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A GENERAL ARCHITECTURE FOR DEVELOPING A SUSTAINABLE ELDERLY CARE E-HEALTH SYSTEM

Yang Guo[1], Guohua Bai[2]
[1,2]School of Computing, Blekinge Institute of Technology, Sweden
Email: [1]xyg@bth.se, [2]gba@bth.se

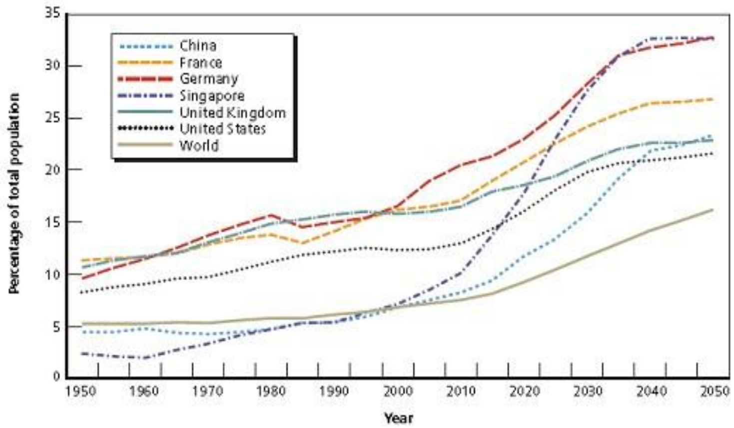
Abstract

Based on some identified problems and challenges to the current healthcare system, this paper proposes architecture for developing e-health system to meet the challenges and resolve some problems. The architecture is based on a solid theoretical model of human activity, and it has properties such as sustainability, generality, and expandability. We demonstrate the properties of the architecture through an ongoing research project. We concluded that this architecture can be widely used to integrate various small scale applications of e-health systems and to resolve some current design problems such as interoperability and knowledge sharing.

Keywords: E-health; Activity Theory; Elderly care; Sustainable Architecture

I. INTRODUCTION - CHALLENGES FOR THE CURRENT HEALTHCARE SYSTEM.

There is a well known fact that the proportion of people aged 65-and-older is increasing quickly. The prediction of World Health Organization (WHO) shows that the ratio of elderly is from 7.6 percent of total population in year 2010 to 16.2 percent in 2050 (Fig. 1). Meanwhile, more and more elderly are living with chronic conditions that need long term and ongoing healthcare, preferably in their home [1]. This trend will continue more dramatically among fast developing countries, especially in China. China is the country that is called getting aged before getting rich. Though the current chronic disease prevalence is notably lower in China than in western countries, the numbers are rapidly increasing, with an estimated 80 percent of total deaths and 70 percent of disability attributed to chronic diseases in 2005[2].



Source: United Nations Population Division 2008

Figure 1. Proportion of Population 65 and Older (projected to 2050)

Elderly are the largest consumer of health care. Generally speaking, elderly consumes three times healthcare resources as much as than other groups [3]. From economic dimension, the healthcare sectors are under great pressure of limited financial resources and man power resources, lack of qualified doctors, nurses, and home healthcare staffs. This is more serious for countries that aging populations are quickly increased before social welfare system well developed and established.

Against this background, there is a growing concern about sustainability of the current healthcare delivery system. The current healthcare delivery system is historically based on the traditional needs to deal with mainly short and episodic treatment, like infection treatment by hospitalization. When elderly care moves across home and different care organizations, a big problem to the current healthcare system is little continuity, lack of interoperability, and knowledge sharing among those care-providers. After seeing the doctor, patients are discharged from hospital, and the hospital normally doesn't communicate with home health providers. There is no one within the care providers to ensure care in the home is appropriate and meshes well with the broader plan of care for that individual. Patients are likely to "ping-pong back and forth between providers" and no provider takes responsibility for how care is coordinated [4].

Technological advances, especially Information & communication technologies (ICT) related biomedical technologies have pushed the frontier of healthcare into the home settings [5]. Tools as integrated of monitoring with therapeutic systems, educational content in the Internet, and data sharing between healthcare sectors are all driving the healthcare frontier towards home settings. The ICT thus provides the healthcare branch with a new possibility to meet the challenges, namely e-health.

