eHASS: A Smart Appointment Scheduling System for eHealth

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***Abstract*—In the eHealth system, the appointment scheduling is an important task for the delivery of healthcare service among different healthcare actors. The key procedure is to do the decision making on the selection of suitable appointments between the care providers and the care receivers. The appointment decision is a sophisticated problem in terms of how to efficiently deal with various parameters of involved healthcare actors. To solve this problem, we suggest a smart system called eHealth Appointment Scheduling System (eHASS). eHASS takes into account both heterogeneity aspects and interoperability requirements of eHealth system. As such, eHASS is capable of jointly considering various appointment characterizations and decision making algorithms for conducting appointment scheduling. The paper reports the eHASS architecture as well as the related work-in-progress.**

I. Introduction

The eHealth is a promising solution approach advanced as the growing prominence of chronic diseases and financial challenges in healthcare spending [1]. It is bringing to the efficient delivery of healthcare service in accordance with people's needs and expectations. The development on eHealth also leads to the substantial provision of innovative technologies from both industry and academia, such as the wearable and mobile systems [2]. Among others, an important task in eHealth refers to as the appointment scheduling, based on which the most suitable appointments are demanded by different healthcare actors. The corresponding procedure is connected to a decision making problem by jointly considering various parameters associated with the involved healthcare actors. This problem is further complicated with the need of employing different candidate decision making algorithms.

A large amount of studies on appointment scheduling have been reported in recent literature. For instance, in [3], the authors suggest an appointment scheduling solution by considering the patient-provider mutual preference. This solution is used to reduce the schedule fragmentation, and thus yielding higher appointment acceptance rate and clinic time utilization rate. In [4], the authors suggest a load balancing strategy for aid scheduling in eHealth. The goal is to optimize the Quality of Service (QoS) of healthcare delivery. In [5], the authors consider the appointment scheduling problem for patients visiting a given place. A queueing theory model is further built up and the corresponding numerical analysis is reported.

To our best knowledge, less focus however has been laid on the heterogeneity aspects and the interoperability requirement existent in eHealth. In our work, the heterogeneity is expressed in terms of vertical and horizontal properties of appointment scheduling system. The vertical property means the joint consideration of different kinds of healthcare actors such as the Care Provider (CP) and the Care Receiver (CR). The horizontal property refers to different characterization parameters associated with appointment availability, which are like, e.g., the time availabilities of CPs, the skill competence of CPs, the disease status of CRs, the cancellation probability of appointments. The heterogeneity aspects further lead to different decision making algorithms for doing appointment scheduling between CPs and CRs. Subsequently, the appointment decision maker requires an interoperability framework across various characterization parameters and different algorithms.

In this paper, a new system called eHealth Scheduling Support System (eHASS) is suggested to schedule the suitable appointment for CPs and CRs. To solve the above addressed requirement problem, eHASS adopts a new parameter Fuzzy Appointment Availability (FAA) defined from fuzzy-logic point of view. The goal of using FAA is to map different types of characterization parameter to an uniform type with respect to FAA. Further, an overlay decision maker is built up, and it is used to jointly consider different decision making algorithms.

The rest of paper is organized as follows. Section II describes the architecture of eHASS. Section III discusses the setting up of an overlay decision maker in eHASS. The related works in progress are presented in Section IV. Finally, we conclude the paper in Section V.

II. Appointment Scheduling System

A. Element Classification

Compared with the other eHealth management systems, eHASS is a novel system with the efficient provision of healthcare assistant. The key idea is to do decision making on scheduling the suitable appointments between CPs and CRs, the so-called appointment scheduling. The corresponding decision making process jointly considers different elements, which are involved in the healthcare assistant. By *element*, we mean the individual entity in the eHealth area, which can be like, e.g., a patient, a nurse, a time slot for meeting, a laboratory, a decision making algorithm.

Further, we classify various elements into four categories, i.e., active unit, information base, interactivity chain, and algorithm factory. They are described as follow.

