


Activity Theory Ontology for Knowledge Sharing in E-health

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***ABSTRACT: Knowledge sharing has become an imperative and challenging issue in the E-health field for improving total quality of services. However, since the E-health subject is a multi-disciplinary and cross-organizational area, to have shared concepts, vocabulary plus a specification of its intended meaning, namely an ontology, has been an obstacle to develop e-health system. We will in this paper propose a knowledge sharing ontology on the basis of Activity Theory. We believe that Activity Theory can provide high level and rich ontology for the developers of E-health system to encompass the multi-disciplinary and cross-organizational knowledge. We validate our approach in the end by demonstrating our project IMIS (Integrated Mobile Information System for Healthcare) that uses the activity theory as ontological architecture for the construction of the whole system.***

***KEYWORDS: activity theory; knowledge sharing; ontology; E-health; IMIS***

## I. INTRODUCTION

Knowledge sharing has become a very important resource when knowledge needed for conducted services is extended outside of its own organization. In the e-health sector, sharing knowledge can realize potential gains and is critical to surviving and prospering in a competitive environment [1]. Knowledge sharing in the e-health sector has become crucial for patient treatment, since the practitioners are required to be research-oriented, creative in healthcare, and ready to take new medical knowledge opportunities that can be acquired through various organizational learning mechanisms[2]. Despite its importance, sharing knowledge is not easy to implement. Knowledge sharing is a fragile process due to the nature of knowledge (explicit, tacit, private, collective, etc.) and people's diverse intentions. Moreover, knowledge is often considered as a valuable asset which is perceived as a source of power and reputation within a social setting. People may be reluctant to share this asset to avoid the risk of losing their power. Sharing knowledge brings some extra costs as well; one needs surplus resources (time, money etc.) and the means to share knowledge (IT infrastructure, meetings etc). Several reasons can be cited but the most limiting factor has been the poor connectivity between a company and its customers and also among the customers themselves [3].

A most important problem in e-health is that there are usually different organizations or individuals, hereafter called 'care providers', providing similar or related services to the same group of people, hereafter called care receivers. These various services and applications in different organizations use different vocabulary, concepts, models, etc. and lead to the difficulty of sharing knowledge and problem of interoperability. For example, in Sweden the hospitals of county councils, municipalities and other social organizations all provide healthcare for elderly who have chronic problem. They have to share their knowledge about the elderly in order to cooperate with each other, however using their own disparate systems which are not able to communicate with each other. Therefore, it is very crucial for E-health systems designer to find a strategy to deal with the diversities in the healthcare information system development. A shared ontology may be a necessity to start with this strategy. Ontology, from technological aspect, is "an explicit machine-readable specification of a shared conceptualization" [4]. Ontology is "a specific artefact designed with the purpose of expressing the intended meaning of a shared vocabulary", "a shared vocabulary plus a specification of its intended meaning" or "a specification of a conceptualization". Ontology may be utilized to promote knowledge sharing within organizations or inter-organizations.

In this paper, we will briefly define the ontology problem existing in the current knowledge sharing activities in e-health. Then we introduce the activity theory to provide a basic conceptual network as an ontological architecture for e-health system design. Finally, we demonstrate our approach by our IMIS project to validate our approach.

## II. KNOWLEDGE SHARING IN E-HEALTH

### A. *Knowledge in E-health*

Knowledge is the whole body of data and information that people bring to bear to practical use in action, in order to carry out tasks and to create new information. Electronic Health Record (EHR) is the most discussed knowledge in e-health. According to Iakovidis[5], clinical information contains medical record of patient which is stored in digital format. This clinical information objective is to provide chain of care and learning for research purposes. Moreover this information is stored in structured and unstructured documents in a variety of formats. EHR can store different types of information for a patient like different lab reports, images, treatments, and patient identification number [6]. Many countries are trying to provide solution to their health care services. In this regard some standardized organizational and technological infrastructure is used to provide basic factors for introducing EHR [7]. According to Jian-Cheng Dong etc. [8], The EHR is an electronic history record produced directly in personal health-related activity and worth keeping for future reference to health care management and clinical decision-making. There have been

many efforts in building and designing the content and structure of the electronic health record. Moreover this emergence of EHR brings new challenges in the field of medical informatics.

### B. *Sharing Knowledge in E-health*

Knowledge sharing is an activity through which knowledge (i.e. information, skills, or expertise) is exchanged among people, friends, or members of a family, a community or an organization [9].

