Group Profile Creation in Ubiquitous Healthcare Environment Applying the Analytic Hierarchy Process

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Abstract. Nowadays, the personalization in ubiquitous healthcare is of utmost importance for enabling the provision of services tailored to the patient's needs and interests. The personalization of the ubiquitous healthcare services is based on the profiles of the entities participating in these services. Such an application is the dynamic creation of the group of the entities that is formed to deliver the healthcare service to the patient. In this paper, we propose an approach for achieving creation of group profiles in a ubiquitous healthcare environment applying the Analytic Hierarchy Process.

Keywords: ubiquitous healthcare, group profile management, analytic hierarchy process.

1 Introduction

Nowadays, ubiquitous healthcare (UH) plays a major role in the patient-centric model since it requires the provision of healthcare to anyone, anytime and anywhere without limitations on time and location. Thus, UH services are designed having the patient as the core entity. The patient not anymore passively receives the healthcare service, but participates dynamically in service deployment and provision. The different states of the patient's health condition lead to different treatment schemes. The entities that are involved in these schemes should be dynamically organized per case in order to form the group that will deliver the UH service. To achieve such personalization in UH services, the existence of the profile for all the participating entities is required as well as the creation of a group profile.

In this paper, we carry on our work from [1], in which a group profile management system for UH environment is presented. In particular, we propose an approach for achieving creation of group profiles in a UH environment applying the Analytic Hierarchy Process (AHP) [2].

Following the introduction, this paper is organized as follows. In Section 2, related work to the group profile management in UH as well as to applications of AHP in UH is presented. In Section 3, the proposed approach for implementation of the group profile creation mechanism is presented. In section 4, a scenario of the implementation of the

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analytic hierarchy process in the group profile creation in UH environment is deployed and then the scenario is evaluated. Finally, Section 5 concludes the paper and discusses the future work.

2 Related Work

2.1 Group Profile Management in Ubiquitous Healthcare

The work in [1] introduces a Group Profile Management System in a UH environment. The proposed system integrates the following four mechanisms: the Event Handler, the Role Assignment, the Group Profile Creation and the Group Profile Update that are responsible for the dynamic creation of the group profile and its management. It is considered that a UH environment is composed by UH entities with the patient being in the center.

Each of the participating entities in the UH environment has a profile. The state of the patient's health condition is the inception for a UH service to be delivered. At a time, the patient's healthcare condition can be in only one state. At each state, certain UH services are provided to the patient by certain entities. For the provision of such services, the determination of the entities that will participate to form dynamically the group is of great importance. For that reason, the group profile integrates two main types of information; the roles and the rules. The roles correspond to the participating entities that are essential for each group in order to accomplish the overall tasks. The group consists of entities with discrete roles in the provision of the UH service. The rules are statements required for the selection of the appropriate entities.

2.2 Analytic Hierarchy Process in Healthcare

AHP, proposed by Saaty [2], is a structured technique for organizing and analyzing complex decisions. It is used with success in a wide variety of decision situations, in many different fields such as everyday life issues [3], socio-economic planning sciences [4], military [5] and resource allocation and management [6]. AHP has also been applied in healthcare for solving multi-attribute decision making problems.

The work [7] deals with strategic enterprise resource planning (ERP) in a health-care system using a multi-criteria decision-making (MCDM) model. The model is developed and analyzed on the basis of the data obtained from a leading patient-oriented provider of health-care services in Korea. Goal criteria and priorities are identified and established via the AHP.

DIABRA (DIABetes Risk Assessment) [8] is a knowledge-based expert system developed to aid individuals to assess their chance for getting Type 2 diabetes. The system core is a quantitative model, implemented by AHP mechanism, to evaluate the developed scenarios. The acquired knowledge as scenarios are scored by AHP mechanism and represented in the DIABRA. The validation results show the expert system gives a highly satisfactory performance when compared to human experts.

This work [9] showed how the AHP decision support technique can be applied to clinical engineering health technology assessment projects. AHP provides a structured method of organizing and documenting the decision process and takes into consideration the many tradeoffs that exist between alternate choices. When an AHP model is properly designed and implemented, it facilitates interdepartmental and interdisciplinary communication and results in a decision support tool that represents a consensus model. The AHP model can then be used to compare health technology alternatives and delivers a composite score for each alternative that identifies the best choice. AHP produces a clinical engineering decision support tool for the hospital that identifies the best technology alternative for their specific need.

