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Intuitive IoT-based H2U Healthcare System for Elderly People

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***Abstract*—The development on newer healthcare services for the elderly citizens has become an immediate necessity today. There have been distinctive health challenges focused in the society through technical innovations. Most of the elderly people today experiences loneliness and psychological depressions, either as a result of living alone/ abandonment or due to reduced connection with their children and relatives. To enhance the quality of services in the elderly healthcare system we have developed a ubiquitous intuitive IoT-based (Internet of Things) Help to You (H2U) healthcare system to integrate various technologies of wearable devices, biosensors and wireless sensor networks in order to provide an intensive service management platform. This method would support the real time activity and monitor the healthcare system for the elderly citizens. In this method the information collected by various wearable devices in real time are stored in the central database which thereby connects people, doctors, and practitioner at the time of an emergency for the right information. This way the system could increase accessibility, efficiency, and also lower the health expenses to improve the comfort and safety as well as management of daily routines of an elderly life.**

***Keywords*—IoT; H2U; healthcare systems; sensors; wearable devices; emergency**

I. INTRODUCTION

Unlike the 19th century challenges that people use to face with the nuances of underdevelopment and lack of facilities, today with the advancements in technology, newer opportunities and facilities have come up in a higher pace to serve the elderly population in various innovative ways. The fantastic revolution in technology has broadened up the chances of possible development in any field of progressive studies. Apart from the developments in hospital equipment's and pharmaceutical products, new catalyst in technological innovations like the internet has become a feasible platform for the elderly citizens. Wellbeing and extreme care can be manifested through applications on smart phones or other smart devices. The connectivity and communication gaps are bridged through these creative applications in a superfluous fashion.

The IoT (Internet of Things) is a next generation technology which is connection of uniquely identifiable smart objects and sensors based on the backbone of Internet. These are connected in advanced manner and it can go beyond machine-to machine interactions [1]. Using this automation the elderly healthcare system can be made more advanced. Global healthcare services are facing challenges because of the rapid growth of elderly population [2], thus a creative way is needed to face this challenge due to recent development in electronics and many number of devices have come up which can monitor patients' health record in real time as well as can be monitored remotely through Internet. The IoT enabled monitoring devices have RFID (Radio Frequency Identification) associated with it. Using RFID these devices can be accessed over the Internet at any time which in turn will allow constant monitoring of the patients [2]. Lawmakers are highly sensitive about the regulation and management of IoT devices as there are increasing estimate of nearly 20 billion devices is thought to be connected to the IoT by the end of decade. So H2U healthcare system for elderly is important to meet the health service demands in order to monitor daily activities of the elderly people. The project is aimed to validate the efficiency of integrating diverse technologies in recording daily activities of elderly people through devices like wearable sensors and actuators in real time. Series of experiments and their results are also executed to show the efficiency of the system. The system performs with high validity and is highly reliable for the elder people.

This paper is organized as follows. IoT and H2U healthcare systems are introduced in section II. The applications of the proposed system for elderly healthcare are detailed in section III. Results obtained from the current work are presented in section IV. The final section concludes our study.

II. IOT H2U HEALTHCARE SYSTEM

A. Architecture

IoT H2U healthcare is a heterogeneous computing system of Apps and wearable devices that connect patients and healthcare service providers remotely. The system functions by deploying wide variety of sensors and actuator to monitor security and safety of domestic environment, personal safety, vital health sign, daily activities, etc. that interactively

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connects the patient with the doctor on 24 hours and 7 days a week basis either through telephonic calls, video conferencing, e-medication, etc.

The collected clinical data are stored in mobile apps and transmitted to the central database server immediately or periodically through the Internet. In case of emergency the H2U healthcare system can send alarm or can trigger alert to the doctor as well as to their relatives and caregiver for the rapid action of that particular end user. Once the alert message is triggered the physician can be ready for an emergency backup for the patient and in the meantime the physician can also review the patient's clinical reports from the submitted medical information of the patient's database that is already stored in the cloud. Fig. 1 shows the interconnection platform and services management to support large daily clinical reports like blood pressure (BP), blood sugar, heart rate, body temperature, body weight, etc. that are recorded and saved in the mobile app and central database of elderly healthcare system. These collected clinical data stored in the patient database are used for future references or sent to the doctor and caregiver immediately to take any rapid action and precautions.

