An Activity Systems Theory Approach to Agent Technology

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ABSTRACT

In the last decade, Activity Theory has been discussed a lot in Human-Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW). Activity Theory was used both theoretically as an analytical method and practically as a development framework for Information Systems. Meanwhile, there is a new trench from Artificial Intelligence. Artificial Intelligence researchers find that the fruit from Activity Theory study may contribute, especially to Agent Technology, with socio-psychological aspects.

In our E-health research, we apply Activity Theory both theoretically and practically into Agent Technology. To facilitate our research, General Systems Theory is chosen to integrate Activity Theory and Agent Technology. On the one hand, we consider Activity Theory as specific subject of General Systems Theory. On the other hand, General Systems Theory contributes to Agent Technology with systematic perspectives. As integration, we introduce Activity Systems Theory as an extension of Activity Theory. Then we apply it into Agent Technology discussion.

The paper starts with the discussion of systematic perspectives of Activity Theory. Then we introduce Activity Systems Theory as an integration of systems science and Activity Theory. Three Activity Systems Theory principles are then applied into the discussion of Agent Technology. In the end, we introduce how we apply Activity Systems Theory into an E-health application.

Keywords: Activity Theory, General Systems Theory, Activity Systems Theory, Agent Technology

1. INTRODUCTION

In the last decade, Activity Theory has been discussed a lot in Human-Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW). The discussion is mainly in two approaches: first, Activity Theory was used theoretically as an analytical method for systems design from the perspectives of cognition [1-3]; second, Activity Theory was used practically as the development framework for Information Systems [4-8].

Meanwhile, Artificial Intelligence researchers explored approaches in Agent Technology from various areas, e.g., game theory [9], market-driven approach [10] telecommunication theory [11], socio-psychology [12] etc. The various approaches give Agent Technology complementary perspectives.

We are doing our research in E-health with both above approaches. We consider the health care situation as a MultiAgent System (MAS) from the perspectives of Agent Technology. Activity Theory supports this system with a framework, based on which we analyze the whole system. Additionally, Activity Theory also provides system architecture for our solution to the E-health.

During the research, we find that the contact point of Activity Theory and Agent Technology lies on that both are consistency with General Systems Theory. Activity Theory is consistent with General Systems Theory in many aspects, for example, *holism*, *hierarchy*, and *feedback (first-order cybernetics)*. We believe that Activity Theory should belong to the paradigm of systems science. Agent Technology always leads to a complex MultiAgent System, which is perfectly suitable for the discussion of General Systems Theory. The principles of General Systems Theory should be also true in MultiAgent Systems. Thus, General Systems Theory plays a role of the 'integrator' of Activity Theory and Agent Technology.

The paper starts with a discussion of systematic perspectives of Activity Theory. As a result, we introduce Activity Systems Theory as an integration of systems science and Activity Theory based on three principles. Then we apply Activity Systems Theory into the discussion on Agent Technology. In the end, we apply our theoretical discussion into an E-health scenario with the introduction of the project *Integrated Mobile Information System in Health Care (IMIS).* The sociological specifications of E-health partially affect our choice for the integration of Activity Theory and systems science.

2. GENERAL SYSTEMS THEORY

General Systems Theory is a response to the failure of mechanistic thinking in the attempt to explain social and biological phenomena in the 50s, e.g., traffic systems, environmental disasters, nuclear threat, drug abuse, AIDS, politic and war, etc. General systems theory is a theory of theories, a law of laws. Kenneth Boulding [13] gave a good description of it:

> General Systems Theory is the skeleton of science in the sense that it aims to provide a framework or structure of systems on which to hang the flesh and blood of particular disciplines and particular subject matters in an orderly and coherent corpus of knowledge.

The precursors of systems science formulated a list of properties for all the systems to possess [14-16]: *interrelationship and interdependence, holism, goal seeking, transformation process, inputs and outputs, entropy, regulation, hierarchy, differentiation, and equifinality and multifinality*.

Besides those properties, the systems scientists also defined a set of laws and principles, from which we selected three for the discussion on Activity Theory [14]:

- *System holism principle*: A system has holistic properties not manifested by any of its parts.
- *Hierarchy principle*: Complex natural phenomena are organized in hierarchies wherein each level is made up of several integrated systems.
- *Feedback principle*: The result of behavior is always scanned and its success or failure modifies future behavior.

System properties and principles are not limited to the above discussion. We hereby select those that are suitable for the discussion on Activity Theory and Agent Technology. In the next section, we will discuss those properties and principles in details within the scope of Activity Theory.

3. ACTIVITY SYSTEMS THEORY (AST)

Activity Systems Theory (AST) is an extension for Activity Theory. Based on three enumerated systems principles above, we discuss the systematic aspects of Activity Theory. First, we introduce Activity Theory briefly.