The work [10] examines clinical laboratory and pharmacy deliveries in middle to large size hospitals, in order to evaluate whether or not a fleet of mobile robots can replace a traditional human-based delivery system. The complexity of the problem derives from its multi-objective character, since several, often contrasting factors must be taken under consideration. The Analytic Hierarchy Process was used to build a decision problem that synthesized economic and technical performance as well as social, human and environmental factors. This research provides a methodology to approach automation introduction evaluation in a hospital environment.

The objective of the work [11] is to introduce the AHP as a preference elicitation method in health technology assessment (HTA). Patient involvement is widely acknowledged to be a valuable component in HTA and healthcare decision making. However, quantitative approaches to ascertain patients' preferences for treatment endpoints are not yet established. It is concluded that AHP can be used in HTA to give a quantitative dimension to patients' preferences for treatment endpoints.

The objective of the work [12] is to illustrate how the AHP can be used to promote shared decision-making and enhance clinician–patient communication. The AHP promotes shared decision-making by creating a framework that is used to define the decision, summarize the information available, prioritize information needs, elicit preferences and values, and foster meaningful communication among decision stakeholders. AHP is a well-developed method that provides a practical approach for improving patient–provider communication, clinical decision-making, and the quality of patient care in these situations.

3 Proposed Approach for Implementation of the Group Profile Creation Mechanism

As we proposed in [1], the group profile creation mechanism is used for the creation of the required group profile based on the current patient's health condition. To determine each of the participating entities of the group profile, we propose the use of the AHP.

To select the appropriate entity is a complex decision since many criteria should be taken into consideration. These criteria are related to the participating entities in the group profile with the patient being the center of the provisioned UH services. For instance, two criteria may be the availability of the potential participating entities and the patient's preference on the potential participating entities.

The potential participating entities that can be assigned to a role are called alternatives. Based on the criteria, the alternatives will be ranked in order to be selected the alternative with the highest priority. AHP is used to determine the entity that will eventually participate in the group profile. The AHP is a method consisting of the following four concrete steps.

In the first step, to select the participating entity that will participate in the group profile, we define the goal, the criteria and the alternatives which are structured in a hierarchy as depicted in Fig. 1. The goal which is the selection of the appropriate entity is in the top level of the hierarchy. The criteria which contribute to the goal are in the middle level, and the alternative participating entities, who are to be evaluated in terms of the criteria, are in the bottom level of the hierarchy.

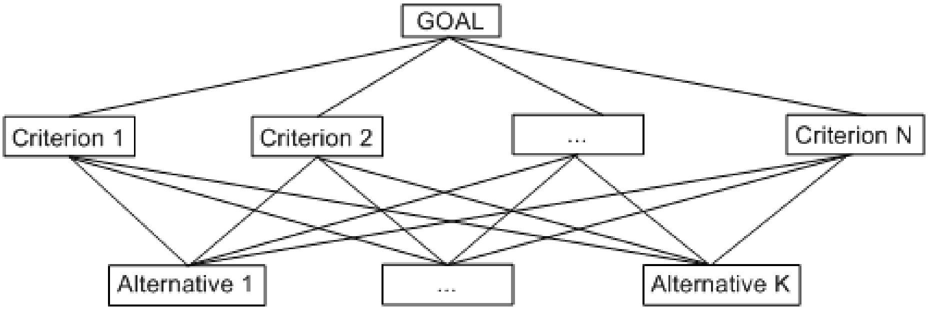

Fig. 1. Principal hierarchical structure

In the second step, according to the AHP process the criteria are constructed as a set of pairwise comparison judgments in a reciprocal matrix i.e. $a_{ji}=1/a_{ij}$, $a_{ii}=a_{jj}=1$. For this comparison, a scale of numbers (1-9), which is validated for effectiveness, is used. That scale indicates how many times more important or dominant one criterion is over another criterion with respect to the criterion to which is compared. The result of this process is the Relative Value Vector (RVV) which is the principal eigenvector of the matrix. The RVV gives the relative priority of the criteria measured on a ratio scale i.e. which criteria have the highest priority with a ratio of influence.

In the third step, the alternatives (bottom level of the hierarchy) are compared in pairwise with respect to how much better one is than the other for the satisfaction of each criterion defined in the middle level. The judgments of the matrices depend on the characteristics of the alternatives with regard to each of the criteria. The process results to the Local Value Vector (LVV) that gives the local priorities of the alternatives on a ratio scale.