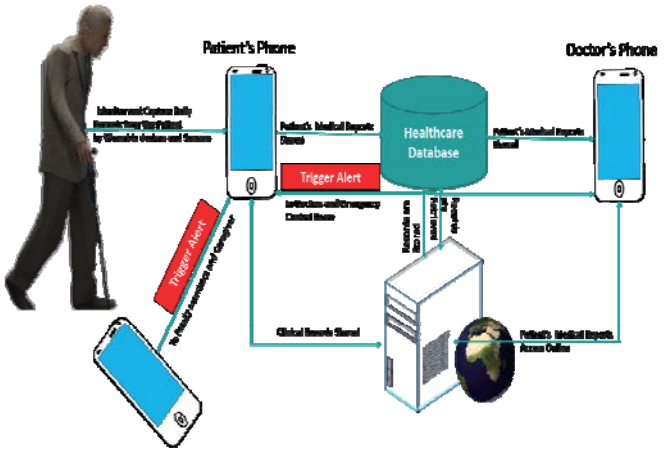

Fig. 1. Architecture of H2U healthcare system.

B. Privacy and Security in H2U healthcare system

IoT healthcare devices and Internet connection are more vulnerable to the security attack due to increase of unauthorized access in the Internet. Hackers can not only target an individual but can also damage the IoT server and devices which in turn can result in massive loss. In near future there is going to be privacy matter related to the IoT. Thus privacy can be a matter of concern in near future which needs to be handled with caution and proper protocols. The security and privacy safety of sensitive and personal patient medical data are major issues and concerns while collecting patient medical data from sensors to mobile device and further submitting these data to the centralized server [2]. For example, they can interfere with the insulin pumps which can threaten a person's life. Currently no standard protocols and regulations are available to monitor how the data will get collected through the IoT. So to protect from the temper and authenticate the user from such confidential database of the patient, in H2U healthcare system, every user is assigned with log in interface and encrypted password subsequently to store the user authentication credential. Under the proposed structure our system thereby can be protected from the unauthorized users.

III. Applications of the Proposed System

The IoT enabled health monitoring system has great advantage over traditional healthcare monitoring systems. The elderly patients can easily wear the health sensing component all the time thereby allowing constant monitoring. The system serves very vital as well as beneficial since the elderly citizens need constant care. As constant monitoring of patients is not possible by doctors round the clock, IoT enabled H2U healthcare proves to be far better as the critical data can be accessed easily via the Internet. This in a way becomes highly productive and convenient as major illness can be detected at the right time [3]. A wireless sensor placed in the elderly patient as well in the living environment is necessary for the creation of a wireless sensor network [3]. Since IoT provides real time data, it will allow better understanding and insight into disease evolution and effects of drug therapy. It can also reduce the errors which are manual as IoT is in an automated system.

The IoT has a central decision unit which can detect emergency and dangerous situations based on the data generated by the sensors of the elderly patients. Moreover, the elderly patients can be monitored indoor as well as outdoor using IoT H2U healthcare system. It also works in an interesting fashion to raise emergency alarms as soon as the server receives the message. Generation of constant reports is facilitated for the elderly person who is being monitored. The central server then analyzes data through the reports and also saves the clinical records in the server so that it can have one to many (1:M) or many to one (M:1) conversation among the patient and doctors in any emergency case. H2U healthcare system provides the following assistance to provision for elderly healthcare system.

A. Emergency Call

The wireless sensor network technology has entered the medicine and healthcare scopes [4]. Health status of elderly patients needs real time monitoring system to protect from early warning for health status information. The elderly nursing plays vital role and intends to provide a contented environment and living space and help as safe and healthy place for the elderly. H2U healthcare provides an emergency designed interface platform to monitor and help the elderly people in an emergency circumstances. The emergency monitoring platform provides high quality examination and judgement of the well-being data of elderly. This interface allows the user to establish automatic communication via phone calls to the emergency control service provider of the hospital or caregiver broker services. It can also report

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emergent alarms from the H2U healthcare apps by clicking the emergency button.

This emergency platform also provides an interface to monitor the health condition of the elderly such as falling down, heart attack, etc. Contact number of their kin and caregiver are added manually or preloaded in the app so that whenever the end-user clicks the emergency button it will directly connect to them or it will connect the emergency control room viz. 911, 999.

