoT devices over time and then forecast the outcome that the data collected from EHR, EMR and IoT enabled sensor based smart wearables are generated and transmitted for further analysis and feedback to the respective medical partitions [21]. AI machines can think like people, move like humans, and function like supercomputers [22]. It makes the detection of illness more quickly and more reliably. The patient's prior clinical history may help the patient and/or a doctor of present to identify possible diseases and can also advise the patient about how to handle the disease and/or gather other evidence to maintain health over the long term [23].

D. Smart Healthcare Systems

Smart Healthcare is a health service infrastructure that uses innovative, modern and advanced technologies like wearable devices, Internet of Things, and mobile Internet to remotely access knowledge, link individuals, materials and organizations relevant to healthcare, and in this way, handle and interact with patient needs in an intelligent manner [24]. In other words, smart healthcare is a movement which traces the concept of 'connect to your patients, manage availability and improve medical practices' with the help of modern and state-of-the-art technological innovations.

The growth in personal attention and awareness of smart healthcare wearable devices arises from the creation of affordable growth in personal ICT technologies like Laptops, computers, mobile phones which turned out to be a leapfrog solution, consisting of large-data remote patient surveillance [25] and smart wearable care devices recognition and acceptance, has been adequately supported by mobile app-based monitoring platforms which placed patients, physicists and hospitals on a common network for ubiquitous real-time access [26].

With the smart systems of cardiac monitoring smart systems, which continuously monitors the blood pressure, heart rate and ECG (Electrocardiogram) [16], [27], the IoT based wearable will continuously generates the data and store it over the cloud, on the other hand, AI algorithm will find the unobserved pattern with the help of supervised learning. By which the system is converted into the smart system which predicts the fall detection or any unwanted events in real-time with high accuracy.

E. Smart Health Monitoring

Sensor enabled IoT based smart devices with integration with artificial intelligence challenges the traditional way of delivering healthcare and disrupting healthcare service management with the smart way of delivering the services with notifications for crucial things. For example, artificial intelligence algorithms for arrhythmia continuously tracks and remembers the cardiac pattern for some time and runs supervised learning, to observe patterns. In future, when the pattern changes significantly, it gives indication of change in cardiac rhythm to users and suggests them to contact the physician [16], [27]. Samsung active watch 2 tracks the heart rate and the breathing pattern, which changes according to the stress level, when the AI algorithm finds sudden significant change in heart rate and breathings pattern, it shows indication of stress to the user and immediately notifies user to perform guided meditation exercise using Samsung health mobile app [13]. Likewise, with the integration of sensor enabled data and artificial intelligence changes the traditional way of health monitoring and provides a better way of living.

AI enabled smart sensor based wearable healthcare systems will not only enable users to maintain the records of daily activities and physiological symptoms, but also helps medical professionals in making quick but precise decisions for future course of treatment for in-patients also. AI and analytics done on the large lab data and IPD papers with supervised learning based on past patient experiences helps intensivist and physician to define a clear course of treatment which reduces hospital stay and readmission rate [28].

F. Care Service Orchestration

In the digital era of industry 4.0, where all the machineries and instruments relate to each other via sensors, the healthcare sector is also going to disrupt its services. Today, hospitals are one of the crucial pillars of the healthcare system (as hospitals are providing all services to all like consultation, admission, critical care, ambulatory services, lab tests, CT Scan, radiology tests, radiations etc. for all acute as well as chronic diseases and disorders). However, in the near future, hospitals will lose their importance and it will be just a small part of a large healthcare ecosystem [3]. Healthcare sector is fragmenting itself, where all the services will work in silos but are connected to each other. For example, hospitals will have patients who need to be operated on for major surgery and critical care patients, however, consultation, lab tests, radiology services and ambulatory services will be out of the hospital soon. In this time, where all are working in silos needs to be connected and integrated seamlessly with each other with the concept of orchestration, where all are doing their own work but in the integrated manner.

Care service orchestration can be defined as a degree to which the technology and process allowed portal development improves the growth and synchronous exchange of knowledge and service-flow throughout the mechanism linking interactive stakeholders by utilizing real-time digital technology that is utilized, to build a favorable atmosphere in which users will engage in a welcoming environment [29], [30]. Care service orchestration follows an integrative method that connects the less centralized systems to an interconnected network that is standardized, allowing for healthcare professionals and managers to provide a higher-level summary of the entire system. This can then be further utilized for a "visual board." In a network of facilities, networking the facilities together enables one to make use of the best capabilities of each facility to the advantage of a larger network.