To deduce the objectiveness of the judgments in the above matrices, the consistency ratio (CR) is checked when each matrix is constructed. The CR should range between 0 and 0.1 in order the matrix to be consistent. To have a final selection of a participating entity that has not been determined randomly, the CR should not exceed the upper limit in all matrices.

The result of the fourth step is the desired vector of the alternatives from which it is deduced the participating entity that will be eventually chosen. This vector is called Global Value Vector (GVV).and is calculated by the following process: a) the LVV of all the alternatives with respect to each of the criteria is laid out in a matrix, b) each column of these vectors is multiplied by the RVV that shows the priority of the corresponding criterion and c) each row is added across. This process is given by the following formula:

$$GVV = RVV \text{ X } LVV \tag{1}$$

4 Implementation and Evaluation

4.1 Scenario

We consider that the current patient's health condition is the emergency state and the patient requires a specific healthcare service. For the provision of this service, the roles that are essential for the group creation are the role of a doctor and the role of a relative. Thus, two different decisions should be made for the group creation. The first one is related to the selection of the most suitable doctor and the second one is associated with the selection of the appropriate relative. In our scenario, the selection of the doctor is analyzed in details below.

Initially, the criteria that will determine this decision are defined. From the patient's perspective, it is important to be treated by a preferred doctor. For that reason, as we presented in [1], the patient has already defined in his profile a catalogue with the potential participating entities for each role of the group profile that he would prefer to participate in his treatment. In this catalogue, the preferred doctors for his treatment are also defined. In this scenario, in the patient's profile there are five potential doctors ranked according to his preferences. Another criterion is the location of the potential participating entity (e.g. doctor). When the doctor is closer to him, the patient may feel safer. From the doctor's perspective, an important criterion is his availability as well as the capabilities of his devices that determine the quality of the provided healthcare service.

In Fig. 2, it is depicted the scenario structured in a hierarchy. The selection of the appropriate doctor is the goal, the five doctors are the alternatives, and the criteria for evaluating these alternatives are four.

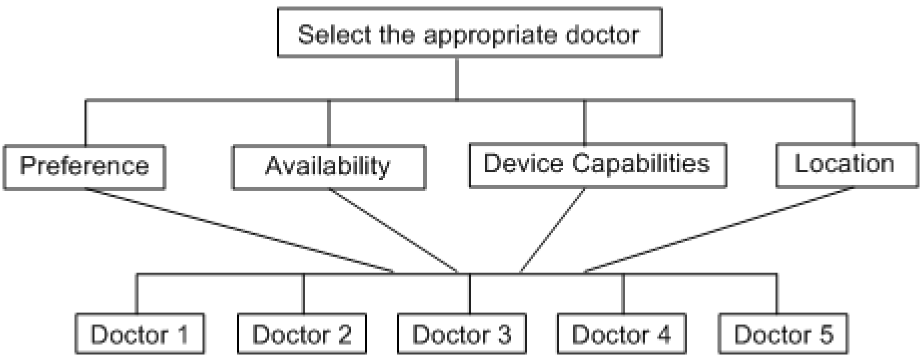

Fig. 2. Scenario analyzed in a hierarchical structure

To apply the AHP in group profile creation we consider that the five potential doctors that exist in the patient's profile have the following characteristics at the time of the decision.

Doctor 1 is on a private examination far from the patient, carrying only his mobile phone of poor capabilities. In the patient's profile, Doctor 1 is designated as the first choice because he is the doctor that formally treats him.

Doctor 2 is at his house which is in the same neighborhood with the patient. However, he has set himself available for offering healthcare service only if needed. He is carrying a mobile phone of new generation. In the patient's profile, Doctor 2 is designated as the second choice for being selected.

Doctor 3 has just walked away from a private examination carrying with him the PDA. He is located close to the patient's house. Therefore, he is totally available for offering his healthcare services, if needed. Moreover, he is ranked as the third preferred selection in the patient's profile.

Doctor 4 is at his office which is very close to patient's house. Non-having examinations and sitting in front of his desktop, he can offer his healthcare services. However, he is set nearly on the bottom of the patient's preferences, as he is non-aware of patient's medical history but he had examined the patient in the past.

Doctor 5 is on duty at the hospital far from the patient's location carrying his PDA. He is designated as the last preferred option in the patient's profile.

4.2 Evaluation

Based on the above scenario, we run the decision making algorithm to select the appropriate participating entity in the UH group profile. Inspired by AHP method, we applied this algorithm for the selection of the one of the five doctors that will participate in the group profile. The results from the simulation are presented in this section.

