Activity System Theory Approach to Healthcare Information System

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ABSTRACT

Healthcare information system is a very complex system and has to be approached from systematic perspectives. This paper presents an Activity System Theory (AST)[1] approach by integrating system thinking and social psychology. First part of the paper, the AST is presented, especially a recursive model of human activity system is introduced. A project 'Integrated Mobile Information System for Diabetic Healthcare (IMIS)' is then used to demonstrate a practical application of the AST especially in constructing healthcare information system. Our conclusion is that the activity system model can provide the service system designers with a comprehensive and integrated framework for designing healthcare information system in specific, and for designing various kinds of service systems in general.

Keywords: Activity System Theory (AST), Healthcare Information System (HIS), Software Architecture Design

1. INTRODUCTION

There are too many elusive and interrelated components or objects involved in healthcare systems, and they are dynamically interrelated. Those complex and dynamic components and relationships must be included in the architecture of Healthcare Information System (HIS) in order to support the complete information needs in healthcare activities. To this purpose, Activity system theory (AST) seems very promising, since AST provides a very comprehensive 'skeleton' for hanging those interrelated and dynamic components and objects as a system – a socio-psychological wholeness.

In the followings, some key concepts and models of AST are introduced first. And a project IMIS (Integrated Mobile Information System for Diabetic Healthcare) is demonstrated that how in practice we can apply AST in developing HIS software architecture.

2. BASIC CONCEPTS AND MODELS OF AST

AST is a systemic way for studying various forms of human behaviors and social practices. It uses the category 'activity' as 'a system of its own structure' or the minimal unit (Leontèv 1981, p46) to approach the relationship of the subjective mind with its social context. Some important concepts and models of the AST, most of which originated from the work of (Davydov, 1982), (Vygotsky, 1978), (Leontèv, 1981), and (Engeström, 1987), are summarized in the following.

2.1 What is Human Activity and Why

An activity is a basic process that a human being or a collective carries on or participates in by virtue of being alive, and it is also the most basic unit for any human or collective performing a specific function or duty. Like foods and water to human physical existence, activity is like foods and water to human mind. No one can survive without participating in various social activities, such as materials production and distribution activities, political and democratic activities, scientific and educational activities, religious activities, sports and various entertainment activities. Activity is 'the nonadditive, molar unit of life' (Leontèv, 1981, p 46).

But how is activity possible? According to Searle (1995), there are two biological primitives of human beings: 'background capacity' and 'collective intentionality' which enable various social activities. The 'background capacity' indicates the capacity of each individual being able to follow social or institutional rules, norms, laws, etc. ".... rule-governed structures of human institutions are followed by people not because they have explicitly learned and memorized the rules, but because they have developed a set of capacities and abilities that render them at home in the society. These capacities and abilities are labeled 'background abilities' (Qvortrup 1996, p33)."

The 'collective intentionality' explains why individuals with their singular intentionality wish to participate in social activities. Searle's (1995) answer is: 'in addition to singular intentionality there is also collective intentionality (p 23).' This collective intentionality is not the sum of singular intentionality, but a new emergent property of collectives. Activities are formed by persons sharing a 'We Intention' with their 'background capacity'.

2.2 Activity is an Internalizing and Externalizing Process

A subject in an activity is a conscious actor or a group of conscious actors. An object is some part of the real world that the subject acts upon. 'If I act, there is something in front of me, an object (Schwarz 1997, p

[1] It is often just called Activity theory in socio-psychological references.

24).' Leontèv considers the activity as the 'middle link' in a three-part scheme between subject and object (Leontèv 1981, p46). The object manifests itself only if there is an interaction with a subject. There is non-separability between object and subject. AST takes social, historical, and cultural properties to be as objective as physical and biological properties, and maintains that consciousness is located in everyday objective practice: you are what you do. And what you do is firmly and inextricably embedded in the social matrix of which every person is an organic part (Nardi, 1996). An object (objective) is always held by a subject, a person or a group of persons who is or are engaged in an activity, provides motives for the activity, and gives the activity specific direction. 'Behind the object, there always stands a need or a desire, to which the activity always answers (Leontèv 1981, p46).'

