CONTEXT-AWARE BASED COGNITIVE HEALTHCARE SYSTEM

AHMED H. ALAHMADI

Department of Computer Science and Computer Engineering,
Faculty of Computer Science & IT, Al Baha University, Saudi Arabia
E-mail: alahmadi.au@gmail.com

Abstract— The majority of healthcare systems are limited in terms of services, location, sources and functionality. This standpoint and others indicate the need of a healthcare system that provides patients with the required healthcare services in a ubiquitous and automated manner. The aimed cognitive context-aware based healthcare system is considered as one of the important ways that can be used to improve the fancy of healthcare systems. In this paper we present a theoretical framework for analyzing and understanding the concept of context-aware computing in the context of building a cognitive healthcare system. We also proposed and discussed an ontology-based model and systematic design process for the proposed approach.

I. INTRODUCTION

With the evolution of healthcare systems the notion of patient's information should not be limited to his/her vital signs, but may include and not limited to: patient's situation, exact-location, time, activity, kin, and surrounding people and environment, etc. Such information allows healthcare systemsto be cognitive and smart in order to recognize the patient condition and react upon this condition. In our belief, this perspective introduces a new topic named; **C**ognitive **C**ontext-**A**ware based **H**ealthcare **S**ystems (CCAHS).
In order to support healthcare evolution, CCAHS's approach aims to create a cognitive system that adapts its functions based on the contextual information to achieve its high level specifications. That is, healthcare is shifted from treatment by professionals based on certain information to self-care, mobile care, home care and preventive care based on any extent of cognizable information. Such a global healthcare system, which links healthcare service providers to an individual's personal and physical spaces, is expected to provide personalized healthcare services at the right time, right place and right manner.
One of the main issues in this field is that: How do we as applications developers make such approach aware and responsive to the relevant context? Since 1994, when the term context-aware was introduced [1], many works have defined it in deferent ways. However, in the early 2000s, H. Lieberman and T. Selker addressed another issue, "*Why is it hard for computer systems to take account of context?*" [2]. Nevertheless, with the development of context-aware computing the concern has moved towards the level of interaction between computer systems, environment and users. The main concerns of the majority recent works are that; How could it be possible to have a computer system with high interaction level and make interacting with computers automated and easier? Note "this concern can be allied to our study as; How is it possible to have a cognitive context-aware based healthcare system? The general aim of this work is to march step by step towards answering this concern.
However, the distractions of context-aware computing have underlined the need to develop and propose novel context-aware module that reduce the impact of ubiquity and enhance the reliability and performance of this module. In this paper we propose a systematic study towards a cognitive context-aware based healthcare system. The study is done based on detailed understanding of the terms context and context-aware in related to our earlier smart mobile e-health monitoring system [3]. Towards this aim, section 2 reviews previous attempts to define and provide a characterization of context and context-aware computing. In section 3, a detailed analysis framework is presented. The proposed cognitive context-aware based healthcare system and the service provision mechanismare presented in section 4. In Section 5, we present the proposed context-aware framework and its systematic process of design of cognitive healthcare system.And, finally, some concluding remarks and discussions are given for future research in the last section.

II. THE CONTEXT OF OUR PROPOSED METHODOLOGY

In this section we discussed the context of our proposed methodology which includes: context and context-aware concept clarification, and the smart mobile healthcare systems perspectives.

A. What is context?

The expression context-aware was first introduced by Schilit and Theimer in 1994 [1]. They defined context as location, identities of nearby people, objects, and changes to those objects. Likewise, context has been defined by enumeration of examples such as location, environment, identities of the people around the user, the time of day, season, and temperature and so on [4]. Furthermore, other works include some other sort of examples like user's emotional state, focus of attention [5]. However, defining context as a list of examples contains some ambiguity when determining whether a

piece of information not listed in the definition is context or not, for example: vital signs!
On the other hand, other works define context merely by providing some synonyms such as the environment or situation. In [6] context is considered as the user's environment element that is cognizable for his/her machine. Also context is described as the user situation or the state of the application's surroundings [7].
In 2000, Dey and Abowd [1] proposed one of the most often cited definitions of context: *'any information that can be used to characterize the situation of entities that are considered relevant to the interaction between a user and an application, including the user and the application themselves'*.
This noteworthy definition of context is an outstanding basis for further research. Here we should cite a tendency that, the definitions of context tend to get broader and more general as time passes.