Care service orchestration postulates itself around the concept of seamless integration with upstream and downstream. Where, data can be shared seamlessly and based on that early intervention of various medical professionals can be achieved [29]. For healthcare organization point of view, healthcare providers need highest degree of integration among them at various levels (as it is critical to share and disseminate the knowledge about latest treatment innovations, protocols, number of beds in hospital, number of tests must be performed under pathology lab, radiology lab etc.), and with the patients also to deliver the service in a satisfactory manner.

IV. RESEARCH METHODOLOGY

The aim of this study is to investigate the effect of smart systems. The study technique chosen was an exploratory study on healthcare, a popular methodology in many science fields, including earlier experiments on health care 4.0 [31]. Such a method has been selected since it has proved effective

in the early stages of the analysis of a phenomenon, throwing light on the interaction between ideas that comprise theories.

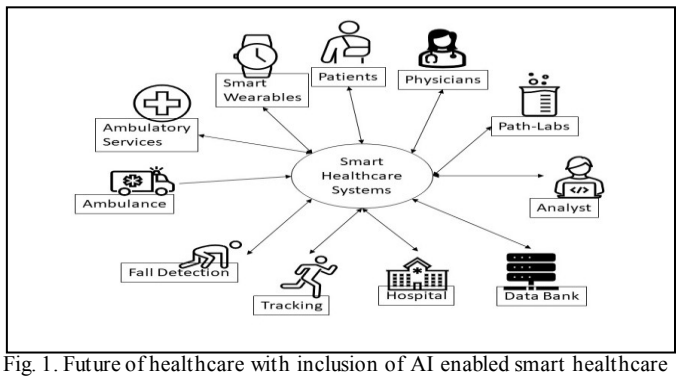

Fig. 1. Future of healthcare with inclusion of AI enabled smart healthcare systems.

Furthermore, this testing approach has certain benefits, such as a strong degree of representativeness, low expense, and a standardized trigger for all respondents. By quantifying the observational data obtained from the respondents, surveys often give predictive importance to the results.

Respondents who work at integration of healthcare and technology were identified and invited to take part in a discussion and survey. With 10 respondents, we completed initial semi structured discussion for shortlisting the underlined smart systems and then respondents rated smart systems technologies in three categories of high, moderate and low impact technologies. Table 1 shows all the related technologies of smart systems in healthcare and its impacts.

V. RESULTS

The concise summary of the result of the discussion is presented in Table 1 along with the smart systems technologies which can be used in healthcare, with its impact as high, low and moderate in the healthcare scenario.

Table 1 – Smart Systems in Healthcare and its impacts

	Usage in Healthcare Scenario	Impact
Remote Consultation	Includes eHealth, mHealth Services	Low
	Remote patient – physician consultation over any audio, video aid	Low
IoT enabled patient monitoring	Includes patient monitoring with aid of wearable sensors	Moderate
	Non-invasive digital technologies for home care	Moderate
	AI enabled Algorithms which predicts the fall detection in case of metabolic disorders	High
Orchestrated Services Technology	Inter-connected medical staff to provide 360 degree services	High
	Ai enabled algorithms which send notification to care professional about emergency situation at patients' end	High
	Highly interconnected integration, which sends notification to ambulatory services, hospitals and other care services	High
AI enabled Services	Realtime Fall detection and notification algorithms	High
	AI enabled algorithms for care professionals' decision making	High

VI. CASE STUDY

We adopted and developed a case study based approach as used by [32] for analyzing the importance of smart systems in the fragmented healthcare scenario. As smart systems are used for assisting diagnosis and treatment, Health management, disease prevention and risk monitoring and converting the hospitals into smart hospitals [24], many case studies are possible. However, for the purpose of this study we developed a case for orchestrated healthcare scenarios using smart systems.

A patient who is suffering from metabolic disorder – diabetes mellitus and cardiac issues uses wearable sensors (wrist band as well as glucose-biosensor). Sensor enabled devices continuously measure vitals and create data repositories. AI enabled smart algorithms with the help of machine learning, keeps analyzing the data. One morning when the patient was doing routine exercises, the patient did not feel well and the same was replicated through sensor enabled data also, as his cardiac functions decreased. AI based algorithm notifies patient to take rest and take care of his well being. On the other end, the smart system notifies the patient physician and care service network also regarding present health conditions. All network partners in healthcare service providers' systems including diabetologists (as patients have diabetic conditions also) are now on standby mode and in ready to act mode, if sensor driven data are not up to the mark. This way, patients can have early intervention from health professionals and get better medical care.

