Assessing Health Symptoms on Intelligent IoT-based Healthcare System

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Abstract. The increased proportion of aging population will demand changes to healthcare systems in developing countries. The increasing demand on the health sector is an inevitable and complicated process. Providing suitable healthcare services is essential for those elderly people who may encounter various medical problems and conditions. Early detection and identification of diseases for treatment, and evaluation of the best alternatives can minimize the involved complications of daily activities for the aged people. To lower the risk for complications we develop an intuitive way of finding the uncertainty of health symptoms by symptom checker. The goal of this empirical study is to further examine and predict certain variations of diseases based on the symptoms that a patient reported. This recommended solution combines conceptual design and technique of multi criteria decision making (MCDM) analytic hierarchy process (AHP) with fuzzy triangular priority weights to deal with the uncertainty of imprecision and ambiguity that resulted from the relative priority scales of various factors of diseases. The method can help users to understand the uncertainty degree of a problem before making the final decision. This paper also validates the efficiency and feasibility of the proposed model to determine the weights of various diseases based on the symptoms and scores chosen by the users thereby providing quality of life assistance services.

Keywords: Symptom checker, healthcare service, interface design, fuzzy AHP, Internet of Things.

1 Introduction

Most parents expect their children to be around when they are aged. But due to changes in family values, many seniors end up in nursing homes or independent-living housing. A large percentage of old people face distinctive challenges such as chronic diseases including heart disease, physical disabilities, diabetes, and depression [1]. Prevention and control of health problems of elderly necessitate a multidimensional approach to
integrate diverse home healthcare systems. Most developed systems focus on the quality of functional aspects of life assistance services that emphasized the convenience and effectiveness based on the concepts of smart home.

To solve such an uncertainty on making decisions for the reported health symptoms a technique of MCDM fuzzy AHP is used in the symptom checker, a medical intuitive diagnosis system platform. The proposed platform aims to help the patients better understand their health problems, predict the type of diseases and guide the patients as to when and where to consult doctors under which departments of the hospital. This research intends to develop a structure decision model that provides the most appropriate strategies to evaluate multiple criteria problems of healthcare faced by the elderly people.

2 Related Work

2.1 Multiple Criteria Decision Making (MCDM)

Multi-Criteria Decision Making (MCDM) is a well-known approach for decision making which analyzed and determined complex problems, and evaluated the best feasible solution from diverse conflicting goals [2-4]. Many authors grouped MCDM into two types based on the analysis process of multiple decision problems, via multi-objective decision making (MODM) and multi-attribute decision making (MADM) for their diverse application disciplines of operational research, ranging from politics and business to the environment and energy by organizing the multifaceted complications [5,6]. This allows MCDM to provide efficient and feasible solutions to the conflicting criteria that satisfy and lead to better decisions.

MCDM problems are very common in everyday life. The use of inappropriate decisions is often the cause of ambiguous problems. MCDM methods can help decision makers to efficiently deal with such conflict states and make wise decisions to yield an optimized hassle free life.

MODM focused on the problems in which decisions were continuous or problems with multiple objectives. MADM dealt with discrete decisions of evaluating how well the alternatives satisfied the objectives and mostly were used in selection or evaluation based on the attributes. There were a variety of common MCDM methods that determined the different conflict situations by evaluating the relative importance based on the specification of needs.

2.2 Fuzzy AHP

Analytic hierarchy process (AHP) methodology was introduced by Saaty which was broadly used in multiple criteria decision making for finding the uncertainty and imprecision dependency in the hierarchical evaluation process [7,8]. AHP has multi directional structure of correlations with clusters and nodes among the decision attributes which consider all the effective component in the decision making.
The goal or objective is the ideal solution that the diverse dimensions from which the alternatives can be viewed based on the criteria decision. Criterion is the relative importance of subject to the goals which are coherent with the decision. For each criterion there may be sub-criteria associated with several sub-sub-criteria. Alternatives signify the diverse varieties of actions obtainable to the decision maker. The number of alternatives is infinite and uncountable when variables are continuous. Usually, the cluster of alternatives is expected to be finite and discrete variables. The alternatives are classified, ordered and finally hierarchically graded based on the weights of their importance.