B. *Medication Reminder*

Several elderly discourage into the perception that they themselves are no longer useful and as a result make little endeavor to keep themselves healthy and active. When the people are aged psychologically their lives have no aspiration to try new things, to challenge themselves, to eat, or exercise properly. It became a trend for the elderly people tends the lack of physical exercise, social involvement losing the ability to use their minds and their bodies thus the older person's negative approach towards aging becomes self-fulfilling and results in having missed their opportunities in life. An ageing population tends to have a higher prevalence of chronic diseases, physical disabilities, mental illnesses [5]. The healthiness needs and health related difficulties of elderly people cannot be viewed in isolation.

Without any physical support in daily activities and help the elderly people will have hard time in the daily chores of life. Prevention and control of health problems of elderly necessitates a multifaceted approach incorporating active collaboration of health. H2U healthcare provides an interface of medication reminder, where physician and caregiver can remotely monitor the elderly patient without affecting the daily activities [6]. This helps in reducing cost and hassle free patient management [7]. It also allows the rehabilitation process and rapid effects of the drug therapy [8]. This interface will alert or notify the schedule medication of their daily prescription given by the medical expert. In this interface any physician or caregiver can set the routine medication time of the pills or injection manually to be taken by the patient. Once the range of the set time is reached, then H2U medication reminder apps will send a notification to the patient as well as it will alarm on the user phone. The objective of this medical reminder is to give user friendly and help the elder people to maintain a healthy life with proper medication.

C. *Symptoms Checker*

This interface will enlist the types of symptoms of various ailments that an elderly patient has. The end-users will be allowed to choose various symptoms according to their problematic health condition. Once the selection is done the interface will enlist the type of the disease and show the related department where the patient can consult to for further clarifications and checkup. We introduce MCDM (Multi Criteria Decision Making) analytical hierarchy process (AHP) that is an approach with hierarchal structure for decision making problems [9-12] to determine and predict the diseases of elderly people based on different symptoms suffered by them. MCDM AHP helps the user to understand the appropriate evaluation of their diseases which would thereby enact prevention through formal approaches. This is a better way to structure information and to advice wise healthcare decision making of dreadful disease in order to enhance the quality of life. The methodology of MCDM AHP is given in Fig. 2.

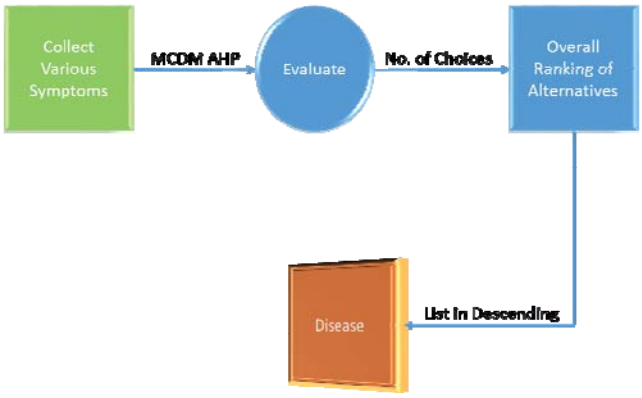

Fig. 2. MCDM AHP for symptoms checker.

Steps for MCDM AHP in symptoms checker are described below:

- Define the problem of various symptoms and determine the kind of knowledge for the patient.
- Combine multiple inputs to form a consolidated outcome of different diseases.
- Construct a set of pairwise comparison matrices of diverse disease and symptoms.
- Overall rank of the alternative diseases from the comparisons to the weight priorities of the symptoms chosen by the patients.

IV. Case Study

To make proper diagnosis for a patient with given various symptoms, a medical knowledge base is essential to inspect the decision of the patient for various health issue. To determine and help the patients with such kind of diseases would they suffer from gathering various symptoms, we consider the MCDM AHP. For the selection of diseases D = {*Diabetes, Cardiac, Ortho, Dental, Eye, Skin*} suffered by the elderly people, 5 linguistic variable scale of absolute numbers are taken to describe the level of match of patient symptoms S= {*Frequent urination, Heart burn, Stiffness in joint, Dry mouth, Blurred vision*, *Scaly skin*} and patients P= {*P1, P2, P3, P4, P5*} on the decision criteria, performance makers are subjectively to choose between more than seven alternatives to avoid the difficulties in decision making. Table I shows the linguistic scales associated with corresponding linguistic variables.

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TABLE I. LINGUISTIC VARIABLE SCALE OF ABSOLUTE VALUE

Linguistic variables	Linguistic Scales
Equally Importance	**1**
Weakly or Slightly	**2**
Moderate Importance	**3**
Moderate Plus	**4**
Strong Importance	**5**
Strong Plus	**6**
Very Strong	**7**
Very Very Strong	**8**
Extremely Importance	**9**

From the case study we can have 6 comparisons of diseases, thus we have a 6×6 matrix. The diagonal elements of the matrix are always set to 1 and then we need to fill up the upper triangular matrix based on the importance of alternatives as shown in Table II.

