보안 헬스 정보 교환을 이용한 온톨로지 지식기반 상황인식 U-헬스케어 어플리케이션 서비스 프레임워크 설계★

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요 약

예방 의료에서 유비쿼터스 헬스케어는 노인 환자들의 수명연장에 대한 연구로 발전되고 있다. 이와 같은 연구들은 수명 연장 및 불의의 사고를 예방하기 위하여 모바일과 무선센서 기술을 사용하여 삶의 질을 향상 시켜 수명을 연장시키고 있다. 그러나 인터넷을 통해 유비쿼터스 헬스케어 응용프로그램이 모바일화 및 보급이 용이해짐에 따라 u-헬스정보 보호와 보안에 대한 위협이 증가하고 관심을 받고 있다. 따라서 본 논문에서는 보안 헬스 정보 교환 기술을 적용한 온톨로지를 이용하는 유헬스 케어 어플리케이션의 지식기반 상황인식 서비스 프레임워크를 제안한다. 본 연구에서는 유비쿼터스 컴퓨팅 환경에서 상황 영역의 보안 헬스 정보 교환 기술을 적용한 온톨로지를 위한 보편적인 어플리케이션 영역에서 상황 추론, 상황 모델링, 지식 기반 지원을 적용하는 것이다. 본 논문에서는 예방 서비스 질 변화를 위한 모바일 웹서비스, 상황 기술, 지식베이스에 대하여 논의한다.

Ontology Knowledge-Driven Context-awere U-Healthcare Service Application Service Framework using Secure Health Information Exchange

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ABSTRACT

The advancement in ubiquitous healthcare specifically in preventive healthcare can lead to longer life expectancy especially for the elderly patients. To aid in preventing premature loss of lives as well as lengthening life span, this research aims to implement the use of mobile and wireless sensor technology to improve the quality of life and lengthen life expectancy. The threats to privacy and security have received increasing attention as ubiquitous healthcare applications over the Internet become more prevalent, mobile and universal. Therefore, we propose Context-aware Service of U-Healthcare Application based Knowledge using Ontology in secure health information exchange. This research also applies ontology in secure information exchange to support knowledge base, context modeling, and context reasoning by applying the general application areas for ontologies to the domain of context in ubiquitous computing environments. This paper also demonstrates how knowledge base, context technologies, and mobile web services can help enhance the quality of services in preventive ubiquitous healthcare to elderly patients.

Key words : Ubiquitous Healthcare, Context-aware, Knowledge-driven, Decision-support, Context Modeling, Context Reasoning.

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1. Introduction

Context awareness is vital for ubiquitous computing environments to adapt computational entities to changing situations. It refers to knowledge and understanding of the surrounding environment within which the decision support system has to operate. Much attention has been devoted by numerous researchers since it was proposed in the past however context-aware services have never been widely available to everyday users. The notion of context is defined as the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user [1]. Within the context of real-time decision support, it is imperative to equip the decision maker with full information based on best possible context model [2]. For instance, the awareness of a person in making a decision or the approximate time to get a patient to a hospital where he/she will get best care, are context attributes.

Context data can be automatically detected and utilized by knowledge-based systems (KBS) with the aid of ubiquitous computing technologies for preventive healthcare applications. It helps patients for their medical diagnosis and treatment as well as prevention of the high risk diseases such as diabetes and heart disease. KBSs use a decision support framework for context-aware data, including activity, position and tracking data, in a ubiquitous sensor network environment at home, office, or in a hospital. To meet patient needs, KBS gather users' contextual data so that patients do not have to specify required information in advance.

The increasing interest of healthcare institutions in sharing access of their information resources paved the way for existing healthcare information systems (HIS) to utilize networked computing systems for recording and accessing medical records. The movement towards interoperable electronic health records and transmission of sensitive patient medical information over the networked computer systems create challenges with respect to protecting the security and privacy of health information [3].