But a subject can act on an object only through artifacts as a mediator (in figure 1, dot line between subject and object). The introduction of artifacts as a mediator in mediating the very classical 'mind-body' paradox or contradiction is a major contribution of AST. 'Mediator objects connect humans not only with objects, but also with other people (Leontèv, 1974).' In particular, mediator objects are understood as objective transmitters for the internalization process and externalization process. The internalization process is the process in an activity transforming the object in focus into its subjective form or image (mental models, theories, skills, consciousness, etc.) that is 'generalized, verbalized, abbreviated, and most importantly, becomes susceptible to further development that exceeds the possibility of external activity (Leontèv, 1974, p18)'. The externalization process is the process that internal process manifests itself in external actions performed by persons, and is converted into objective results and products (Davydov, 1982; Vygotsky, 1978; Leontèv, 1974).

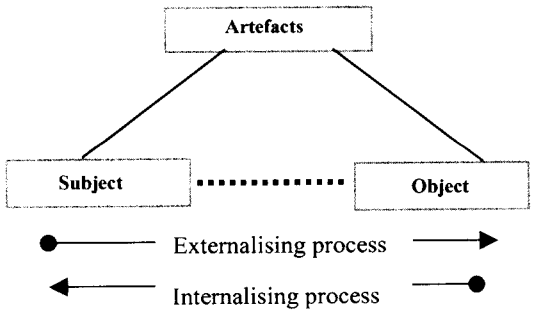

Figure 1. Activity mediated by artifacts

2.3 The Three Levels of Activity Model

An activity is structured and analyzed at various levels. Leontèv (1974) provided a three-level scheme of activity (figure 2). According to this schema, a collective activity is driven by a communal motive. This motive is formed when the collective 'need meets an object' that has potential to fulfill the need. Different activities can be distinguished on the basis of their different motives and then an activity is realized or accomplished by actions or clusters of actions that are generated or related to some concrete goals. Participating in an activity comprises conscious actions that have immediate, defined goals. These actions must in turn be technically implemented through operations that are well defined, habitual routines in accordance with conditions during the operation

The action and operation are dynamically defined: when an action has been practiced long enough, the action will be collapsed into an operation and new kind of action will be created with its corresponded new operations. On the other hand, when conditions change, an operation can again 'unfold' and return to the level of conscious action (Kuutti, 1996).

The distinction between individual goal-directed action and collective object-oriented activity is of central importance. One and the same goal directed action may accomplish various different activities and transfer from one activity to another. On the other hand, the object and motive of a collective activity may typically be sought after by means of multiple alternative goals and actions (Engeström, 1999). This complex many-to-many relationship in an activity needs some concrete field observation and data analysis in order to derive understandable work model and data structure. HIS system must consider this many-to-many network relationship in its software architecture in order to support the real cooperative work.

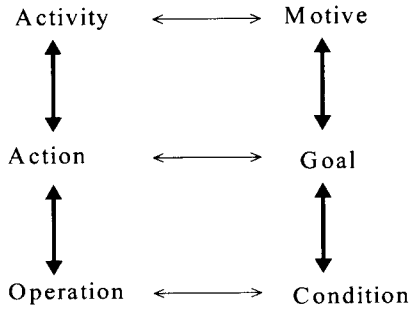

Figure 2. Three levels of an activity

2.4 Model of Activity System

For much current sociology, in a certain sense only individuals exist: the individual human being is the ontologically given starting point from which everything else must be deduced. Consequently, socialization, norms, values, and culture are popular means for explaining why individuals unite into something called society (Qvortrup, 1996). AST, however, takes the relationship between an individual and his or her social cultures, norms, and values as a molar unit of an activity and believes that activity is only developed under conditions of co-operation and social interaction among people (Leontèv 1981, p55). Even though Leontèv pointed out the importance of social factors in an activity, it is Engeström (1987) visualized the social context, such as community, social

and cultural rules, norms, and social labor divisions into one unified system and logical interrelation (figure 3).

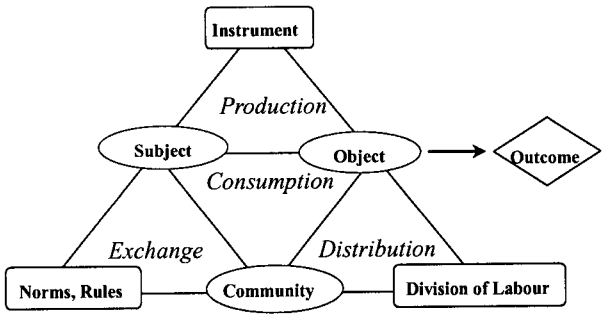

Figure 3. The structure of human activity (based on Engeström, 1987, p78)