To fill the upper triangular matrix the following rules are used.

- If the judgment value is on the left side of 1, we put the actual judgment value.
- If the judgment value is on the right side of 1, we put the reciprocal value.

TABLE II. PAIRWISE COMPARISION MATRIX OF DISEASE

	Diabetes	Cardiac	Ortho	Dental	Eye	Skin
Diabetes	1	6	5	4	5	4
Cardiac		1	2	5	1	1/2
Ortho			1	1/6	1/3	1/5
Dental				1	1/2	1/3
Eye					1	1/2
Skin						1

To fill the lower triangular matrix, we use the reciprocal values of the upper diagonal. If a_{ij} is the element of row i and column j of the matrix, then the lower diagonal elements are filled with the following given formula

$$a_{ji} = \frac{1}{a_{ij}}. \tag{1}$$

Thus, the lower triangular matrix comparison can be completed as shown in Table III.

TABLE III. COMPLETE PAIRWISE COMPARISION MATRIX OF DISEASE

	Diabetes	Cardiac	Ortho	Dental	Eye	Skin
Diabetes	1	6	5	4	5	4
Cardiac	1/6	1	2	5	1	1/2
Ortho	1/5	1/2	1	1/6	1/3	1/5
Dental	1/4	1/5	6	1	1/2	1/3
Eye	1/5	1/1	3	2	1	1/2
Skin	1/4	2	5	3	2	1

After a full comparison matrix pair is created, the normalized matrix (Table IV) for the criteria is created as follows:

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_i}. \tag{2}$$

TABLE IV. NORMALISED PAIRWISE COMPARISION MATRIX OF DISEASE

	Diabetes	Cardiac	Ortho	Dental	Eye	Skin
Diabetes	0.48	0.48	0.23	0.38	0.51	0.61
Cardiac	0.08	0.08	0.09	0.05	0.10	0.08
Ortho	0.10	0.04	0.05	0.02	0.03	0.03
Dental	0.12	0.16	0.27	0.09	0.05	0.05
Eye	0.10	0.08	0.14	0.19	0.10	0.08
Skin	0.12	0.16	0.23	0.28	0.20	0.15

The relative weights among the compared diverse diseases are calculated below and the results are given in Table V:

$$w_i = \frac{\sum_{j=1}^{n} r_{ij}}{n}, \; i=1,\ldots,m. \tag{3}$$

TABLE V. RELATIVE WEIGHT FOR THE DISEASE

Diseases Attribute	Sum of the Column	Weight (w_i)
Diabetes	2.69	0.45
Cardiac	0.48	0.08
Ortho	0.26	0.04
Dental	0.75	0.12
Eye	0.68	0.11
Skin	1.15	0.19

To determine the judgement of consistency of decision to be a desirable Consistency Ratio CR, which is the ratio of Consistency Index CI and Random Index RI as follows:

$$CR = \frac{CI}{RI}. \tag{4}$$

Saaty gave a measure of consistency called Consistency Index (CI) as deviation or degree of consistency using the following formula [4]:

$$CI = \frac{\lambda_{\max} - n}{n-1}, \tag{5}$$

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where
λ_{max}=(2.69*0.45)+(0.45*0.08)+(0.26*0.04)+(0.75*0.12)+(0.68*0.11)+(1.15*0.19) = 6.57 and *n* is the size of matrix.

$$CI = \frac{6.57-6}{6-1} = 0.115. \quad (6)$$

And the Random Index RI is given in Table VI.

TABLE VI. RANDOM INDEX (RI)

n	1	2	3	4	5	6
RI	0	0	0.58	0.9	1.12	1.24

The Consistency Ratio CR is calculated as follows:

$$CR = \frac{0.115}{1.24} = 0.092 \quad (7)$$

If the value of Consistency Ratio CR is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ration CR is greater than 10%, we need to revise the disease judgements. In this case study the Consistency Ratio CR is 9.2%, so the judgement is accepted for the disease pairwise comparison.

Further, to find the relative weight of various diseases based on the symptoms of the patient, we compared pairwise symptoms for diverse diseases. The final weight for various diseases in terms of pairwise symptom comparisons is shown in Table VII.