II. WHY E-HEALTH

New challenges and possibilities mentioned above have caused the healthcare organizations try to transform current paradigm of healthcare system which is based upon a 'provider driven' model into a 'patient-centric' system. With the development of ICT, healthcare practice supported by electronic processes and communication, so called e-health, can be a potential solution to this transformation [6]. E-health can empower patients to self-manage their health to a great extent and help shift care from high cost of institutional and hospital settings to patients home [7].This shift would be consistent with fundamental culture changes with respect to that elderly wish to live in their home as long as possible, and as independent and active as possible. The benefits of e-health can be summarized as the following three points [8]:

A. *Information Sharing*

By using ICT, the diagnosis and treatment information can be shared instantly between patients and those who may be concerned, like the doctors, nurses, care givers, and the patients' families, etc. During the whole treatment process, the information concerning the patients' symptoms, the treatment solutions applied, and the effectiveness of such solutions, etc, can be shared instantly among different medical establishments, thus the efficiency in making up new workable treatment solution will be greatly improved. Meanwhile, the instant communication technology can also help doctors from different locations to discuss the treatment plans online, and then give instructions to the patients, doctors, or those who may happen to be around the patients for operation. Lastly, with the network set up, patients can share their experience and treatment solutions online with those who may be suffering from similar symptoms. With such practice applied, the efficiency in sickness treatment can be highly improved.

B. *Effective Healthcare*

During the whole treatment process, the patients may be transferred to different care givers for treatment of different purposes. The role for different healthcare professional may differ dramatically. Without a clear definition for the role players and a good management for the activities involved during the whole treatment process, the patients may miss the best time for medical treatment.

E-health system can provide with a clear role allocation and activity workflow concerning different treatments and coordinating different parties. Elderly can better understand their process during the whole treatment. With knowledge of the process, the patients will be more willingly to make an active participation, and hence to increase the effectiveness of healthcare.

C. *Patient Oriented*

In the past, due to the lack of knowledge about their symptoms and the effectives of the various medical treatment solutions, patients were rendered in an inactive role. Most decisions are made by the doctors or healthcare professionals. With the information shared in the e-health system, patients are now getting more ideas about how to manage their health. The opinions proposed by the patients will be coordinated with that from the healthcare professionals. Thus a solution will be worked out with a more focus on the patients' needs and their personal demands.

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Different from traditional healthcare systems, e-health provides continuous healthcare both in hospital and at home. In next chapter a spectrum of e-health solution for elderly will be introduced.

III. A SPECTRUM OF E-HEALTH SOLUTION FOR ELDERLY

E-health, telemedicine, health informatics in many cases are interchangeable synonyms [9], and in this paper we use e-health as a general term to cove this broad area. E-health is defined as the use of information and communication technology, such as computer, Internet, mobile devices, to improve or to enable health care services [10]. It spans a broad spectrum from mobility support, diagnostic and therapeutic tools, and self management related to knowledge consulting. From technology used and interactive properties, the author specifies e-health into three levels when it is applied to elderly healthcare.

First Level or stand-alone: Devices are single purpose (e.g. blood-pressure meter, blood-glucose monitor) without connection to Internet (possibly connected to a home computer). The devices are well accepted by users, but with limited impact to the healthcare sectors (passive therapeutic and self-management functions).

Second level or one-way connected system: Devices are connected to computer and internet, but only sending data from patients to some third party database servers or to professional healthcare providers (e.g. alarm system, telemonitoring system). Patients can get advices and education materials from some internet server, but without interactivity and personal oriented services.

Third level or interactive connected system: devices are connected via internet or wireless to personalized services with therapeutic decision support. The system should have intelligent, proactive, and preventive functions with trusted feedback and juridical responsibility of the healthcare providers. It is this systemic solution that can change the healthcare paradigm from today's provider oriented delivery system to patient centric healthcare system.