Contradiction is a crucial concept or a general category in AST which describes the relationships between components and their complementary nature, such as mutuality, interdependence, diversity, and dynamics that are deemed immanent in a development process. Contradictions manifest themselves as problems, ruptures, breakdowns, and clashes. AST sees contradictions as sources of development (Engeström, 1987; Bai & Lindberg, 1998; Turner P. & S. Turner 2001). Activities are virtually always in the process of working through contradictions (Kuutti, 1996). In figure 3, together with the classical contradiction 'Subject-object' mediated by instrument, two new contradictions are identified after the introduction of community, the contradiction 'subject-community', and the contradiction 'object-community'. In a similar manner as the instrument is introduced as the mediator of the contradiction 'Subject-object', Engeström introduces 'norms, rules' as the mediator of the contradiction 'subject-community', and introduces 'division of labor' as the mediator of the contradiction 'object-community'. Based on Marx's terminology of social production, exchange, distribution, and consumption, he further maps those four human fundamental activities as four sub-triangles.

According to figure 3, the development of human production, exchange, distribution, and consumption activities are accordingly driven by four contradictions. Firstly, production activity is driven by the contradiction 'subject-object'; namely, by using instrument ('tool' in the terminology of Vygotsky, or artifacts in figure 1 by Leontèv) the subject works and produces the objects that correspond to the given need or an outcome. Secondly, the exchange activity is driven by the contradiction 'subject-community', namely, the subject exchanges his/her labor value (exchange value) within the community to obtain his/her needs (use value) according to the community's rules and social law (second mediator). Thirdly, the distribution activity is driven by the contradiction 'object-community', namely, the outcome of the object is distributed for social re-production among members (organizations, companies) of the community according to the principles of the division of labor (third mediator). Finally, the total social activity system (the whole triangle) is driven by a new kind of contradiction: 'production-consumption', namely, by the paradox that we produce output and, simultaneously, we consume the output in order to re-produce it. The contradiction of 'Production-Consumption' provides an inner and never-ending energy that drives an accumulating cycle of consumption and production. 'Were it not for the paradox that consumption necessitates production, and vice versa, activity would not exist (Holt 1993, p99).'

Besides the contradictions between the constituent components of an activity in the above which Engeström called the secondary contradiction, he has also identified other three levels (types) of contradictions: the primary contradiction is within each constituent components of an activity; the tertiary contradiction is between an activity and its culturally more advanced form of the activity (new activity vs. old activity); and the quaternary contradiction is between the central activity and its neighboring activities (Engeström, 1987, p89).

3. The IMIS PROJECT – APPLYING AST IN HIS SOFTWARE ARCHITECTURE DESIGN

3.1 Background of the Project

Most diabetic patients regularly contact with their care providers in various ways. Studies in the USA (American Diabetes Association, 1989) and in Sweden (Rachmani R., et. al. 2002) showed that the self-treatment and supervision of diabetic patients can greatly increase their quality of their daily life if they are provided with reliable and easy access to their care providers (doctors, nurses, relatives, etc.). Also if care providers and diabetic patients are able to communicate with each other before the patient visits the care providers (if the visit is judged necessary after the communication), the quality of the visit is increased, and the quality of care or treatment of the visit gets even improved if they continue communicate after the visit. In Sweden, a guideline for diabetic healthcare (Socialstyrelsen Stockholm, 1999) stated that 'To a good quality of diabetic healthcare there needs a team work in which diabetic patients are in centre. They need training, support, and supervising so they can take care themselves, control own situation, and self-treatment. They need to have access to the care team which consists of doctors with competence and interests for diabetic patients, and nurses special trained for diabetic care who can provide with patients good advices, and cooperate with dietician and foot therapist.' Communication between all the team members and patients is an essential need if the self- treatment of diabetic patients is possible. The IMIS (Integrated

Mobile Information System for Diabetic Healthcare)[2] project focuses on software architecture of information sharing in this context. Since healthcare activities compose a complex social system, the architecture of HIS must cover the complex system components and map their relationships. AST model (figure 3) provides the designers with such a needed architecture.

3.2 The Architecture of IMIS

One important task of IMIS project is to find a comprehensive and sustainable structure for software design. Based on the theoretical discussion in the above, the model of AST (figure 3) has the following characteristics:

- The elements identified in the model cover all necessary information in an activity;
- The model is generally applicable to all kinds of activities (decision making in the center or operation in the field); and
- The model has recursive properties, and therefore it can be expanded to all levels (individuals, groups, communities) of activities.