1) Active Unit: it includes different healthcare actors like, e.g., CP, CR, tools, community network. Specifically, both CPs and CRs are essential elements in eHealth. They can communicate with each other by using a face-to-face or a remote based manner, for instance, a meeting with a doctor or a telephone call from a nurse. Tools are referred to as the items used for healthcare assistant, for instance, a laboratory, transport systems, the electronic health record, the X-rays and the relevant diagnostic knowledge. Community network is regarding the social elements like, e.g., family relatives, healthcare centers, shopping centres, banks.

2) Information Base: it has two different parts, which are the information content and information collection. The information content is about the characterizations of healthcare actors. Examples of such information are the chronic diseases suffered by the CR, the electronic health record for the CR, the competence of the CP, the time availabilities of the CP, and the availabilities of the laboratory. The information collection is referred to as the ways of collecting different information. It can be done through solutions like using wearable systems and information exchange among healthcare actors.

3) Interactivity Chain: it is related to the interactions and communications among different healthcare actors. Examples of interactivities are booking an appointment with a doctor, reporting outcomes by either nurses or by doctors, checking results by either patients or by the patients' relatives.

4) Algorithm Factory: it has various candidate decision making algorithms, which can be used to do healthcare decision. While, different algorithms may have different characteristic features and respective decision criteria. For instance, a key characteristic feature related to fuzzy-logic is given by the *fuzzy membership degree*. Furthermore, a particular decision criterion may have a prescribed method to decide on the most suitable appointment for a patient.

B. Two-layer Representation

To conduct the appointment scheduling, the eHASS needs to deal with two important tasks. The first task is to process the information about the relevant healthcare actors and their characterizations, the so-called *information processing*. The second task is to select one or more decision making algorithms, and thus scheduling the appropriate appointments between the CPs and CRs, the so-called *overlay decision making*. Subsequently, we suggest a two-layer based representation for eHASS, as shown in Fig. 1. In the figure, the lower and upper layers are connected to the first and the second tasks, respectively.

1) Activity theory ontology model: the lower layer contains various healthcare actors and their interactivities, which can be represented in accordance with an activity theory ontology model. Such model is suggested and described in our previous work [6]. Here, the activity means the basic unit that preserves the essential quality of the focuses from the human practice point of view [7]. The underlying idea of activity theory is to explain the inseparability of subjectives and objectives. The main advantage of using the aforementioned model is related

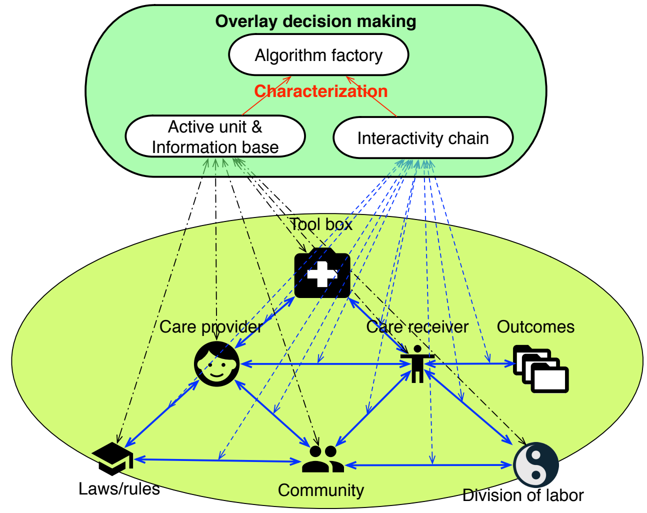

Fig. 1. Two-layer representation of eHASS.

to the flexibility and extendibility of representing various healthcare actors for conducting knowledge sharing in eHealth.

2) Overlay decision making: the upper layer is referred to as the function called overlay decision making. On this layer, both active unit and information base are connected to the healthcare actors on the lower layer, where the interactivity chain is connected to various interactivities among these healthcare actors. Regarding the algorithm factory, it is connected to other three categories of elements for doing decision making on appointment scheduling.