B. Context-aware systems and applications

As mentioned above, context-aware computing was first explained in 1994 as systems that *"adapts according to its location of use, the collection of nearby people and objects, as well as changes to those objects over time"* [1]. In [8], context-aware is defined as the capability of providing the most flexible computational services based on real-time sensing of context. In addition, context-aware computing has been presented as the ability to detect, sense, interpret and respond to the context of the user's local environment [9]. Some other works considered context-aware applications as those which dynamically adapt their behaviour according to the context of the application itself and the user [10]. Analogous definition was proposed in [11], with hint at the importance of having no much user interaction. Moreover, context-aware computing aims to implement context of users, devices, environment, etc to offer essential services for a particular person, space, and time as indicated in [12]. To conclude, the majority of context-aware computing definitions are likely to fall into one of two main categories: using context or adapting contextdesignations.

C. The smart mobile healthcare system perspectives

The majority of healthcare systems are limited in terms of services, location, sources and functionality. The aimed cognitive context-aware based healthcare system is considered as one of the important ways that can be used to improve the fancy of healthcare systems. The most important factor is that, treating patients in the environment where he/she feel free, comfy and safe has a significant impact on their rehabilitation. "*The importance of an atmosphere in the healthcare environment that promotes the health and well-being of patients is evident*" indicated in [14]. At this point we can say that, all these standpoints and others indicate the need of a healthcare system that provides patients with the required healthcare services in a ubiquitous and automated manner. Here is Cognitive Context-Aware based Healthcare System. Towards this aim and based on the review done above a detailed cognitive context-aware based healthcare system is proposed and discussed henceforth.

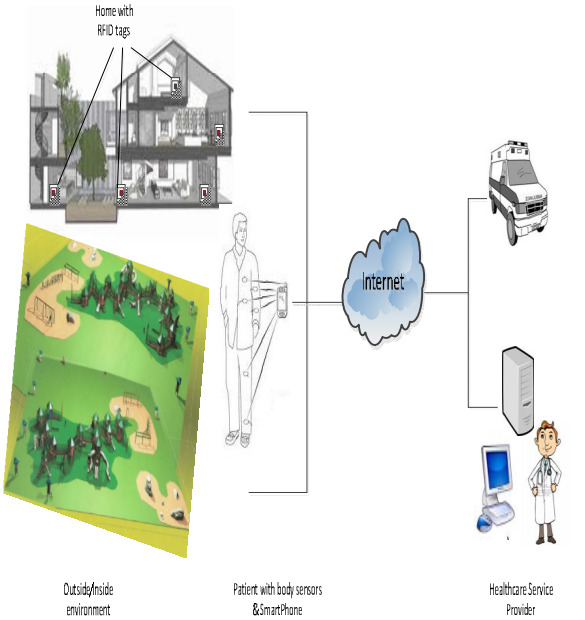


Figure 1. Overall configuration of the CCAHS's network.

The network architecture of the system is proposed based on a high level of scalability. The design of three levels of interconnected networks is flexible enough to guarantee the availability of the system in all expected situations. Figure 1 shows the architecture of our system's network consisting of body sensors connected via Bluetooth to a smart phone. The exact location of the patient in the home environment is recognized using RFID tags distributed in each part of the house. These tags also help in determining the current activity of the patient. Through internet, the smart phone can contact directly to healthcare providers or paramedics if needed.

III. PROPOSED METHODOLOGY

Although, context definition in [1] appears to be one of the most excellent 'General' definitions, implementing this definition in a particular system may contain some overlapping or lead to some overhead processing. In more details, the expression *"any information that can be used to characterize the situation of entitiesthat are considered relevant to the interaction between a user and an application"* contains a huge amount of information and entities. A quantity of this information or entities may be less important than other and/or can be recognized by other information. However, the aim of such definitions is to provide the system designer with a general understanding of what context is, and then modify it to meet the system requirements and QoS objectives.