In this study we considered hybrid MCDM with Fuzzy AHP [9,10] as the conventional MCDM approaches were incompetent in dealing the uncertainty condition of judgement. Fuzzy analytic hierarchy process (Fuzzy AHP) [11-15] is one of the techniques of multiple criteria decision making in a fuzzy environment for complex inter-relationships among the criteria and alternatives. The best alternatives can be selected or the weights of criteria and sub-criteria can be determined according to the pairwise comparisons and relationships between the criteria and sub-criteria to get the intuitive judgement of the set goal.

3 Determining Symptom Checker

In the aged societies a significant number of elderly persons have at least one or more chronic conditions that require immediate medical attention or assistance [16]. But some elderly people living at home alone failed to recognize those symptoms due to lack of medical knowledge or social interaction, resulting in delayed diagnosis and treatment planning.

Symptom checker is a geriatric service management platform [17]. Through the constant monitoring of the patient’s symptoms the system can help determine the effective strategies of treatments. It will also assist those caregivers to educate the elderly patients about their ailment and direct them to specialized departments or doctors for consultation for the better treatment of their health issues.

3.1 Architecture of IoT H2U healthcare system

IoT-based H2U (Internet-of-Things based Help-To-You) 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 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 caregivers 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.

The interface of the devised IoT-based H2U healthcare App is shown in Fig. 2. The system is composed of many useful functions such as insurance, first aid, emergency support, symptoms checker, assistance, medical report, and medication.

![Fig. 1. Architecture of H2U healthcare system.](image1)

![Fig. 2. Interface of the proposed system.](image2)

### 3.2 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 on 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, 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. 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. To protect from security breach 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.

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 is beneficial since the elderly citizens need constant care. As constant monitoring of patients is not possible by doctors around 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 [22]. A wireless sensor placed in the elderly patient as well as in the living environment is necessary for the creation of a wireless sensor network [22]. 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 manual or human errors as IoT is 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 raises 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 patients and doctors in any emergency case.

4 Case Study

To predict and help the patients with any kind of diseases they have suffered from gathering various symptoms we design a system with MCDM fuzzy AHP. The design operation of the symptom checker is shown in the following ways. We defined the 9 linguistic variable scale of absolute numbers with triangular fuzzy scales to tag the relative preference based on the importance of comparison of different elements of the subjects. The 9 standard entities are taken to describe the level of match to patient symptoms $S=\{Chest\ pain,\ Tooth\ ache,\ Fever,\ Thirsty,\ Weight\ loss,\ Blurred\ vision,\ Dizziness,\ Swelling,\ Depression\}$ on the decision criteria, and diseases $D=\{Mental\ illness,\ Diabetes,\ Skin,\ Eye,\ Dental,\ Ortho,\ Cardiac\}$ as alternatives suffered by the elderly people.

Fig. 3 shows a hierarchical structure of various attributes of criteria as Symptoms and alternatives as Diseases to set the goal for qualitative judgments verifying the prioritization of uncertainty decision [18].

Table I shows the fuzzy numbers associated with corresponding linguistic variables and triangular fuzzy numbers [19].

Since there are 9 sets of criteria of symptoms from the case study we can have 9 comparisons based on the criteria to create a 9x9 matrix. The diagonal elements of the
matrix are always set to 1 and then fill up the upper triangular matrix based on the importance of alternatives.

To fill the upper triangular matrix the following rules are used [20].
- If the judgment value is on the left side of 1, the actual judgment value is inserted.
- If the judgment value is on the right side of 1, the reciprocal value is inserted.