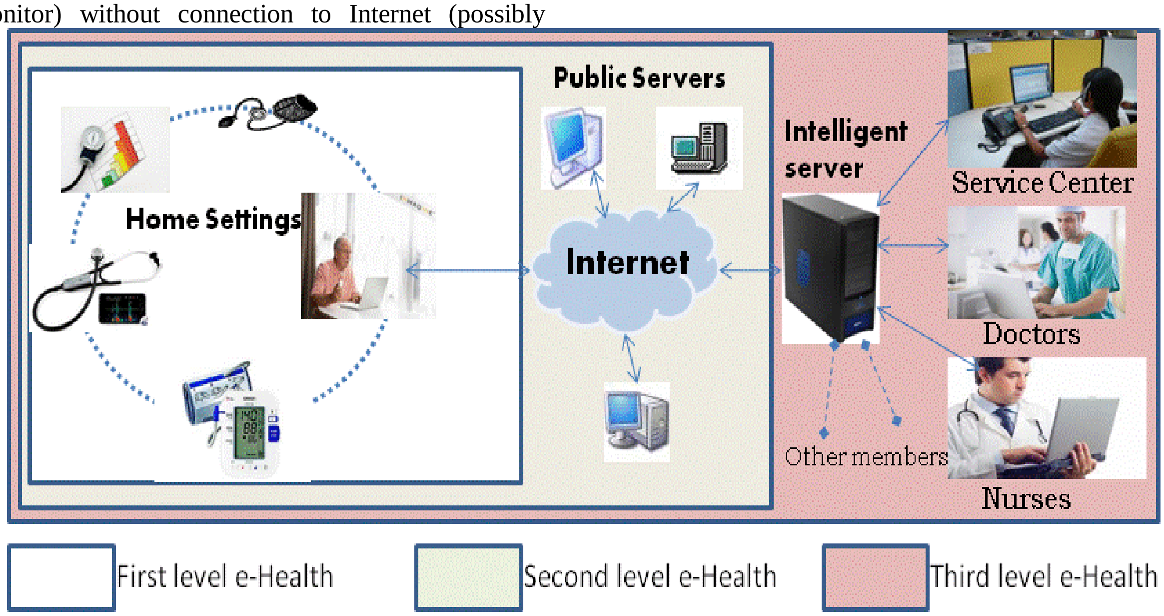

Figure 2. The three-level of e-health system

The three-level of e-health system is demonstrated by Fig 2. The first level system is quite matured in the market and mostly is covered by social insurance or willing to be paid by privates. The second level of e-health system is mostly mentioned in the literatures or industries. It is not yet well accepted, not matured in the markets, and not covered by social insurance. The third level of e-health system is the future system, and needs a systemic implementation and paradigm change. Only through this kind of systemic solution can we achieve a fundamental improvement to the current healthcare system.

One good example of the third level of e-health system is demonstrated by a project so called 'Telecare services' in Taipei city [11]. The system

International Journal of Information Technology and Business Management
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provides 328.000 people over 65 with remote care, mobile applications, and location-based services. The system enables patients to keep track of their own vital signs (blood pressure, blood glucose, pulse rate, etc.); it also allows the Telecare Call Center to monitor the health of subscribers, taking necessary steps when detecting abnormal readings (Fig 3).

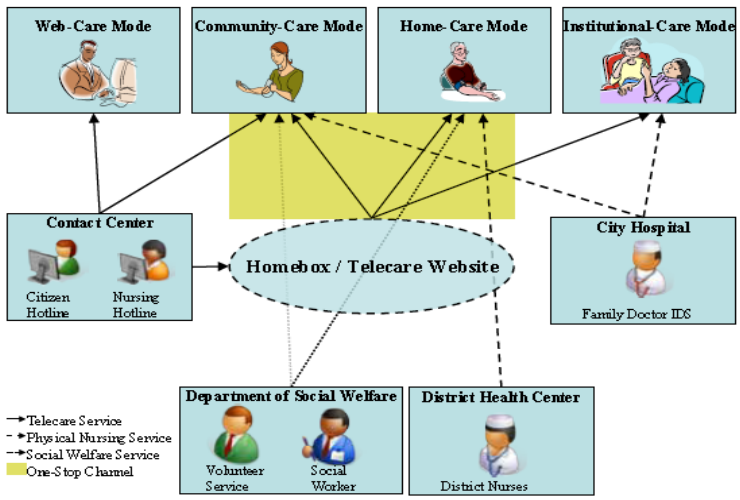

Figure 3. Telecare service systemic architecture

The implementation of 'telecare service' system has adopted a systemic approach by involvement of actors from all social-economic-technological departments, such as Department of Health, Department of Social Welfare, Department of Information Technology, Legal Affairs Commission, Taipei City Hospital, and 12 district health centers. Without this multi-involvement by actors from all relevant departments, it will be not possible to implement the e-health system. The author deeply believes that one key factor of success for the complete e-healthcare solution is to apply systemic methodologies, process, architecture, and involvement of stakeholders in developing the system. In this paper, the authors propose architecture for the third level e-health system design based on an Activity System model, which is stem from cultural-historical development psychology. A systemic architecture based on an Activity Theory model will be introduced in the next chapter.