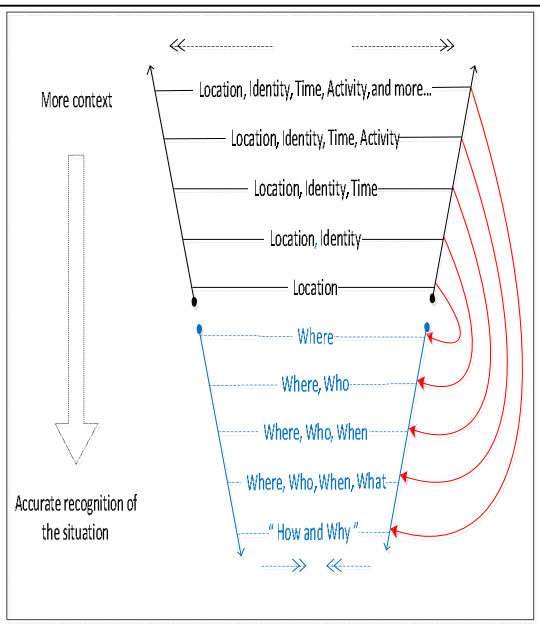


Figure 2. The relation between context and accurate recognation of the setuation using the *six Ws* as an example.

Based on the above study two main observations deserve to be emphasized. The definition of context tends to be extensive and more general as time passes to cover as much as possible of contextual information. On the other hand, the aim of context-aware application gets more specific in the direction of recognizing the accurate situation of the user in order to provide the essential services required. As shown in Figure 2, for context-aware application the more contextual information that can be adapted lead to more accurate recognition of the user's situation and high QoS consequently. As it is widely known, the Five *Ws* and one *H*, or the Six *Ws* are questions whose answers are considered basic in information-gathering. These *Ws* have been mentioned differently in many related studies as the categories of context. As discussed in [13] autonomic decision-making is another cross-cutting issue and refers to the ability of a context-aware system to perform adjustment operations by means of its internal knowledge to decide why, when, where and how adaptations are performed, without any human participation in the decision making process.

In our perspective, towards a clear understanding of what context-aware healthcare systems is, the vision and the concept behind expressions need to be recognized. In computer science, application is a black box where inputs goes in from one side and output, which is completely determined by the input, comes out from the other side [2]. In order to expand this view, application should to take account of the surrounding information as an implicit input and output. Specifically, the application can decide its function and output, based not only on the provided input, but also on that information. This information is what we call context and that application is what we call context-aware. Consequently, context can be any information that affects the functionality of a context-aware application which is neither its input nor output. Figure 3 illuminates this perspective in healthcare systems. Simply, the application is unknowledgeable black-box that has no illustrations but its input, while on the contrary context-aware application has the ability to take account of everything decipherable including the output as a feedback.

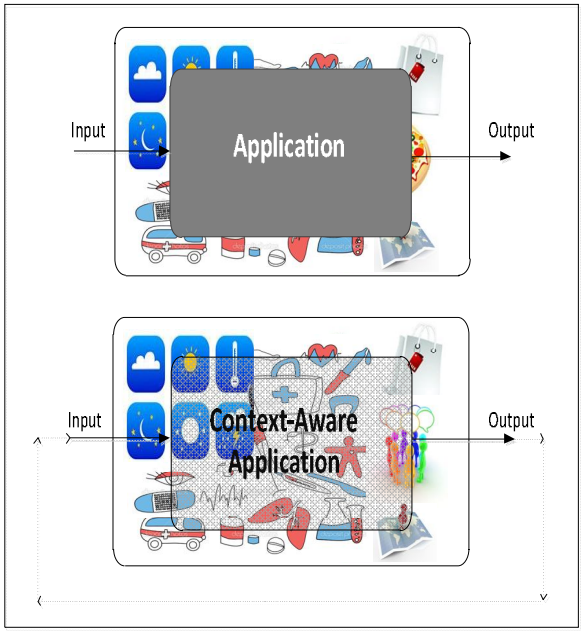


Figure 3. The general prospictive of a black-box application and a context-aware healthcare application.