Organizations have recognized that knowledge constitutes a valuable intangible asset for creating and sustaining competitive advantages [1]. Knowledge sharing activities are generally supported by technology, such as knowledge management systems. However, technology constitutes only one of the many factors that affect the sharing of knowledge in organizations, such as organizational culture, trust, and incentives.

To be specific, some issues of knowledge sharing between different healthcare providers are:

- To have access to distributed clinical information at any place with any time.
- To have access to different information communicating tools (ICT) based services.
- Doctor and patient both can consult with each other.
- Patient can access his/her electronic health record.

There are many standards to address clinical knowledge among healthcare organizations. The main objective of these standards is the exchange of clinical record by defining some structures and markup. Studies about these standards are focusing on the structure and the content, functionality of the requested retrieval of the record, complementarities of different standards and how they influence in the market relevance [10]. In the absence of standardized and sharable clinical information we can have lots of problems in different aspects [11]. Many countries are trying to develop and utilize health care information for providing different services. So it is even important to build up a high and global level model for knowledge sharing among nations, since people are now traveling more and more crossing the border and they need healthcare services no matter where they are.

Different standards in the local level will exist since the varieties of the specific services are impossible to be unified and standardized. E-health system must allow the local level flexibility and able to encompass the varieties. Meanwhile the e-health system must provide a sharable platform to allow different standards to communicate each other and able to share knowledge. This requires a high level and recursive model and ontology to guide designers constructing the e-health system. We have found that activity theory can provide such a solution, and we propose it as an ontological architecture for constructing e-health systems.

## III. INTRODUCTION OF ACTIVITY THEORY

The cultural-historical theory of activity, also known as Activity Theory (AT), is a framework of knowledge that seeks to explain the unity and inseparability of subjective mind and the objective human practice [12]. The origins of the theory can be found in the work of the Russian developmental psychologist Lev Vygotsky[13], Aleksei Nikolaevich Leontev[14], and especially further expanded by Engeström[15]. 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 by Vygotsky and Leontev to recapitulate and visualize the components and relationships that compose an activity (Fig. 1). A philosophical discussion about the model and relationship can be found from [15], and will not be discussed here. We just take up some points that contribute to the purpose of constructing ontology for e-health system.

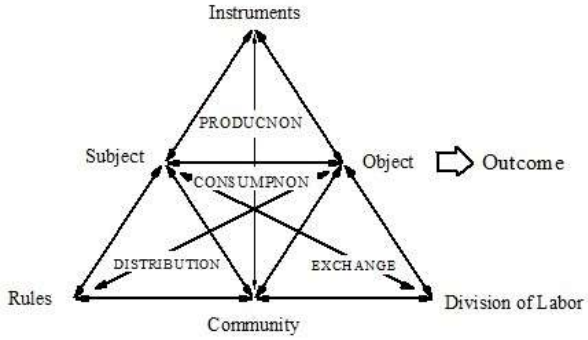


Figure 1. Engström's model of activity system

An activity is always conducted by some goal-oriented actors, a subject, directed towards an object or outcome that is being transformed. According to the theory a basic feature of human activity is the use of artefacts/instrument as mediation. Much of human interaction with the world is mediated through various artefacts/instrument. This triple relationship is represented in the top part of the triangle (Subject –Instruments – Object – Outcome). The subject and object are related to and members of a community that is shown in the bottom part of the triangle. The Division of Labour between the Object and the Community is to specify responsibility of the Object's all needs. The Rules are to legitimize the actions of the subject actors involved in the activity [16].

Activity Theory has become a focal point of interest recently among developers of Information Systems (IS) [16,17]. In this paper we are using Activity Theory as a framework to develop knowledge sharing ontology for Healthcare System.

We specialize the work activity of a doctor (Subject) working at a healthcare centre for elderly (Object). The outcome of the activity is to cure the elderly from their health problems and illnesses. The instruments include such tools as EHR, X-rays, laboratory, and medical devices - as well as partially internalized diagnostic knowledge and treatment-related concepts and methods. The community consists of the staff of the clinic, other collaborating clinics and hospitals, municipality's home nurses. The division of labor determines the tasks and decision-making of the physician, the nurse, the nurse's aide, and other employee categories. Finally, the rules regulate the legislate actions taken by the doctor, use of time, the measurement of outcomes, and the criteria for rewards, etc.

If we take the point of view of another subject in the community, for instance a nurse in the same elderly healthcare activity, the model will keep the same, however, only the contents will be different. Also, if we take the elderly as the subject of the activity system, their object will be the healthcare providers, which include doctors, nurses and other staff in healthcare center. Yet, they share the same architecture/model. This property of the model that is applicable in different levels and for multiple actors is a recursive property. Recursive property of a model can be used for constructing a system for multiple users in different organization levels which is exactly the case for e-health system.