IV. WHY ACTIVITY THEORY MODEL AND HOW IT WORKS

Many studies pointed out a lack of consolidated theoretical approaches for identifying sustainable platform and vital components for developing e-health system [12]. Without a general and shared architecture for developing e-health system, many efforts can lead to a short and fragmented project, and difficult to evolve to a systemic and sustainable e-Health solution. However, due to the multiplicity of actors, different purposes, and varieties of the specific services, it is impossible to unify and standardise all elements within the same architecture. E-health system architecture must allow the local level flexibility and able to encompass the varieties. Meanwhile the e-health system architecture must provide a sharable platform to allow the multiplicity of actors to communicate each other and able to share knowledge. This requires a high level and recursive architecture to guide designers constructing the e-health system. Let's say that we want to build up a building for sustainable/lasting multi-functional use. It is important for the architects to first identify the necessary and shared functional building blocks and their relationship for different types of purposes (such as windows, doors, roofs, floors, etc.). We have found that activity theory can provide with such architecture for the design of e-health systems

The concept 'Activity' has a very general meaning that covers human being's most important 'thing' we are all socially involved in. We are doing various activities in work, education, family, and healthcare. We may not feel mentally healthy and normal if we are deprived from the rights of conducting various activities (human right). Activity Theory (AT), also called cultural-historical development theory of activity is a framework of knowledge that seeks to

International Journal of Information Technology and Business Management
29th July 2014. Vol.27 No.1

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explain the unity and inseparability of subjective mind and the objective human practice [13]. The origins of the theory can be found in the work of the Russian developmental psychologist Lev Vygotsky[14], Aleksei Nikolaevich Leontev[15], and especially further expanded by Engeström[16]. In Activity Theory, activity is the basic unit that preserves the essential quality behind any human practices. Engeström developed a triangle model based on previous work of Vygotsky and Leontev to recapitulate and visualize the components and relationships that compose an activity (Fig. 4).