This paper aims to propose a knowledge-driven and context aware service framework for decision-support applications for the highly dynamic and changing healthcare domain especially for preventive healthcare of elders. To meet the unique requirements of preventive healthcare application for elderly patients with high risk diseases, a software framework and architecture for the rapid development of knowledge-driven and context-aware-based application were designed. The KBS uses a decision support framework for context-aware data, including activity, position and tracking data, in a ubiquitous sensor network environment at home, office, or in a hospital. In offering adaptive healthcare services, we selected mobile-based agents as the key enabling technology because they offer a single, general framework in which large scale distributed real-time decision support applications can be implemented more efficiently.

2. Related Works

Several context-aware systems have been developed to demonstrate the usefulness of context-aware computing technology. Early works focused on building application-specific context-aware systems such as the Cyberguide [4] project which provided a context-aware tour guide to visitors. The ContextToolkit used an object-oriented approach to provide a framework and a number of reusable components to support rapid prototyping of sensor-based context-aware applications.

Additionally, knowledge based systems for health diagnosis and therapy is a major topic for medical informatics and healthcare. Widely-used applications to support clinical decisions have a significant impact on healthcare systems. Researches on clinical decision support are still intensively done and regarded as a major part of medical informatics research [5]. KBS are also expanded and implemented using mobile ad hoc networks (MANETs). Several researches [6][7] propose approaches for the integration of semantic-enhanced radio frequency identification (RFID) into mobile ad hoc networks. In these researches, semantic annotations could be put into RFIDs attached to objects so that tagged goods storing semantically rich description featuring the product the tag is attached to.

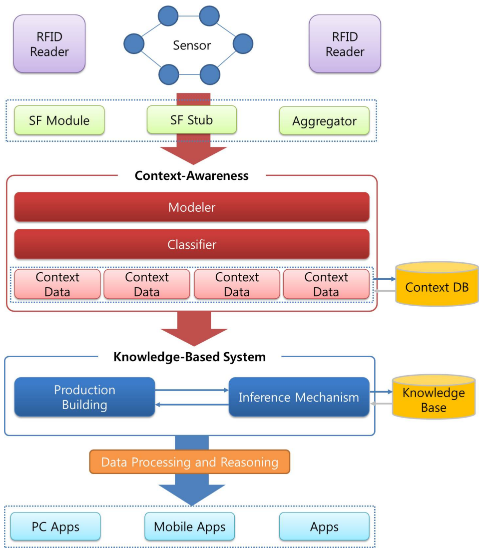
Currently, research works have focused on providing infrastructure support for knowledge-driven and context-aware systems. The advantage of the infrastructure-based systems has been emphasized in [8]. A middleware for context awareness and semantic interoperability was developed by [9] in which they represented context ontology written in DAMLC + OIL [10]. Context has been used in distributed event-based applications for wide-area networks. Constant monitoring will increase early detection of emergency conditions and diseases for at risk patients and also provide wide range of healthcare services for people with various degrees of cognitive and physical disabilities [14]. The integration of sensing and consumer electronics technologies is studied by [15] to allow people to be constantly monitored.

3. Ubiquitous Healthcare System

The ubiquitous healthcare system integrates heterogeneous and wearable devices to the patients and places wireless sensors inside a home, hospital, or office. This aids elderly patients in their medical diagnosis and treatment and provides better lifestyle and avoids sudden death of elderly patients due to high risk diseases such as chronic obstructive pulmonary disease (COPD), diabetes, and heart diseases. Prompt medical diagnosis and treatments can prevent sudden death of elderly patients when they experience shock or in acute situations [11]. Also, healthcare providers are continually informed about the health status of the elderly patient.

The system architecture of the knowledge-driven and context aware ubiquitous healthcare system is depicted in Fig. 1. The system consists of major components: ubiquitous sensor nodes and subsystems, a workstation serving as a local server, a central server, and application interface for terminal PC or mobile device. The system is designed containing several features and functionalities that are present in already existing u-healthcare systems. However, unlike other healthcare systems, this system was developed mainly for elderly persons or high risk patients and aimed as a preventive ubiquitous healthcare system. It measures patient activities and external features to determine patient health status. The context information helps provide further insight into the natural cause and progression of the patient's condition and enhances the accuracy of early symptom detection.