## IV. IMIS: KNOWLEDGE SHARING PLATFORM BASED ON THE ACTIVITY THEORY MODEL

We believe that the above activity model composes the most important ontology and related knowledge for various human social activities in general and healthcare activity in specific. In the following, we demonstrate how to use the ontology in constructing a knowledge based healthcare system to validate our approach.

The project 'Integrated Mobile Information System for Diabetic Homecare (IMIS)' is a project financed by VINNOVA (The Swedish Governmental Agency for Innovation Systems) from 2001-2001 and 2003-2006. IMIS is to integrate both healthcare providers (such as hospital care, primary care, home care, and school care) and healthcare receivers (especially chronic, diabetic, and elderly care) into a web based and mobile platform in order to increase healthcare interoperability, integrity, mobility for both sides.

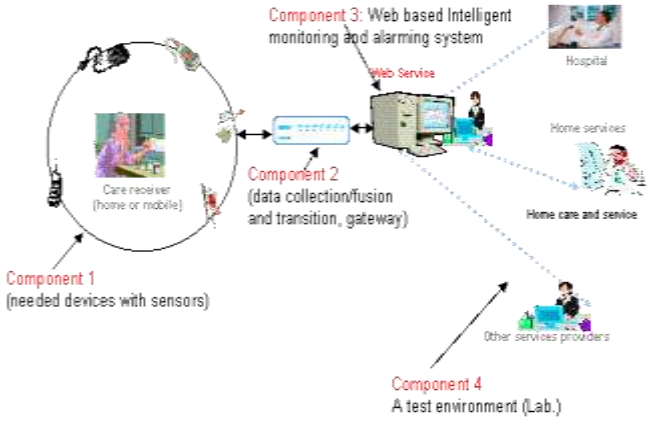


Figure 2. The architecture of IMIS – integrated platform for both care providers and receivers

The proposed architecture is shown in the Fig. 2. The focus for the IMIS is the construction of component 3: a web based intelligent monitoring and alarming system based on ontology of the activity theory model.

### A. *System for Both Care Providers and Receivers*

Very common for today a system is either developed for users as care providers (hospitals system, homecare system) or users as care receivers (patient self management) separately. However, according to our suggested activity model, the two are inseparable to each other in conducting healthcare activity. Therefore our designed system integrates the two independent parts (subject vs. object) into one system, and makes the subject-object relationship as a mutual and reciprocal one another.

Through registration (Fig. 3), the users (either care providers or care receivers) define their specific role in the activity, such as doctor, nurse, home assistant, relative, parent to a child who has diabetes, or elderly. Accordingly there will be a certification management to validate the specific role the user's input. After successful registration and validation, the role of the user will be the key to decide which information is relevant, and what user interface should be used, etc.

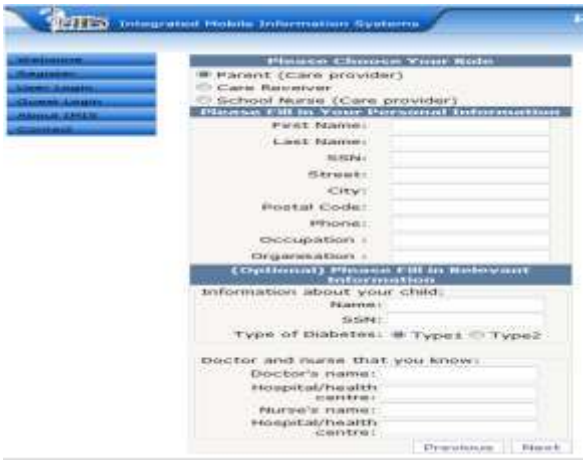


Figure 3. User's Role Registration (e.g. shows as a parent's role)

### B. *Subject Login & Auto-recognition of Role's System*

When a user is successfully registered and verified his/her role in the system, the user can get into his/her role system by name and password. The system will automatically direct the user to the role's system accordingly. Fig. 4 shows the user Christian Persson as a school nurse logs in.


Figure 4. Login as predefined role – Christian is a school nurse

It is always team work in conducting an activity. One member must know well about his/her team members in order to share information and responsibility about the targeted object. In this case, Christian needs relevant contact information about all other members (Fig. 5). Especially, in a shift work to take intensive care about an elderly, knowing

former and successor's work situation and keep tracking some happenings are vital to patients/clients life.