C. Scientific Functionalities of eHASS

Based on the above-addressed two-layer representation, we suggest three scientific functionalities for eHASS. They are described as follows.

1) Overlay decision maker: so far, most of decision making algorithms (e.g., fuzzy-logic, game theory) have so far been independently used for different research problems. Because there may exist different metrics (e.g., the doctor's time availabilities, the patient's diseases) for doing appointment scheduling for eHealth, this raises the need of jointly considering different decision making algorithm with aiming at managing them to work together.

2) Queueing modeling: the particular appointment decision strategy may affect the overall performance of the whole appointment scheduling system. Investigation of related performance characteristics is usually based upon theoretical analysis or simulation experiment. In eHASS, we use the queueing modeling to carry out theoretical analysis.

3) Appointment scheduling simulator: to validate the theoretical study on the appointment scheduling performance, we develop a simulator to conduct simulation based experiments. The simulator consists of two parts. The first part is to configure the simulation parameters and scenarios, for instance, the numbers of CPs and CRs, the appointment duration. The second part is to simulate the dynamic behaviors of both CPs and CRs, and to deal with the interactivities among them. The interactivities can be like, e.g., the appointment request from CRs, the arrangement of appointment time slot.

D. eHASS Structure

We show the eHASS structure in Fig. 2. In the figure, the components in the area of grey color compose the eHASS. The detailed description is as follows:

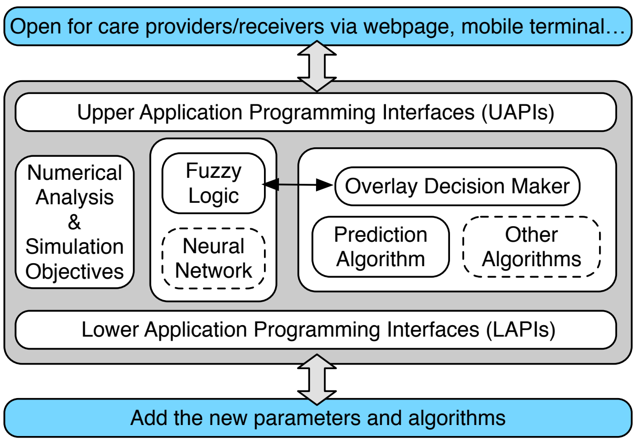

Fig. 2. Abstract structure of eHASS.

1) UAPIs: they indicate that eHASS is open for upper users (e.g., CPs, CRs) by using tools like web techniques and mobile terminals.

2) LAPIs: they imply that new parameters or new decision making algorithms can be added into eHASS.

3) The arrows inside the eHASS: they show the internal functions of eHASS. The fuzzy-logic/neural-network module is responsible for processing all input appointment characterizations with respect to the uniform decision criterion. Then, the overlay decision maker uses the processed information to do suitable appointment scheduling based on candidate decision making algorithms, e.g., Markov chains base prediction, graphic theory.

Clearly, the key module of eHASS is the overlay decision maker, and it is presented below.

III. Fuzzy-logic based Decision Making

Because the appointment between the CP and the CR can be scheduled with respect to different parameters, the scheduling procedure becomes a multiple-constraint based decision making problem. To solve this problem, a three-dimension model is used to represent the appointment characterizations, and an overlay decision maker is constructed by using fuzzy-logic.