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

\[
b_{ji} = \frac{1}{b_{ij}}, \quad i, j = 1, 2, \ldots, n;
\]  

Thus, the lower triangular matrix comparison can be completed as shown in Table II.
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Table 2. Complete Pairwise Comparison Matrix of Criteria Symptoms

<table>
<thead>
<tr>
<th></th>
<th>Chest Pain</th>
<th>Tooth Ache</th>
<th>Fever</th>
<th>Thirsty</th>
<th>Weight</th>
<th>Blurred Vision</th>
<th>Dizziness</th>
<th>Swelling</th>
<th>Depression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest Pain</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.07,23, .70</td>
<td>0.13,27, .60</td>
<td>0.13,27, .60</td>
<td>0.13,27, .60</td>
<td>0.07,2, .70</td>
<td>0.1,1,1</td>
<td>0.22,18, .70</td>
</tr>
<tr>
<td>Tooth Ache</td>
<td>1.3,5,6</td>
<td>1,1,1</td>
<td>0.22,28, .50</td>
<td>0.07,23, .70</td>
<td>0.02,18, .80</td>
<td>0.07,23, .70</td>
<td>0.13,2, .70</td>
<td>0.1,1,1</td>
<td>0.07,23, .70</td>
</tr>
<tr>
<td>Fever</td>
<td>1.4,4,4</td>
<td>2.3,6,4</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.07,23, .70</td>
<td>0.13,27, .60</td>
<td>0.07,2, .70</td>
<td>1,1,1</td>
<td>0.47,23, .30</td>
</tr>
<tr>
<td>Thirsty</td>
<td>1.7,3,7</td>
<td>1,1,1</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.02,18, .80</td>
<td>0.02,18, .80</td>
<td>0.1,1,1</td>
<td>0.2,18, .80</td>
<td>0.22,18, .80</td>
</tr>
<tr>
<td>Weight Loss</td>
<td>1.7,3,7</td>
<td>1,1,1</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.62,11, .80</td>
<td>0.13,2, .70</td>
<td>0.13,2, .70</td>
<td>0.1,1,1</td>
<td>0.22,18, .80</td>
</tr>
<tr>
<td>Blurred Vision</td>
<td>1.4,4,4</td>
<td>2.3,6,4</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.13,2, .70</td>
<td>0.62,11, .80</td>
<td>0.13,2, .70</td>
<td>0.62,1, .70</td>
<td>0.22,18, .80</td>
</tr>
<tr>
<td>Dizziness</td>
<td>1.3,5,6</td>
<td>1,1,1</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.62,11, .80</td>
<td>0.13,2, .70</td>
<td>0.13,2, .70</td>
<td>0.62,1, .70</td>
<td>0.22,18, .80</td>
</tr>
<tr>
<td>Swelling</td>
<td>2.5,3,7</td>
<td>1,1,1</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.13,2, .70</td>
<td>0.13,2, .70</td>
<td>0.13,2, .70</td>
<td>0.62,1, .70</td>
<td>0.22,18, .80</td>
</tr>
<tr>
<td>Depression</td>
<td>2.0,3,6</td>
<td>1,1,1</td>
<td>1,1,1</td>
<td>0.02,18, .80</td>
<td>0.13,2, .70</td>
<td>0.13,2, .70</td>
<td>0.13,2, .70</td>
<td>0.62,1, .70</td>
<td>0.22,18, .80</td>
</tr>
</tbody>
</table>

Then a normalized matrix, with its entry \( k_{ij} \), is created after full comparisons of the matrix and it is represented by the following formula.

\[
k_{ij} = \frac{b_{ij}}{\sum_{j=1}^{n} b_{pj}},
\]

To evaluate the weights for each criterion and for each alternative with reference to a given criterion the fuzzy synthetic extent analysis method is adopted here [21]. \( A_i \) with respect to \( i^{th} \) criteria is achieved where \( C \) is the set of criteria and \( n \) is the number of criteria, \( m \) is the number of decision alternatives, the subscripts \( i \) and \( j \) represent row and column respectively defined as below:

\[
A_i = \frac{1}{\sum_{i=1}^{n} \prod_{j=1}^{m} M_{ij}^{-1}},
\]

After obtaining the weights of different criteria of symptoms associated with fuzzy synthetic extent of triangular fuzzy numbers, the relative weights are calculated as given below:

\[
w_i = \frac{w_i}{\sum_{j=1}^{n} w_j},
\]

where \( w_i \) represents the normalized weight for the \( i^{th} \) criterion. Similar mathematical methodology for weight calculation was used to estimate the weights for the given alternatives Diseases with respect to criteria Symptoms, and one of their respective results is shown in Table III.