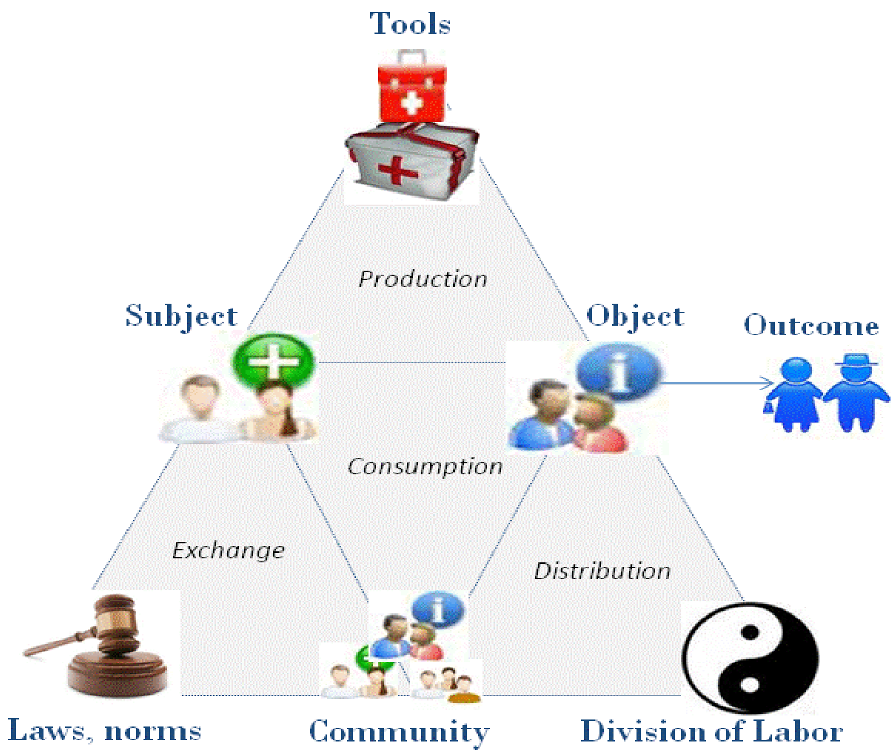

Figure 4. Engström's model of activity system

According to the model, an activity is always conducted by one or several goal-oriented actors, a subject, who is directed towards or acting on an object in order to produce an outcome. According to the theory a basic feature of human activity is the use of artefacts/instruments as mediation. All human activities are mediated by various artefacts/instrument. This triple relationship is represented in the top part of the triangle (Subject – Tools – Object – Outcome). For example, we study the healthcare providers' activity. The subject/actor of conducting the healthcare activities (e.g. diagnosis, advices, monitoring) are people who provide with healthcare to the targeted patients that are accordingly defined as an object of the healthcare activity. Outcome will be the actor's goal for performing the activities, for example, patient becomes healthy or the targeted disease cured (the two goals are not the same. Even the latter is commonly accepted, it is however not patient oriented, instead it is disease oriented). It is vitally important to understand the crucial role of artefacts/tools in an activity. The artefacts/tools include both physical and non-physical types, such as computer, internet, software, data, information, models, theories etc. A successful activity must use right tools in the context of the users (subject) and targeted object or task. Another important characteristic of the activity model is its subject-object mutuality, i.e., depending on the focus of activity the subject and object can be exchangeable. In the above example of healthcare activity, if we focus on the patient activity how they manage their own health to contact the doctor, then the subject will be the patient, and object the doctor. This interchangeable and mutually interdependent subject-object within neighbouring activities is the key to design a shared architecture for different roles of actors. In our case, the care providers activities and care receivers

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activities are neighbouring activities, and therefore they can share the same architecture of the system instead to build separately a healthcare providers system and then a receivers system which in turn creates problem for interoperability and knowledge sharing.

The subject and object are always part of and members of a community which includes also other actors who share the same object and contribute to the outcome of the targeted activity. This important recognition of social settings is shown in the bottom part of the triangle. In the elderly healthcare activity, the members of community for a doctor (as subject of the activity system) to take care of an elderly (object) could include other doctors, other elderly, district nurses, home nurses, relatives to the elderly and neighbours etc. They all contribute to different parts of the outcome – healthy elderly. However, comparing to the top part of the triangle which is visually observable (you can see an actor is using a tool producing an outcome), the bottom part of community is not visually observable, or it is to be recognised and to be constructed. It is like an ice berg, and what we see is the top, but much bigger and also important part is under the surface.

To work cooperatively among members of community, there need two more important mediating components, one is the division of labour, and another is the rules related regulations including laws, culture, tradition, norms, work routines, and contracts. The Division of Labour is to specify responsibility how to take care of different needs of the objects. For example an elderly will need both medical care (responsibility of hospitals) and home care (responsibility of municipality services). When some needs of elderly are not met, the labour division should clearly identify the responsible actors and allocate the needs to the actors. If the needs should be met cooperatively among different labour divisions, then the joint responsibility must be seamlessly connected with each other. For example, an elderly after dispatched from hospitalisation will need continuous home healthcare. The handover process must be a joint responsibility for the hospital and the municipality that is responsible for the home healthcare. Information Technology (IT) can play an important role to link the actors towards a holistic process oriented to the elderly. For example, a project called 'IT supported seamless healthcare' conducted in Sweden has focused on the handover process. A digital protocol is shared by different actors and followed after each step during the whole process of the elderly care [17].

The Rules are to legitimize the actions of the actors involved in the activity, including security policy; standard for payment and services; time distribution; and need assessment and specifications, etc. It plays an important mediating role for all members in the community to share and understand the 'play rules'. This part can be also ontology for the design of e-health system when we need to represent shared knowledge cross the border of actors.

V. A VERIFICATION OF THE MODEL – IMIS PROJECT

The triangle structure of an activity described by Engeström (1987) has been used in many cases as an analytical model to clarify a context or to analyze a problem. In a project 'Integrated Mobile Information System for Healthcare (IMIS)' we apply the model as an externalising tool to design the architecture of the e-health system. It serves as an ontological 'microcosm', a model of database, to abstract some fundamental components and relationships in real activity of the healthcare work. This architecture is shown in Fig 5.