A. Appointment Characterization

We consider an eHealth system with M CPs, which are denoted by a set $\{p_m|m = 1, 2, ..., M\}$. For the simplicity purposes, the CRs are assumed to have the same priority to obtain the healthcare assistant from CPs. While, the appointment availability of CP is assumed to be characterized by a set of independent parameters $\{e_n|n = 1, 2, ..., N\}$. Examples of these parameters are the CP's time availability, the CP's skill competence, the CP's familiarity on the patient's diseases, the patient's time preference. We let $a^m_{e_n}(t)$ denote the observed parameter value of e_n for the CP p_m at time t, where $n \in \{1, 2, ..., N\}$ and $m \in \{1, 2, ..., M\}$. Then, the characterizations of appointment availability of all CPs at time t can be represented by a matrix:

$$\mathbf{A}(t) = \begin{bmatrix} a^1_{e_1}(t) & a^1_{e_2}(t) & \dots & a^1_{e_N}(t) \\ \vdots & \vdots & \ddots & \vdots \\ a^m_{e_1}(t) & a^m_{e_2}(t) & \dots & a^m_{e_N}(t) \\ \vdots & \vdots & \ddots & \vdots \\ a^m_{e_1}(t) & a^m_{e_2}(t) & \dots & a^m_{e_N}(t) \end{bmatrix} \quad (1)$$

Further, the time period used for the appointment scheduling between CPs and CRs is denoted by $(t, t + K\delta]$. This time period is identically divided into K slots, and these slots are labelled as $\{t_k|k = 1, 2, ..., K\}$. During each time slots, every CP is assumed to be either available for or be occupied by an appointment. We then obtain a set of appointment characterization matrixes at discrete time points $\{t_1, t_2, ..., t_K\}$, which is expressed as $\{\mathbf{A}(t_0), \mathbf{A}(t_1), ..., \mathbf{A}(t_H)\}$.

Subsequently, the characterizations of appointment availability for M CPs in the time interval $(t, t + K\delta]$ can be represented by a three-dimension model. The three dimensions are referred to as three domains, namely, time, care provider and parameter.

B. Uniform Decision Criterion

Due to the parameter diversity of the above-formulated appointment characterization, the overlay decision maker needs to set up an uniform decision criterion. To do this, a new parameter called FAA is introduced. The goal of using FAA is to map different types of parameter values to an uniform type, i.e., fuzzy membership degree.

FAA is a fuzzy-logic based parameter, and it is used to represent different levels of appointment availability between CPs and CRs. For simplicity purposes, in this paper we adopt three typical levels, which are formalized as three fuzzy sets *"high-level"*, *"medium-level"* and *"low-level"* appointment availabilities, respectively. With regard to parameter e_n, these three fuzzy sets are denoted by α_{e_n}, β_{e_n} and γ_{e_n}, respectively. Further, let σ_{e_n} denote the set of all possible values of parameter e_n. For the CP p_m at time t, we have $a^m_{e_n}(t) \in \sigma_{e_n}$.

According to the fuzzy set theory, a function denoted by g_{e_n} is introduced to act as the characteristic function of the fuzzy set σ_{e_n}. Specifically, g_{e_n} is generalized to a *fuzzy membership function*, based on which the value range of $g_{e_n}(a^m_{e_n}(t))$ is given by an unit interval $[0.0, 1.0]$. Subsequently, the fuzzy membership degrees of $a^m_{e_n}(t)$ to three fuzzy sets of FAA are denoted $g^\alpha_{e_n}(a^m_{e_n}(t))$, $g^\beta_{e_n}(a^m_{e_n}(t))$ and $g^\gamma_{e_n}(a^m_{e_n}(t))$.

Let $\pi_\times$, π_+, and π_- denote the importance weights of three fuzzy sets α_{e_n}, β_{e_n} and γ_{e_n}, respectively, on decision making for appointment scheduling. Then, the FAA-based characterization of appointment availability for the CP p_m under the parameter at time t is given by

$$\xi_{e_n}^{m}(t) = g_{e_n}^{\alpha}(a_{e_n}^{m}(t))\pi_{\times} + g_{e_n}^{\beta}(a_{e_n}^{m}(t))\pi_{+} + g_{e_n}^{\gamma}(a_{e_n}^{m}(t))\pi_{-} \tag{2}$$