3.1 Activity Theory

Activity Theory is a philosophical and cross disciplinary framework for studying different forms of human practices as development processes, with both individual and social levels interlinked at the same time [2, 17-19]. Activity Theory has its roots on the classical German philosophy, writings of Marx and Engels, and Soviet cultural-historical psychology. Recently, some researchers devoted themselves to mapping Activity Theory to models for the use of applying it into application areas [20, 21]

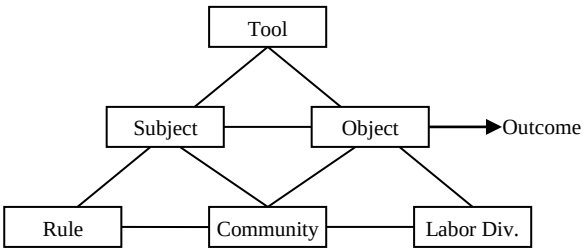

Figure 1 An activity system, from Engeström [21]

3.2 Activity System

The key concept in Activity Theory is activity system. An activity system embodies the necessary components to achieve one common objective within a context. An activity system comprises six components, namely, *object, subject, tool, rule, division of labor* and *community*. (See figure 1) The *object* is something to be transformed, and is always treated as the centre/focus of the activity. *Subject* is the transformer. *Tool* includes all the artifacts that the *subject* uses to transform the *object*. During the transformation, the *subject* must obey the *rules* within a *community*, while the *object* decides the *labor division* of the activity. After the transformation, an outcome is generated. *Community* is either the physical place where the activity happens or a virtual sphere that includes the other five components. These six components interrelate and form an activity.

An activity system is always learning and developing. Activity systems periodically face situations, in which their internal contradictions are aggravated and demand a qualitative reorganization, or re-mediation, of the entire activity [22].

3.3 Systems Principles in Activity Theory

As a specific system, activity system obeys the systems principles. In this section, we apply three systems principles into Activity Systems Theory:

- System holism principle. Activity is the least sphere for analysis. Activity is the synonym of 'context' in Activity Theory. An activity is a holistic system. All the activity components together provide a systematic view of the target system. Studying activity partially leads to misunderstanding of it.
- Hierarchy principle. Subject transforms object though actions and operations. An activity composes actions or chains of actions, which in turn composes operations [17]. Activity, action, and operation are associated with motivation, goal, and condition respectively. (See figure 2)

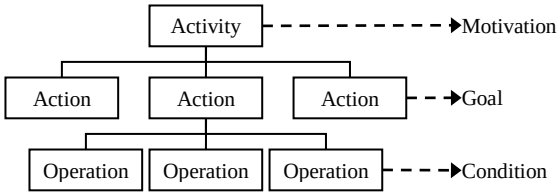

Figure 2 Hierarchy of Activity-Action-Operation

- Feedback principle. Activity systems co-exist in groups. An activity always sends its outcome to another activity. The destination activity continues to send its outcome to another. Finally, the outcome of one activity is sent back to the original activity. To start a new loop, the original activity takes consideration of the outcomes from other activities. Thus, the activity system network is constructed through the feedback among activity systems.

4. AGENT TECHNOLOGY WITHIN THE SCOPE OF ACTIVITY SYSTMES THEORY

We just explained Activity Systems Theory with General Systems Theory principles, based on which we will discuss Agent Technology in this section.

4.1 Holistic Perspectives of Agent Technology

Intelligent agents coordinate in an environment/context. An agent cannot perform any activities, if excluded from the environment/context. We should always consider the agent and its context together as a holistic entity. In figure 3, we give an example of health care activity. We consider the nurse with his/her IT supported tools as a composite agent. The agents take care of patients with the help of *tools*. There are two kinds of nurses in the health care scenario, namely staff nurse and district nurse, according to the *division of labor*. To achieve this health care activity, the nurses should obey the norms and rules. All the agents work within a group called MultiAgent System (MAS). With such an activity system considered, we may get a complete picture of the health care agent. In the systems analysis stage, such picture is necessary for us to give a clear and precise definition to the agent.

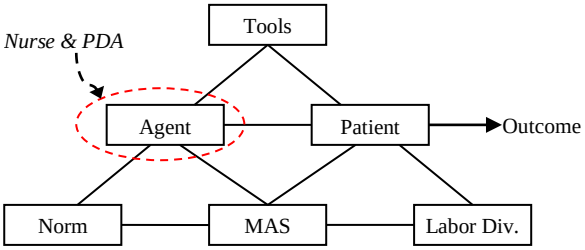

Figure 3 An E-health activity system

4.2 Hierarchical Perspectives of MultiAgent Systems

Based on the Activity Theory hierarchy, we classify agents into three groups, namely activity agent, action agent, and operation agent. (See figure 4).