International Journal of Information Technology and Business Management
29th July 2014. Vol.27 No.1

ISSN 2304-0777 www.jitbm.com

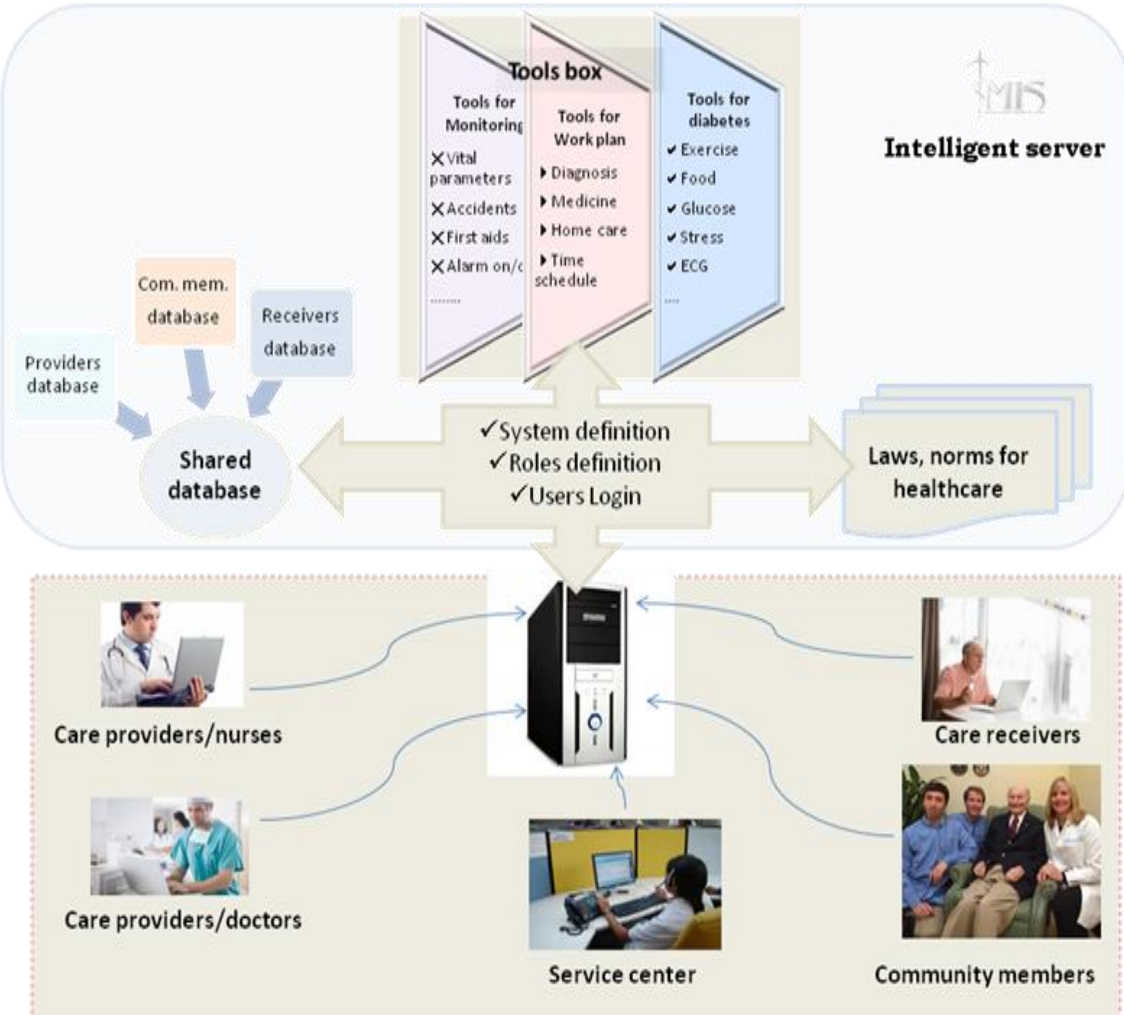

Figure 5. IMIS Architecture

Very common an e-health system is either developed for care providers (hospitals system, homecare system) or for care receivers (patient self-management) separately. This separation leads often problem of interoperability and knowledge sharing. According to the activity model, we know that the two (care providers and care receivers) are inseparable to each other in conducting healthcare activity. In our approach, the IMIS integrates the two independent parts (subject vs. object) into one system, and makes the subject-object relationship as a mutual and reciprocal one another.

To start using the IMIS, the users (either care providers or care receivers) will need first to register their role in using the system, such as elderly, doctor, nurse, home assistant, relative, or other members of the community. After verification of their role, the system will specify related sub-systems, data, interface, namely his/her 'role system' to the specific users.

After the user specified his/her 'role system', next important step is to find the right tool to do the activity in focus. Tool is one of the most important components of activity in conducting an activity. The usefulness and fitness of the tools in relation to the tasks and the users are vital to success. The tools must be users (subject) oriented according to the different role in the healthcare activity. In our IMIS system, we have designed different tools boxes for different roles and individuals according to the 'role system'.