Figure 5. Christian's team info. as a collective subject

### C. *Various Tools for Conducting Healthcare Activity*

Tool is one of the most important artifacts mediating the relations or contradictions [18] between a subject and object, in this case, care providers vs. receivers. The usefulness and fitness of the tools in relation to the tasks and the users are vital to success. The tools must be subject/users oriented according to the different role in the healthcare activity. In our example in Fig. 6, the school nurse Christian could have tools such as message board/e-mail, booking calendar, diary of his care receivers, various tools for diet, and many more can be added when he feels needed. There will be different tools available for different roles and individuals dependent on the login key.


Figure 6. Various tools for Christian's nursing work

### D. *Knowing the Object*

Knowledge about the targeted object, in this example, the care receivers, is certainly a necessity for achieving some expected outcome/goals. The knowledge can be for example, health journal, diets, relatives, daily practice, and history that is relevant to health (Fig. 7).


Figure 7. Knowing the object/care receivers

### E. *Connecting the Social Network as Community*

All individuals will share some interests and knowledge with some other people who create an autopoietic (self - creation) network, namely a community. This is especially helpful for parents to exchange experience and obtain knowledge when their child first time gets diabetes. This community is also very helpful for elderly to feel connected with society and friends, to avoid the loneliness and repression. Fig. 8 shows a network/community for a parent.


Figure 8. Community – a social network sharing the same interest

### F. *Shared Responsibility – Labor Division*

A contradiction in all modern societies is that on the one hand the more and more specified labor divisions and on the other hand the complexity of different health services that requires a systemic and integrated approach in order to meet the multiple needs. Knowledge about who is responsible to what, i.e. the labor divisions, is thus crucial. Whenever a need of the care receivers is not served, there will be a responsible division to take action or new measures to meet the need. For example, in Sweden elderly care is normally shared by county council/hospital and the municipalities/home services. A clear labor division between the two organizations is not always possible especially when an elderly home has sudden heart failure after some chronic diseases. The transferring process of the elderly must be well specified and also co-operated. Under some critical situation, some overlap must exist in order to secure human life.

The labor division is an important knowledge in our system, and very dynamic co-constructed through a laboring process. We will not give the screenshot of this part since most contents are context specific.

### G. *Complying with Social Regulations*

Health services are extremely sensitive related to various regulations, laws, and protocols, since it is life critical system. E-health is relatively new kind of service and information about care receivers is the fundamental resource to implement e-services, such as digital receipt, remote consultancy, remote monitoring. All the services are based on personal information and identity. To whom and what information should be accessible is often regulated by various laws and regulations, for example, the law of personal number (identity) in Sweden. When a service provider is providing with a service to a receiver, he or she must know what is allowed and not allowed according to different regulations, including costs/services regulations, need assessments regulations, etc.

The knowledge about different regulations and laws is very crucial and yet very difficult to remember all. Then it is very important that the IMIS can provide this knowledge as reference to all care providers for conducting service activity.

Again, we will not present the screenshot here for the sake of clarity.

### H. *Evolutionary Development with Embedded Feedback Learning Mechanism*

E-health system is a very complex and dynamic system, and cannot be designed as one shot business. Therefore an evolutionary development must be adopted in order to take care of dynamic needs, new technologies, and new tools. We have created an embedded feedback learning mechanism to support this evolutionary development [19]. Under each functional page of IMIS, there is a feedback box that the users can open and write directly their suggestions to the designers. Since the suggestions are always linked to the current page where the users are oriented, it is very direct for the designers understanding the suggestions. Fig. 9 shows an example how Christian suggests the designer to add a new function text field as 'door code'. Since recently many elderly homes have installed new digital lock, and the IMIS has not predicted this need. After the designer received this suggestion, it takes minutes to implement this desired, yet not able to know before, function for Christian.


Figure 9. Embedded feedback learning mechanism

## V. DISCUSSION

This paper basically explores an ontology framework for knowledge sharing based on the Activity Theory. The purpose of this paper is to provide the e-health system designer a platform that can be used to integrate and share knowledge among all actors involved in the healthcare activity. Concepts and principles from Activity Theory as ontology for knowledge sharing are in an abstract level, and will not replace the local levels of different organizations and even not the levels discussed in agent technology. We find out through our studies that Activity Theorists are consistent with Agent Technology researchers in the abstract level. However, how to technically design and implement each knowledge component in our knowledge sharing ontology is left for our future research, which will be based on this approach.


## ACKNOWLEDGMENT

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