The system employs wearable physiological biosensors which are used in conjunction with other context awareness sensors, such as accelerometer sensors. Moreover, RF transceivers can also be fitted together with sensor nodes to track patient's activity and position.



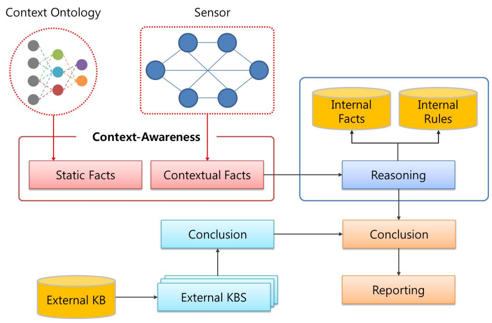
(Fig. 1) System architecture

3.1 Knowledge Based System

Knowledge Based Systems (KBS) are systems that employ central repositories where explicit domain knowledge can be inserted and upon which automated inference procedures can be executed in order to extract implicit knowledge. KBS play a role very much like database management systems (DBMS). In traditional KBSs, a knowledge base (KB) is seen as a single fixed entity which is immediately available either in local storage or via a high-throughput network link.

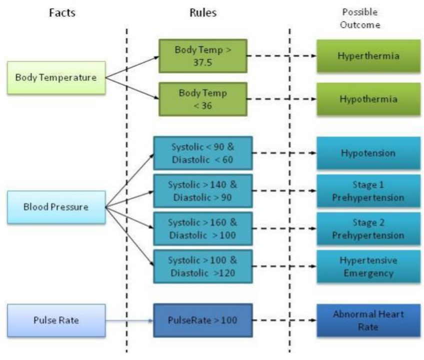
The knowledge-based framework supports all tasks that are required for context-based application control, where contexts can be any events that are relevant to user interaction with the application, including explicit inputs. The knowledge-based ubiquitous healthcare system with context awareness for this research is based on the use of knowledge representation approaches from description logics (DL) formalisms in pervasive and ubiquitous computing as well as in semantic-enhanced discovery frameworks based on RFID.

When implementing KBS for ubiquitous healthcare system, KBS acquires contextual fact or data through a sensory network, as well as static facts or data from a conventional fact base or database. In artificial intelligence, expert system emulates the decision-making ability of a human expert [12]. Expert systems are designed to solve complex problems by reasoning about knowledge. One of the key differences is an added contextual subsystem to complement conventional expert system components as depicted in Fig. 2.



(Fig. 2) Contextual subsystem

In the framework of the system, facts are classified as internal facts and external facts. Internal facts are stored in the internal expert system and are self-generated through direct user interface while external facts are gathered from external sources of facts in a static or contextual manner.



(Fig. 3) Facts, rules, and possible outcomes

As such, static facts can be originated from an ontology that is seldom affected by the changes in context. On the other hand, contextual facts are sensor-sensed and thus, are affected by the contextual changes. Shown in Fig. 3 are the facts and rules taken from the contextual facts from the patient.

3.2 Context Awareness

Context awareness is regarded as an enabling technology for ubiquitous computing systems. The availability of sensing technology is seen as a factor enabling a shift in human-computer interaction (HCI) from explicit interaction such as direct control by the user to a more implicit interaction based on situational context. For example, context-awareness for in-home pervasive networks may assist residents and their caregivers by providing continuous medical monitoring, memory enhancement, control of home appliances, medical data access, and emergency communication [13].