VII. PROPOSITION DEVELOPMENT

Figure 1 indicates the future of healthcare delivery systems when full potential of smart systems, Information Technologies, Machine Learning and Artificial Intelligence will be utilized. The figure clearly states how the futuristic healthcare will be, when hospitals, patients, data scientists, data banks, ambulatory services, ambulance, path labs will be orchestrated because of the state-of-the-art modern technological innovations. This smart system not only tracks the users' daily activities but also gives notification via mobile apps when physiological vitals are not in their normal range or patterns are significantly different from the normal patterns.

These technologically advanced smart systems help medical practitioners and professionals for finding the patterns of in-patient and out-patient both and by analyzing the hidden pattern of data using AI/ML (Artificial Intelligence/ Machine Learning) algorithms and allow them for early intervention

during the emergency. When the patient's health is monitored and data is shared in real-time with the medical professionals, all the stakeholders are able to perform their own role responsibility. These orchestrated services between different healthcare stakeholders creates value for healthcare and beneficial for patients.

We propose that with the integration of IoT enabled smart devices, which tracks and share vital physiological data in real-time with users, when integrated with the capabilities of artificial intelligence creates smart systems which give indication and notification to users (patients and medical practitioners) during the emergency situation. In the conditions of emergency, the network of stakeholders build and integrate and provide the orchestrated services, while all working in silos but integrated for serving patients through smart systems (Figure 2).

G. Propositions

1) P1: Integration of Sensor enabled IoT based devices and artificial intelligence will enable smart healthcare systems.

2) P2: Smart healthcare systems will enable real-time patient health monitoring.

3) P3: real-time monitoring of patient/user's vital physiological vitals enables care service orchestration among the care service network providers.

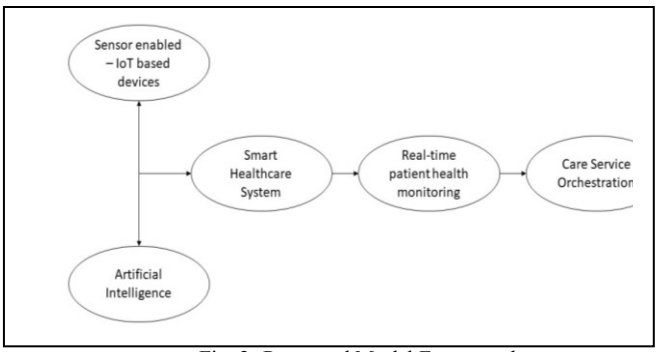

Fig. 2. Proposed Model Framework

VIII. CONCLUSION

The study presented a basic framework for IoT and AI enabled smart healthcare services of the future. The study discusses how the future of healthcare will be with the integration of artificial intelligence with the sensor enabled IoT based health devices and how together both the systems will create the smart healthcare system of the future.

The framework of the future healthcare services has been introduced by going through the literature of Artificial Intelligence, Machine Learning, Smart system usage, IoT in the field of healthcare. The usage of sensor enabled IoT based wearables along with artificial intelligence has been introduced in the study along with how the smart systems enables the network of medical professionals to remotely monitor the patient which enables them in creation of orchestrated healthcare services. The study describes a detailed and holistic framework for the futuristic healthcare services, where patients, physicians and other healthcare professionals are seamlessly connected to provide on-time, on-demand healthcare services.

The study discusses the futuristic smart healthcare systems as an enabler to real-time patient monitoring and care service orchestration among the network partners. This study uses the literature support only for creation of propositions. However, our study lacks the essence of large-scale data guided empirical validation. However, the future scope lies in developing proper measurement scales for the constructs of smart healthcare systems and real-time patient health monitoring and converting the proposition in testable hypotheses, from which data-based evidence can be opted.

Although the study was limited to literature-based framework development, it provides a holistic framework enabling healthcare professionals to provide superior healthcare care services. However, the scope of the study will be limited to the healthcare sector only. On the other end, the study opens opportunities for future researchers to convert the propositions in the testable hypotheses and validate the results of the study empirically.

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