International Journal of Information Technology and Business Management
29th July 2014. Vol.27 No.1

ISSN 2304-0777 www.jitbm.com

Knowing the targeted object is a necessity for conducting an activity and to achieve some expected outcome/goals. All information about the object relevant to the activity can be organized into an 'object database'. As we said in the above, the subject and object are reciprocal in our system. Therefore the object database and subject database are also reciprocal.

Care providers, care receivers, and other people who in one way or another contribute to the outcome of healthcare activity, are organized together as a community. Through the shared database in Fig 5, the member, either care providers or care receivers, can get access to other members of the community and to share knowledge and to cooperate in the healthcare activity. This community is also very helpful for elderly to feel connected with society and friends as peer, to avoid the loneliness and repression.

Services today are very specified and located to various labor divisions. For example, elderly care in Sweden is normally provided by county council/hospital and the municipalities/home services. A clear labor division between the two organizations has to be defined especially when an elderly suddenly has heart failure in home and need to be transferred cross the border of home care of municipality to hospital care of county council. Sharing knowledge among those labor divisions is crucial when a need of the care receivers has to be provided jointly by several labor divisions. This important component is firstly identified through 'role system', and then shared database about cooperation among labor divisions.

E-health is a life critical system and it is strictly regulated by various laws, culture, norms, etc. New kinds of services enabled by new technologies, such as IT enabled digital receipt, remote consultancy, remote monitoring often require new regulations. Many regulations, including costs/services regulations, need assessments regulations, privacy and integrity regulations, etc. are very crucial and yet very difficult to remember all. Therefore it is very important for any e-health to provide with references to different kinds of laws and regulations. In Fig 5, the IMIS architecture includes this reference as a database named 'laws, norms for healthcare'.

VI. USE CASES – INTEGRATED E-HEALTH SYSTEM

To demonstrate how the different components specified in the architecture work together to provide a holistic and integrated solution to elderly home, we take four interconnected use cases to demonstrate some representative scenarios in the followings. The colored text indicates the use of identified components in the architecture.

Use case 1: Elderly home input measured body parameters (glucose, blood pressure, heart pulse rate) into IMIS system.

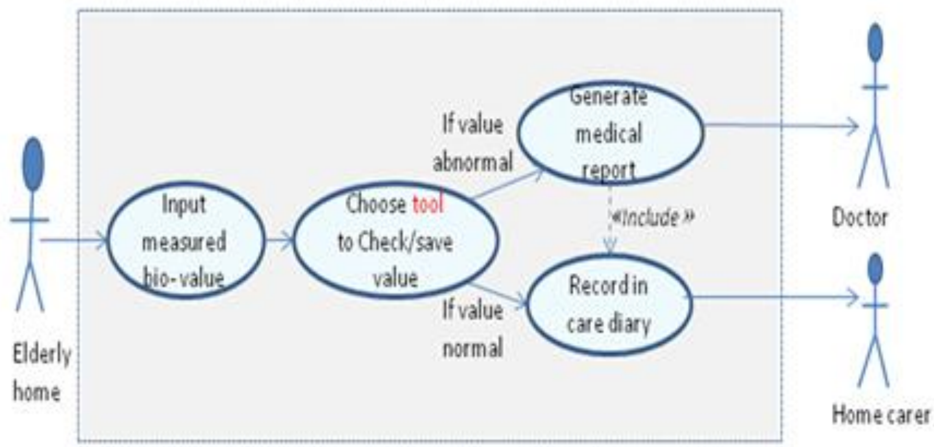

Figure 6. Use case 1

When an elderly home measured his/her body parameters, such as glucose, blood pressure, heart pulse rate etc. and inputs into the IMIS system, some tools will be used from the IMIS tool box to save and

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check up the value if it is normal or not based on pre-settings or tracks. If the value is abnormal, the IMIS will generate an analysis report about the situation (relationship and tendency analysis) to the responsible doctor(s). Also, a summary or reference will be sent to the home care for diary of daily care. There can be many tools designed in the tool box according to the needs of the pair (subject – object), and many cases the tools can be already made by some third partners. It is very important that the IMIS system can integrate those tools flexibly (plug in) according to the requests of users.

Use case 2: Doctor receives signals from elderly and requests diagnose and action.