Context-aware computing allows applications to build a richer understanding of the user's actions within the computing environment [16]. Areas of context gathered might include personal such as the user's current activity, technical such as the kind of device that is being used, and environmental such as temperature, climate, location, and time. Context can be categorized as primitive such as the user's physical location or zip code, or composite such as building name or address that comes from one or more primitive contexts. User location is the context that is most widely accepted as key for context-aware services. GPS, RFID, and access points are generally used to acquire location data which are used in proactive personalized services such as tour guide systems.

In this research, the system architecture is designed to provide an efficient infrastructure support for building context aware services in ubiquitous computing environments. A platform deploys the context-aware and service oriented architecture on the heterogeneous hardware and integrates software components with the web service technologies. As a result, the flexible system is capable of attending elder persons by providing appropriate services such as interactions, healthcare activities, etc. in an independent and efficient way. The technology to set up the communication links must be chosen in real time depending on the particular context. The major requirements of such a ubiquitous system are dynamicity and context-awareness wherein they have to easily self-configure and adapt to the situation variability.

The system architecture consists of the following components that act as independent service components. The system architecture consists of the following components that act as independent service components.

① Context Interpreter. It performs inference procedures triggered by context events according to the predefined rules and knowledge base.

② Context Interface and Access Control. Context Interface provides the interface for the authorized service providers and users to access and manipulated the observed context information of elder people.

③ Context Database. It stores context information for later retrieval.

④ Context Event Broker. It is a message center with the publish/subscribe mode to broker context messages.

⑤ Web Services Adapter. Provide a gateway for agents to exchange messages with external context services.

⑥ Virtual and Physical Sensors. They communicate with smart appliances or devices through device dependent API or network sockets.

The context interpreter performs context processing which includes deriving high-level contexts from low-level contexts, querying context knowledge, maintaining consistency of context knowledge and resolving context conflicts. It consists of context inference engine, context modeler and context Knowledge Base (KB). The context inference engine provides deduced context based on direct contexts, detecting inconsistency and conflict in the context knowledge base. The context KB provides a set of API's for other service components to query, add, delete or modify context knowledge. It contains context ontology in sub-domain and their instances which can be defined by users in case of specified contexts or acquired from various context providers in case of sensed contexts.

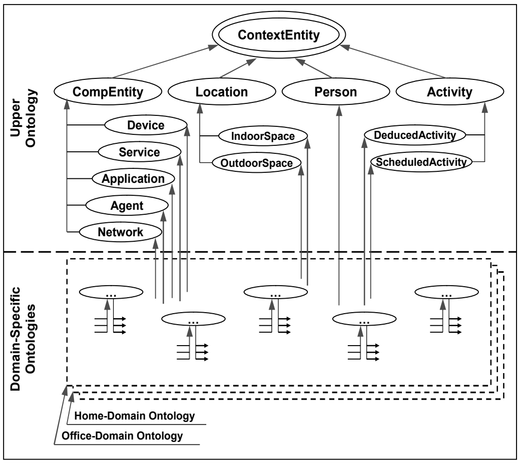
The Context Inference Engine uses the Context Modeler and related ontology to provide context input to the system for handling messages in XML. Accessing the services provided by the system is restricted by the access control. The component for access control maintains a list of all authorized users which contains their defined access control types. In the system, we implemented a rule-based approach for reasoning on contexts. A rule-based system allows developers to construct knowledge base consisting of rules and facts, and to deduce new facts using context inference engine. As a result, the decision-support system is able to provide appropriate services in a timely manner depending on the situation. The web service adapter provides a gateway for agents to communicate with external context service. Each service can lookup and then bind to other services dynamically with a context repository. The external context providers and consumers feed and monitor the context events to provide appropriate services to the smart home environment.

3.3 Context Modeling and Reasoning

Context modeling is the specification of all entities and relations between these entities which are needed to describe the context as a whole. The use of context ontologies can solve the problem of using proprietary representation schemes which hinder the interoperability of the different computation entities. Modeling context using an ontology-based approach allows us to describe contexts semantically in a way which is independent of programming language, underlying operating system or middleware.