TABLE VII. RELATIVE PAIRWISE WEIGHT FOR THE DISEASE IN TERMS OF SYMPTOMS

	Frequent urination	Heart burn	Stiffness in joint	Dry mouth	Blurred vision	Scaly skin
Diabetes	0.43	0.32	0.35	0.28	0.27	0.33
Cardiac	0.09	0.10	0.09	0.10	0.10	0.11
Ortho	0.04	0.05	0.04	0.06	0.07	0.07
Dental	0.13	0.15	0.14	0.12	0.14	0.10
Eye	0.12	0.14	0.13	0.16	0.15	0.16
Skin	0.20	0.24	0.23	0.27	0.28	0.23

Consistency Ratio CR for symptoms pairwise comparison for different diseases is shown in Table VIII.

TABLE VIII. CONSISTENCY RATIO CR FOR DIFFERENT DISEASE W.R.T SYMPTOMS PAIRWISE COMPARISION

Diseases Attribute	CR
Diabetes	0.098
Cardiac	0.079
Ortho	0.049
Dental	0.086
Eye	0.072
Skin	0.080

From the CR values of different diseases with respect to symptoms pairwise comparisons show that the judgment of symptoms pairwise comparison is acceptable.

Possibility weight percentage for different diseases are given in Table IX.

$$Weight = \sum_{i=1}^{m} p_{ij} * w_i, \; j=1,\ldots,n. \quad (8)$$

And p_{ij} is the weight for disease for symptoms pairwise comparison from Table VII and w_i is the relative weight for different diseases pairwise comparison.

TABLE IX. POSSIBILITY WEIGHT PERCENTAGES OF DIFFERENT DISEASES

Diseases Attribute	Weight %
Diabetes	0.361
Cardiac	0.094
Ortho	0.054
Dental	0.133
Eye	0.136
Skin	0.225

The proposed case study for the symptom checker using MCDM AHP illustrates that the determination of the relative criteria weight and evaluating the disease of each individual based on their health problem as per the symptoms selection provides the probability of diseases that the patient may suffer. It has shown that the proposed approach is useful and effective to classify the possibility of disease suffered by the patient, based on the percentage score of relative weight of the patient symptoms. Disease can be arranged in descending order of various symptom weights chosen by the patient. Thus we can indicate that patient has more chance to suffer Diabetes by 36%, Skin by 23%, Eye by 14%, Dental by 13%, Cardiac by 9%, and followed Ortho by 5%, respectively, as shown in Fig. 3.

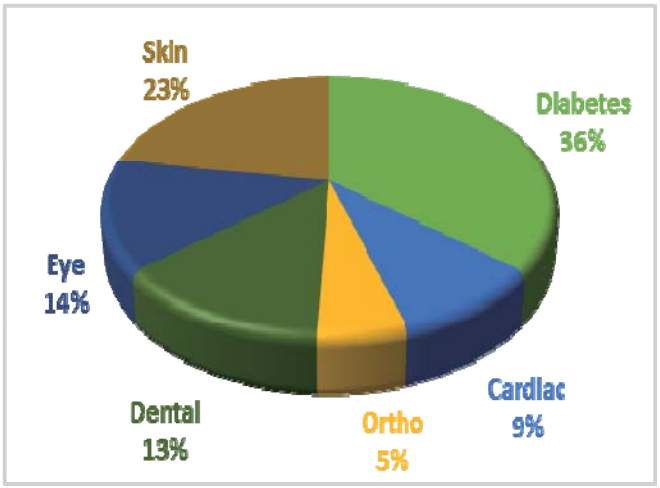

Fig. 3. Percentage score of patient disease base on the relative weight of symptoms.

V. Conclusions

This IoT H2U health predictive analytics care system can provide early treatment and detect danger signs quite early to prevent the need for hospitalization. The length of hospital stay is minimized and the physician and nurses can be connected and monitor the patients based on the report generated by the real time sensors and daily clinical updates by the patient on the database server. It will also help the patient to intervene from any worries hopefully preventing any difficulties when they stay alone in home. The interaction through the IoT system is quite cost-effective and ensures higher security level in terms of communication.

Integrating various wearable devices of elderly healthcare in H2U app and enhancing the privacy and security of the patient central database that is shared in the Internet is under investigation. We will also work more on the symptom checker to be more precise with different approaches of multi criteria decision making MCDM by using different fuzzy approaches and optimization of the weights of symptoms chosen by the patients.

Acknowledgment

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