To specify this philosophy, context in healthcare systems refer to any information that has allusions to enhance the health services provided by the system. The core of context in healthcare system is *"any information that can be used to characterize the situation of the patient and enhance the view of his/her health condition"*. Within this definition three foremost types of context are expected: environmental context (EC), vital signs (VS), and the physical activity (PA). Environmental context can be any of the general contextual information that is considered relevant to the purpose of the system similar to any context-aware system. Where the other two types are healthcare system related context. Vital signs normally refer to body temperature, pulse rate, blood pressure, and respiratory rate, but may also include other measurements. In healthcare systems VSs are considered as an essential part of a case evaluation. The third type is the information that is gained in relation to the other two types. This type is highly required to adjust the normality or abnormality of the vital signs based on environmental context. For example, various measures are often used to assess the progress of patients being treated for Congestive Heart Failure (CHF),respiratory rate in relation to physical activity are among these measurements. In more details the pulse rate (VS) may be considered normal if

the patient is sleeping (PA) where it is abnormal if he/she doing an exercise (PA) in the park (EC).

Using those perspectives, we proposed a simple framework to analyse the use of context in context-aware based healthcare systems. Using seven main axes we characterize context-aware functionalities in healthcare systems (see figure 4). The first three axes, which arecovered in this study, refer, respectively, to the following questions: What context is used for? What are the context items of information? What are the methods and means of collecting this context?

Purpose of use of context: in our system context is used in three main cases: (i) presentation of health information and services to the patient, (ii) execution of a medical service and (iii) tagging of context to medical information for later retrieval.

Items for context representation: through the analyses of the context-aware healthcare systems, it is potential to illustrate the items of context used. Synthesising our view of the literature we examined, we identified three main classes to split items of context into: (i) patient, (ii) environment and (iii) activities.

The methods and means of collecting context: to collect context, body sensors, RFID tags and other type of sensors are distributed and data is delivered to a smart phone and then to the server.

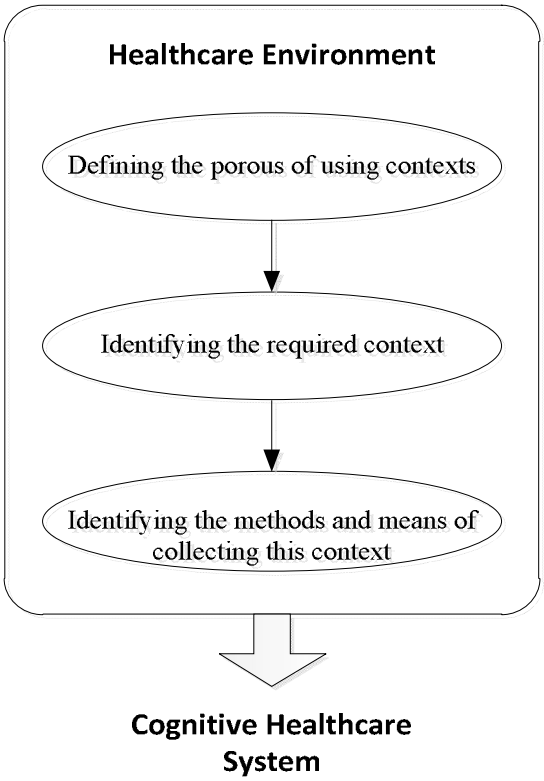


Figure 4. Context-aware functionalities as puzzle-pices

IV. CONTEXT-AWARE BASED COGNITIVE HEALTHCARE FRAMEWORK

CCAHS is a system that actively and autonomously adapts and provides the appropriate health services to patients and healthcare providers, based on the advantage of contextual information without too much user interaction. We propose a cognitive context-aware framework as a middleware to solve the problem of interoperability between our proposed system's parts.