The pairwise comparison matrix for the criteria with respect to the goal is depicted in Fig. 3. Comparing the criteria on the left with the criteria on the top as to their importance, it emerges that the patient's preference has the highest priority with 55,34% of the influence. The CR is 0.071.

	Preference	Availability	Device	Location	Relative Value Vector
Preference	1	3	6	8	0.5534
Availability	1/3	1	5	7	0.3023
Device	1/6	1/5	1	3	0.0969
Location	1/8	1/7	1/3	1	0.0474

Fig. 3. Pairwise comparison matrix of the criteria

There are four 5 X 5 matrices of judgments since there are four criteria in the second level, and 5 doctors to be pairwise compared for each criterion. These pairwise comparison matrices for the alternatives with respect to each one of the criteria are depicted in Fig. 4.

CRITERIA		Doctor 1	Doctor 2	Doctor 3	Doctor 4	Doctor 5	Local Value Vector
PREFERNCE	Doctor 1	1	3	5	7	9	0.5028
	Doctor 2	1/3	1	3	5	7	0.2602
	Doctor 3	1/5	1/3	1	3	5	0.1344
	Doctor 4	1/7	1/5	1/3	1	3	0.0678
	Doctor 5	1/9	1/7	1/5	1/3	1	0.0348
							CR=0.053
AVAILABILITY	Doctor 1	1	6	1/5	1/2	7	0.1728
	Doctor 2	1/6	1	1/8	1/7	2	0.0478
	Doctor 3	5	8	1	3	9	0.4970
	Doctor 4	2	7	1/3	1	8	0.2492
	Doctor 5	1/7	1/2	1/9	1/8	1	0.0331
							CR=0.065
DEVICE	Doctor 1	1	1/3	1/5	1/9	1/5	0.0400
	Doctor 2	3	1	1/3	1/7	1/3	0.0805
	Doctor 3	5	3	1	1/3	1	0.1975
	Doctor 4	9	7	3	1	2	0.4684
	Doctor 5	5	3	1	1/2	1	0.2135
							CR=0.017
DISTANCE	Doctor 1	1	1/7	1/3	1/4	3	0.0702
	Doctor 2	7	1	5	3	9	0.5127
	Doctor 3	3	1/5	1	1/2	6	0.1516
	Doctor 4	4	1/3	2	1	7	0.2313
	Doctor 5	1/3	1/9	1/6	1/7	1	0.0342
							CR=0.043

Fig. 4. Pairwise comparison matrix for the alternatives with respect to each of the criteria

The desired Global Value Vector of the alternatives is depicted in Fig. 5.

$$\begin{bmatrix} Doctor\ 1 \\ Doctor\ 2 \\ Doctor\ 3 \\ Doctor\ 4 \\ Doctor\ 5 \end{bmatrix} \equiv 0.5534 + \overset{Preference}{\begin{bmatrix} 0.5028 \\ 0.2602 \\ 0.1344 \\ 0.0678 \\ 0.0348 \end{bmatrix}} + 0.3023 \overset{Availability}{\begin{bmatrix} 0.1728 \\ 0.0478 \\ 0.4970 \\ 0.2492 \\ 0.0331 \end{bmatrix}} + 0.0969 \overset{Device}{\begin{bmatrix} 0.0400 \\ 0.0805 \\ 0.1975 \\ 0.4684 \\ 0.2135 \end{bmatrix}} + 0.0474 \overset{Distance}{\begin{bmatrix} 0.0702 \\ 0.5127 \\ 0.1516 \\ 0.2313 \\ 0.0342 \end{bmatrix}} = \begin{bmatrix} 0.3377 \\ 0.1906 \\ 0.2509 \\ 0.1692 \\ 0.0516 \end{bmatrix}$$

Fig. 5. Priority ranking of the alternatives

Observing the resulted GVV, Doctor 1 has the largest priority to be selected to participate in the group. This selection is also the most desirable with respect to the patient's preferences (the highest priority criterion). Doctor 3 is the second choice to participate in the group even if he was not declared as the second choice in the profile.

5 Conclusion and Future Work

In this paper, we have proposed an approach for achieving the creation of group profiles in a UH environment applying the AHP. The results indicate that AHP leads to an optimal selection of the participating entity taking into account all the required criteria. As future work, we intend to customize the AHP in order to optimize its performance for group profile creation in a UH environment. The integration of the customized AHP in the group profile creation process will lead to a more efficient health delivery process.

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