The Possibility of final weight percentage priority for different diseases with respect to the symptoms are calculated from the given formula:

\[
\text{Weight} = \sum_{i=1}^{m} \sum_{j=1}^{n} p_{ij} \times w_i, \; i=1,2,\ldots,m, \; j=1,2,\ldots,n\;
\]
And $p_{ij}$ is the weight for diseases with respect to symptoms pairwise comparison and $w_i$ is the relative weight for different criteria symptoms pairwise comparison.

Comparing the weights of the diseases based on the symptoms we can designate that patient has more chance to suffer Ortho by 19%, Cardiac by 18%, Dental by 17%, Eye by 10%, Diabetes by 7%, Skin by 3% and followed Mental Illness by 1%, respectively.

**Table 3. Evaluation of Symptom Chest Pain with Alternative Disease**

<table>
<thead>
<tr>
<th>CHEST PAIN</th>
<th>Mental Illness</th>
<th>Diabetes</th>
<th>Skin</th>
<th>Eye</th>
<th>Dental</th>
<th>Ortho</th>
<th>Cardiac</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental Illness</td>
<td>1.1</td>
<td>.02,.18, 80</td>
<td>.02,.18, 80</td>
<td>.13,.27,.60</td>
<td>.13,.27,.60</td>
<td>.02,.18, 80</td>
<td>1.0</td>
<td>.01</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.35,65</td>
<td>1.1</td>
<td>.02,.18, 80</td>
<td>.02,.18, 80</td>
<td>.07,.23, 70</td>
<td>.13,.27,.60</td>
<td>.07,.23, 70</td>
<td>.08</td>
</tr>
<tr>
<td>Skin</td>
<td>1.35,65</td>
<td>1.35,65</td>
<td>1.1</td>
<td>.02,.18, 80</td>
<td>.07,.23, 70</td>
<td>.02,.18, 80</td>
<td>.02,.18, 80</td>
<td>.15</td>
</tr>
<tr>
<td>Eye</td>
<td>1.73,77</td>
<td>.7</td>
<td>1.35,65</td>
<td>1.35,65</td>
<td>1.1</td>
<td>.07,.23, 70</td>
<td>.02,.18, 80</td>
<td>.02,.18, 80</td>
</tr>
<tr>
<td>Dental</td>
<td>1.44,41</td>
<td>4.3</td>
<td>1.44,41</td>
<td>4.3</td>
<td>1.44,41</td>
<td>4.3</td>
<td>1.1</td>
<td>.02,.18, 80</td>
</tr>
<tr>
<td>Ortho</td>
<td>1.35,65</td>
<td>.02,173,77</td>
<td>1.35,65</td>
<td>1.35,65</td>
<td>1.25,65</td>
<td>1.11</td>
<td>.07,.23, 70</td>
<td>.30</td>
</tr>
<tr>
<td>Cardiac</td>
<td>0.01</td>
<td>1.44,41</td>
<td>1.35,65</td>
<td>1.35,65</td>
<td>1.44,41</td>
<td>1.44,41</td>
<td>1.1</td>
<td>.21</td>
</tr>
</tbody>
</table>

### 5 Conclusions

This predictive decision support tool with MDCM Fuzzy AHP allows concrete and precise identification of most appropriate options of various uncertainty faced by every individual in daily life. Fuzzy AHP with the fuzzified predictive symptom checker can provide flexibility of early diagnosis and detect any health related threat quite early to avert the need for hospitalization and chronic consequences. Health care uncertainty issues faced by elder people will be resolved by this design and implementation but to arrive at more precise and accurate judgement with inter or intra level dependencies relation we will superimpose ANP in this existing design to generalize from Fuzzy AHP version. This proposed structure may help to overcome and deal with various networks of interrelationships among numerous issues of structured hierarchically problems of interdependence among the multi directional criteria and alternatives.

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