Moreover, let the set $\{w_n|n = 1, 2, ..., N\}$ denote the importance weights of *N* parameters on on decision making for appointment scheduling. Based on this equation, the numerical appointment availability of CP p_m at time t is computed as

$$\eta_m(t) = \xi_{e_1}^{m}(t)w_1 + \xi_{e_2}^{m}(t)w_2 + ... + \xi_{e_n}^{m}(t)w_n + ... + \xi_{e_N}^{m}(t)w_N \tag{3}$$

Subsequently, the most suitable CP for the appointment at time t is associated with the largest value of $\eta_m(t)$, and it is obtained as follows:

$$\eta^{*}(t) = argmax\{\eta_1(t), \eta_2(t), ..., \eta_M(t)\} \tag{4}$$

C. Group Decision Making

In the above subsection, we assume that the importance weights of all FAA-based decision factors can be prescribed. However, in some particular cases, we may not pre-assign a FAA-based decision factor with an adequate weight value. In these cases, we need another algorithms called *group decision* to do decision making on appointment scheduling.

The group decision is proposed by Blin [8], and it is also based on fuzzy-logic. The key idea of group decision making is to define a set of group orders, as well as using graphic theory. The group orders are associated with the comparison results of different parameters with regarding to their importances on doing decision making. The graphic theory is used to plot a set of directed graphs by using the obtained group orders. Due to the space limit, the procedure of carrying out group decision making is not presented in this paper, while the detailed description is reported in the previous work [9].

IV. Latest Results

We developed a prototype system called Activity Information System (AIS) with using the eHASS to do appointment scheduling. The corresponding development was accomplished through the web technologies like, e.g., HTML, Java/JavaScripts, MySql. For the experimental test purposes, we also deployed the prototype in the Zhengzhou University Hospital, China, by the end of 2015 (Fig. 3). Due to time limits, we first conducted a survey based system evaluation. Specifically, there were 60 CPs in terms of doctors, nurses and the family members participating in the survey, as well as 100 CRs. Eventually, the response rates to the survey were around 92% and 87% for CPs and CRs, respectively. The discussions about these results are describe below.

On one hand, around 80% of CPs and around 85% of CRs show the interest in the developed system. While, an important problems is addressed in the survey results of CPs. That is, it is difficult for CPs to assist the emergent healthcare by using current system. On the other hand, only 50% of CRs are sure about that they can get benefits from AIS. The reason for this result is that most CRs are elderly people, and they are not familiar with web technologies. This motivates us to do further development on AIS by making the simple client running on smartphones.

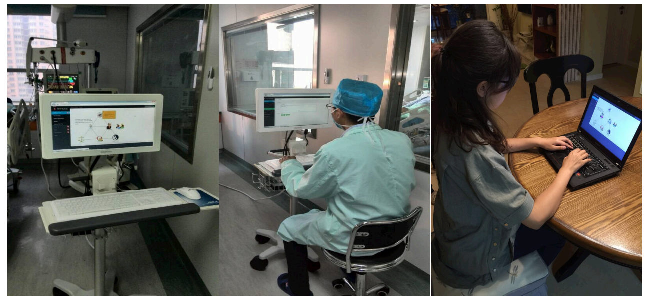

Fig. 3. Practical deployment and test of developed prototype.

V. Conclusion

The complexity of doing appointment scheduling in eHealth is considered. A new system called eHealth Appointment Scheduling System (eHASS) is suggested for appointment scheduling. eHASS is designed to jointly take into account various parameters and decision making algorithms to determine the suitable appointments between the care providers and the care receivers. To do this, the elements of eHealth system are classified in four sets: active unit, information base, interactivity chain, and algorithm factory. Based on this classification, the functionalities and structure of eHASS are presented. Further, the setting up of an important eHASS module, i.e., overlay decision making, is discussed in details. Our latest work results related to the development of eHASS are also presented. Future work is to investigate and improve the system performance of eHASS.

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