Therefore, it is used as the architecture for information sharing between healthcare actors. This architecture is served as an externalization and visualization tool, an informatics' microcosm to abstract and condense the big and messy reality of the healthcare activity system.

In our project, three kinds of working activities will be supported by the IMIS. The first is central activities of decision makers, such as, group leaders and managers of the healthcare. The second is operative level of activities in the field of care work, and communication between field workers and the base. The conceptual structure is demonstrated in figure 4.

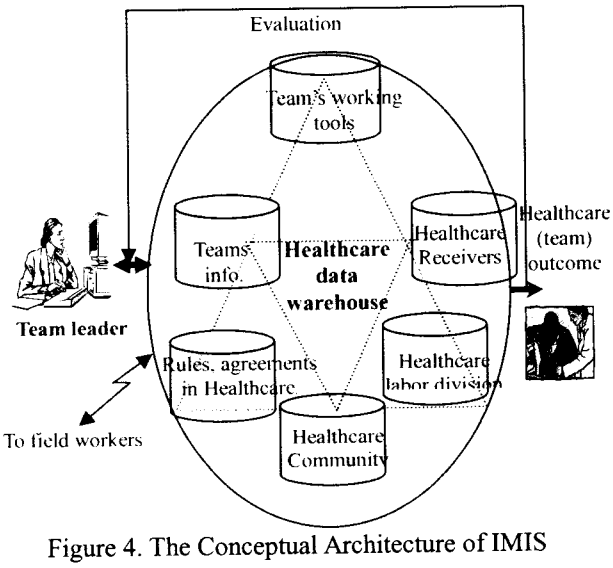

Figure 4. The Conceptual Architecture of IMIS

[2] The project (2003-2006) is financed by VINNOVA: The Swedish Agency for Innovation Systems (http://www.vinnova.com)

3.3 Support Decision Activities and Operation

To support decision making in healthcare activities, such as human resources management, business re-engineering, work schedule, needs assessment, the IMIS must provide the decision makers with necessary components, information, and knowledge. According to AST, to carry this decision activity, the decision makers have to know: (1) the subject – the healthcare team, (2) the object – the diabetic patients, (3) artifacts – various tools (physical, mental) used, (4) laws, rules, standards – regulation for what and how healthcare should be done, (5) community – cooperative partners, and (6) labor division – responsibility to whom and what. Those 6 dimensions guide the construction of databases (healthcare data warehouse). Probably the different parts can be found in various existed databases, and in this case the IMIS is like an intelligent agent that integrates the needed knowledge from other sources for the decision makers.

To support operational tasks in the fields of healthcare the information in IMIS must be targeted (personalized just-for-you, just enough), mobile. More over, the contents must be constructed as a recursive subset of the overall architecture in order to integrate part of field work into the healthcare warehouse. This recursive structure between decision activities and operations is very important not only for consistent and verified date, but also for the communication peer-to-peer and between the decision makers and the healthcare workers. Communication between different (data) structures implies extra translation, or transformation. This will lead to problem of validity and reliability of data, problem of fragmentation, and problem of extra cost of human resource. Just because the SAT model is generally applicable for all kinds of activities (recursive or heritable properties), the components specified in the model cover also the needs for healthcare workers in the field. Without changing the generic architecture of components specified in healthcare data warehouse, we can construct the part of IMIS for the field workers by just changing some specific contents. Since this part is installed in the hand computers of field workers, and the contents are individually configured by each field worker, it can be seen as a dynamic subset of the healthcare data warehouse.

4. CONCLUSION

Based upon the concepts and models of AST, we have developed software architecture for HIS in the healthcare setting. Currently, a working prototype was designed with Nokia 9210 as nodes for the mobile part of the field workers, and a web server as a base for the team leaders. Based on some primary observations from some tests by users, the comprehensive architecture could cover the various information need for healthcare work, and meanwhile the structure could integrate existed applications, such as alarm system and other segregated applications. Another positive comment from

the users was that the relationship depicted by the model was consistent with their mental model of their work reality. After this pre-study, we will develop the IMIS system from the conceptual stage to practical implementation. The method of user-centered design together with AST concepts and models will be applied in the future design work. We may then have much more knowledge and verification how well the AST model could be applied in complex service management system in general.

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