The context ontologies consist of the upper ontology for the general concepts and domain-specific ontologies which apply to different subdomains. The upper ontology is fixed once it is defined and will be shared among different domains. The domain-specific ontologies are composed of a collection of low-level ontologies which define the details of the general concepts and their properties in each subdomain such as home domain, office domain or vehicle domain as shown in Fig. 4 [17].

Context reasoning refers to further deduction of previously implicit facts from explicitly given context information. Context reasoning is necessary in calculating high-level context information from a low-level sensor data. It is also necessary in checking and solving the inconsistencies in sensor data.



(Fig. 4) Context ontology

Ontology is a formal explicit description of concepts and provide for representing knowledge about a domain and for describing specific situations in a domain. There are three main areas of application for ontologies according to [18]. They are for communication and knowledge sharing, logical inferencing or reasoning, and knowledge reuse. One language that can be employed in modeling and reasoning about context information is the OWL Web Ontology Language [19] which has received strong support from the academic, medical and commercial sectors.

<Table 1> Context ontology using OWL

```
  <owl:Class    rdf:ID="ContextEntity"/>
        <owl:Class rdf:ID="Location">
            <rdfs:subClassOf rdf:resource="#ContextEntity"/>
</owl:Class>
<owl:ObjectProperty    rdf:ID="locatedIn">
      <rdf:type rdf:resource="FunctionalProperty">
      <rdfs:domain rdf:resource="Room">
      <rdfs:range rdf:resource="xsd:double">
</owl:ObjectProperty> ...
<owl:ObjectProperty    rdf:ID="food_intake">
      <rdf:type="owl:TransitiveProperty"/>
      <rdfs:domain rdf:resource="#Healthy"/>
      <rdfs:range rdf:resource="#Vegetable"/>
      <owl:inverseOf rdf:resource="#has_nutrient"/>
</owl:ObjectProperty> ...
```

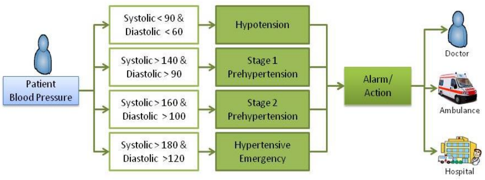
In this research, the context ontology is written in OWL as a collection of RDF triples, where each statement being in the form (subject, predicate, object), where subject and object are ontology's objects or individuals, and predicate is a property relation defined by the ontology. For instance, in the example application scenario entities can be modeled using OWL as shown in Table 1. The use of OWL not only facilitates semantic interactions with context information but also improves the scalability of decision-support applications.

4. Decision Support Scenario

In this research, we illustrate the decision support application scenario in the field of preventive care for the knowledge-driven and context-aware service framework in ubiquitous healthcare. Consider an elder patient who has a systemic, arterial hypertension and needs to check his blood pressure regularly. One solution is to keep his blood pressure under control. To do that, he follows a strict diet prescribed by his nutritionist. However, as most elders do, they have a hard time keeping up with their health regime. He also needs to do routine medication according to his health conditions but sometimes he tends to forget to take in medicines on time. In some cases, he wants to eat good but unhealthy foods. As a result, there is a need to monitor his dietary behavior as well as his physical activities.

Such cases can be improved with the aid of intelligent environment technology which includes sensors, context-aware reasoning and web services where it can provide personal reminders for health measurements, meals and medication. It can also issue health alerts to that timely medical assistance will be provided during emergency cases. Mobile devices can be used to monitor the elder's general activities, meals and medication anytime and anywhere.

As elderly patients are continuously monitored, their vital signs determine the status of their health. For instance, if the blood pressure is 149/90 mmHg, it is in Stage 1 Prehypertension, then the patient need to do some actions such as taking some medicines and follow prescriptions at home. As an example, the physicians define categories using vital signal data such as patient blood pressure (Fig. 5).



(Fig. 5) Decision support

However, a serious situation happens when the patient's vital signs reach the level of hypertensive emergency, patients need to be given first aid and readily be in contact with their physician. The system will be able to automatically identify the patient health measurement level and the system will determine the location for the nearest hospital to call an ambulance.