A. Context Modeling

A context model is very dependent on a provided service, that is, domain-dependent. Therefore, it is obligatory to deal with various context models in our context-aware framework. We design an ontology based context model for cognitive context-aware based healthcare system. Using the OWL (Web Ontology Language), we design the following ontology based context model. Our ontology is composed of Patient ontology, Environment ontology, Vital Sign ontology,Physical Activity ontology, Device ontology, and Healthcare Provider ontology. The Patient ontology is used to identify the patient and his/her basic information. Where, Environment, Vital Sign and Physical Activity ontology are used to describe the health status of the patient.Patient health status is recognized via the location, activity, time, pulse,respiratory rate, blood pressure and physical activity. The Device ontology is used to define the body sensor system, smart phone and RFID tags. And finally the Healthcare Provider ontology identifies doctor and paramedic who provide remote services to patient. The relations among classes are depicted in Figure. 5.

B. Systematic Design Process

In this study we followed the top-down approach; as we believe this methodology emphasize planning and a complete understanding of the system. In this approach, the research proceeds from the abstract entity to get to the concrete design. It starts from the general aims of the system then move on to provide a clear apprehension of how this aims can be done which is our research question in this work. Figure 6 illustrate the proposed systematic design process.

Firstly, it is necessary to identify and underline the system's objectives and specifications in the first instance. This level investigate what services are expected from the system and why. Once the requirements and objectives of the system are highlighted the high level communication architecture of the system can be schematic. In this phase all the expected communication scenarios should be accentuated. The third phase is the most significant part in this work. This stage aims to define the set of context that can be used to achieve the objectives. Subsequently, the same investigation is done for the subsystem objects. Then the means and methods of obtaining these objectives are emphasized, and finally the verification level. After each step of the approach it is obligatory to ensure that, the approach thus far meets the system specifications.

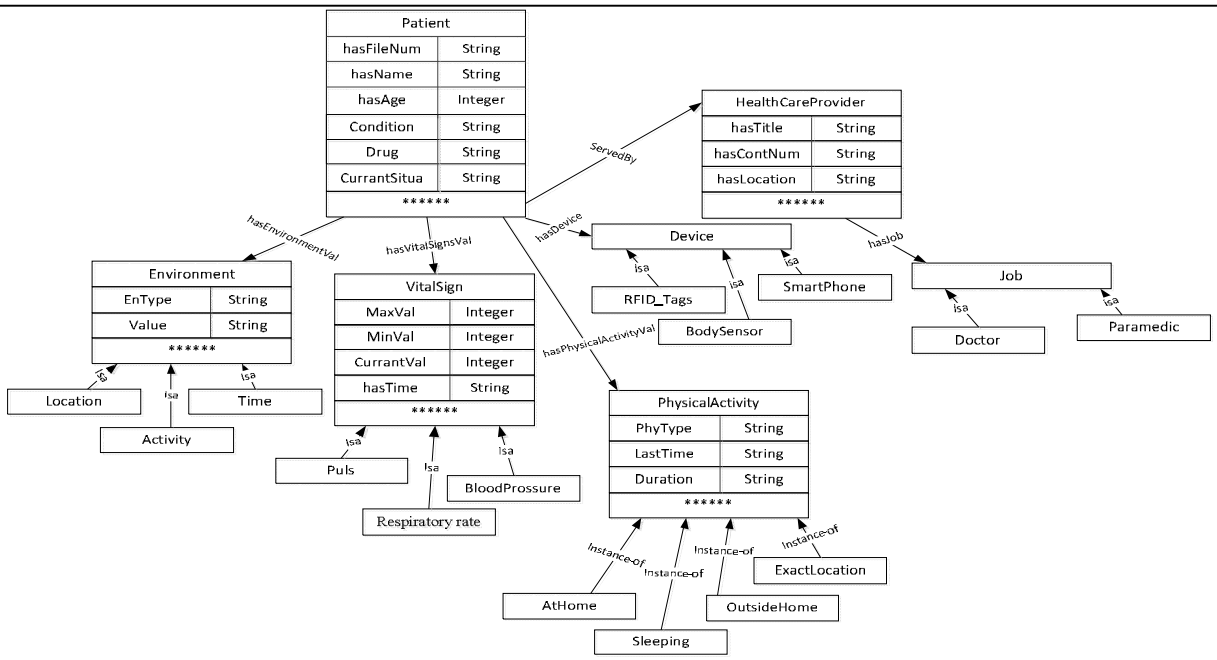


Figure 5. Ontology based context model.