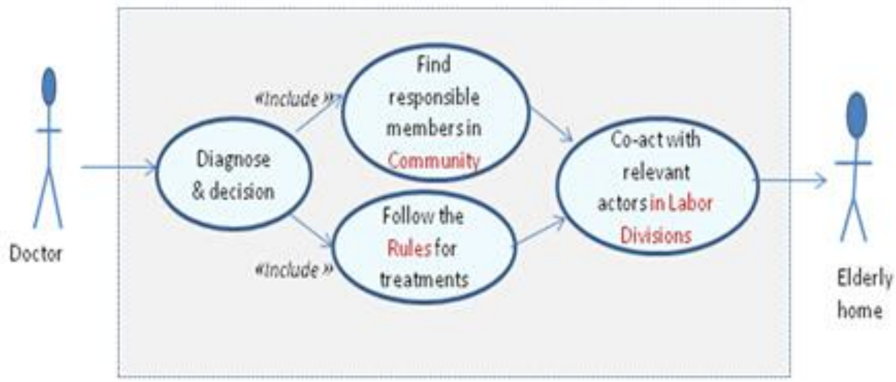

Figure 7. Use case 2

When a doctor received a signal from elderly home and an analysis report from IMIS which indicates a need for a new diagnose and decision, the doctor will have to first conduct some basic diagnosis and make decision for the actions. Then s/he will have to identify other relevant members (other doctors, nurses, elderly children, home care etc.) within her/his community and to follow the basic rules and routines (social, moral, ethical, operational, etc.) to carry out the needed actions. The actions will involve mostly other labor divisions and therefore s/he has to co-act with relevant actors according to the responsible areas (labor division). To co-act with relevant actors according to labor division is an important step to make a systematic treatment for elderly as person, instead as disease.

Use case 3: Elderly home has an accident and alarms sent out to IMIS system.

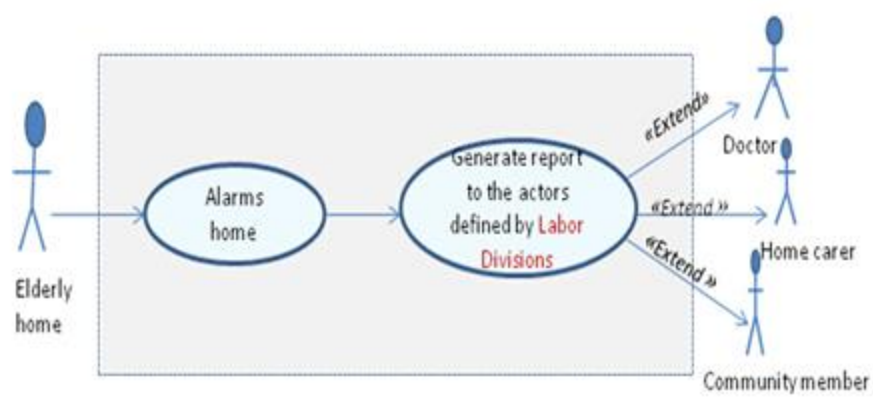

Figure 8. Use case 3

When an accident triggered out an alarm, the IMIS system will first identify the type of alarm, such as emergency of a fall, heart failure, home alarm. Based on the type of alarm, the IMIS system will find the responsible division of labor to report the situation. For example, if the alarm is from heart failure, then the report will be sent to SOS emergency, doctor, and ambulance; if the alarm is sent by the home alarm then the report will be sent to police department, or neighbors.

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Use case 4: Elderly home needs community care *(being connected)*

Figure 9. Use case 4

Elderly at home can feel themselves isolated and lonely if no community is connected to them. Also elderly people could have problem to move around performing daily tasks like shopping, cleaning, etc. When they need such community care, the IMIS system could provide the right person to contact with from his/her community.

VII. Conclusion And Disscusion

In this paper, we have demonstrated that different user groups, either as elderly at home, various care providers, or members of a community, can share the same architecture. While the contents can be accordingly configured after different users' needs, the elements and their relationships in the architecture will be kept the same. This recursive property of architecture can be used for constructing a system for multiple users in multiple levels of an organization, such as health care organizations. Since different users and organizations share the same architecture, the interoperability and knowledge sharing can be simply achieved. This recursive property is also important for system sustainability since it can be evolved to integrate and update new applications, new user groups, and new type of services.

We have developed a prototype to verify our approach. By using user cases we showed how the architecture can be designed and used by different user groups. However, we have not implemented the system into real use, and validation to the feasibility of proposed architecture will be proceeded in the future projects.

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