5. System Interface and Evaluation

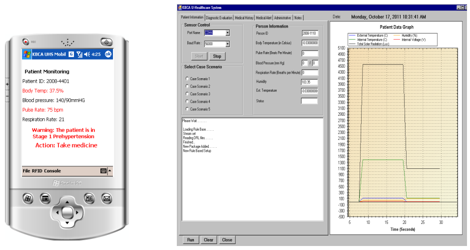
The knowledge-driven and context-aware ubiquitous healthcare system integrates heterogeneous and wearable devices. It was developed using Microsoft Visual C# 2008 with context interpreter for construction and maintenance of an application or service. For the semantic web framework, it implements the Jena2-HP's Semantic Web Toolkit. Authorized users can retrieve information remotely via Internet-ready mobile devices.

The ontology for context modeling and reasoning was developed using OWL. Besides communications to sensors for vital signs monitoring and identification such as wearable sensors and RFID readers, the gateway also manages a variety of smart devices that can be smart chair, smart table, etc. The raw data as categorized as sensed context are processed by context interpreter to provide useful context information. The system automatically updates the current context from sensors and performs context-aware reasoning using forward chaining rule inference.

<Table 2> Evaluation results

Criteria	Rating
User-friendliness	9.25
User acceptance	9.10
Applicability	9.52
Usefulness	9.35
Robustness	9.68
Reliability	9.43

We evaluated the applicability of the knowledge-driven and context-aware service framework for ubiquitous healthcare especially for preventive healthcare by conducting a survey of the system to elicit responses from 75 random users, 50 selected health-care personnel, and 25 elders. The evaluation results are shown in Table 2 in which the criteria for evaluation were rated by respondents in a scale of 1-10. The results clearly showed that the user acceptance are lower compared to other criteria due to elders being hesitant and afraid to use new technologies but they show eagerness to learn and use the system with proper assistance and time spent in getting acquainted with the system.



(Fig. 6) Ubiquitous Healthcare Service
a) PC-based interface b) Mobile-based interface

The knowledge base and context awareness enables the utilization of a mobile device for various modalities and allows the use of explicit control commands such as RFID tags. Doctors, healthcare personnel, family members, and caregivers can regularly monitor the elder's status (Fig. 6a). The system gathers the sensed context in order to provide prompt and appropriate services to the patient. On the patient's mobile device, the results are shown as Fig. 6(b).

6. Conclusion

This researched has implemented a

knowledge-driven and context-aware for decision-support ubiquitous healthcare system designed to facilitate preventive healthcare for elderly patients. The system provided a variety of services for the elders, as well as related services for healthcare personnel, family, and service providers. Connecting all healthcare services together in a knowledge-driven and context-aware service framework, the decision-support ubiquitous healthcare system integrates them to provide personalized services to elderly patients. Context data can be automatically detected and utilized by knowledge-based systems with the aid of ubiquitous computing technologies for preventive healthcare applications. It helps patients for their medical diagnosis and treatment as well as prevention of the high risk diseases such as diabetes, heart disease, etc. Knowledge-based systems further provide knowledge to doctors to make timely and prompt report and decision mechanisms on patient's behalf.

A software framework and architecture for the rapid development of knowledge-based and context-aware-based application was designed to meet the unique requirements of preventive healthcare application for elderly patients with high risk diseases. It has shown that the application of ontology can be used to support context modeling and reasoning by applying the general application areas of ontologies to the domain of context in ubiquitous computing environments. The application of ontology for context information in ubiquitous computing environments lies in the interoperability of different devices. The current implementation deals with preventive care scenarios to elders in order to demonstrate all the system functionalities. For future studies, we will explore more complex cases such as handling conflicting data from multiple sensors.

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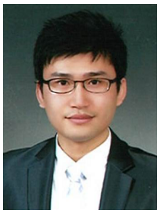

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