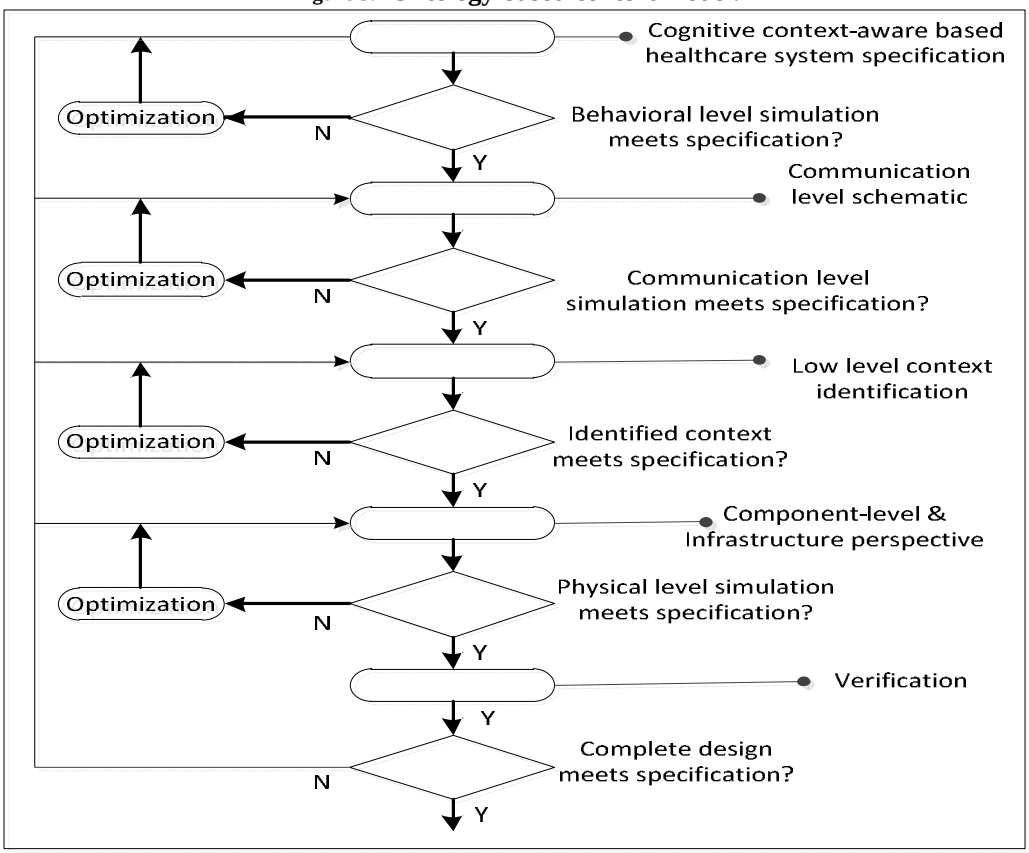


Figure 6. The systematic design process

CONCLUSION

In this paper we proposed a cognitive context-aware based healthcare approach which is considered as one of the important ways that can be used to improve the fancy of healthcare systems. We presented a theoretical framework for analyzing and understanding the concept of context-aware computing in the context of building a cognitive healthcare system. We also proposed and discussed an ontology-based model and systematic design process for the proposed approach. Future work includes using our proposed voting mechanism and concepts [15], to design ontology based fault-tolerant context-

aware middleware for cognitive healthcare system.

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