In figure 4, the hexagon represents the MultiAgent System. Each ellipse represents an agent or a group of agents. Within the hierarchically organized MAS, the individual agents act on three levels – activity, action, and operation. On each level, agents have specific responsibilities. The activity agent is represented by the composite triangle in the hexagon. Activity agent takes charge of the whole activity. An activity agent plays a role like the project manager in the real life. Usually there are just several activity agents in a MultiAgent System. It is responsible for organizing the action agents. The action agent is represented by the single triangle in the rectangle on the right side. If activity agents are those who make plans, then action agents are those who execute the plans. An action agent only keeps the knowledge of its tools. The action agent does not have to perform the actions itself. The action agent aims at a specific task. Based on AST, the action/task is continually decomposed into operations, which are taken by the operation agents. The operation agent is represented by an arrow and ellipse. Operation agents are usually very skilled with their tools. Usually the tool is neglected in the representation of an operation agent. Operation agents are those who are really doing things, e.g., the group members.

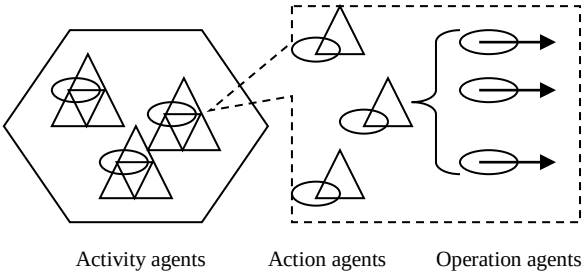

Figure 4 MultiAgent Systems hierarchy

4.3 Feedback Regime in MultiAgent Systems Coordination

Based on feedback principle, we consider MultiAgent Systems coordination as a network. In such a network, agent's behavior is always scanned and sent back to itself or forwarded to others. Feedback is necessary for the systems stability. Activity Systems Theory believes that the agents always send messages/outcomes to other agents who will send messages/outcomes back to the original ones as feedbacks.

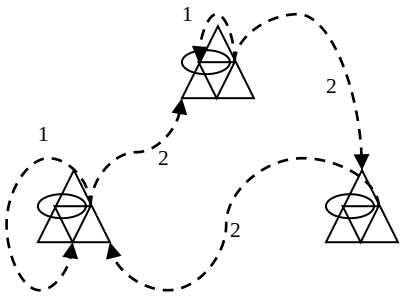

Figure 5 MultiAgent Systems coordination based on feedback

Figure 5 shows a picture of the feedback regime in MultiAgent Systems coordination. The dash lines represent two kinds of feedback in MAS. The lines numbered with '1' are the intra-agent feedback. Lines numbered with '2' are the inter-agent feedback. The behavior of an agent is directly (intra-agent) or indirectly (inter-agent) sent back to itself. The intra-agent feedback realizes the stability of an individual agent. The inter-agent feedback realizes the stability of the MultiAgent Systems.

5. ADOPT ACTIVITY SYSTEMS THEORY INTO E-HEALTH

We are doing our research in the project **Integrated Mobile Information Systems (IMIS)** in Blekinge, Sweden. The project aims at providing a communication platform and IT services to both the diabetic patients and their care-providers (doctors, nurses, etc). All the stakeholders in E-health scenario communicate with each other and form a complex network. IMIS project provides IT service, so-called IMIS agents, to the users. The project considers health care as a MultiAgent System. With the IMIS agents, the users are considered as agents in the E-health MultiAgent System. (See figure 6)

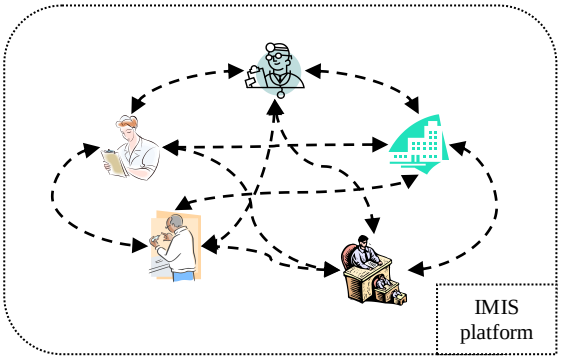

Figure 6 E-health MultiAgent System in IMIS

5.1 IMIS solution based on Activity Systems Theory

IMIS solution is designed through a three-step methodology, which is based on three AST principles: holism, hierarchy, and feedback.

The first step is to define the basic activity for analysis and design. Figure 7 illustrates an example of IMIS activity. This activity describes Doctor Hans gives treatments to the patient Kent with the help of IMIS communicator. In this activity, the Doctor and patient are considered as agents that communicate on IMIS platform. The activity is a holistic one. The basic unit for E-health MultiAgent System is the activity, instead of the individual agent. To describe the health care situation, many activities need to be defined in IMIS platform, e.g. the activity of patients contacting nurses for help, the activity of doctor contacting nurse for co-operation, etc.

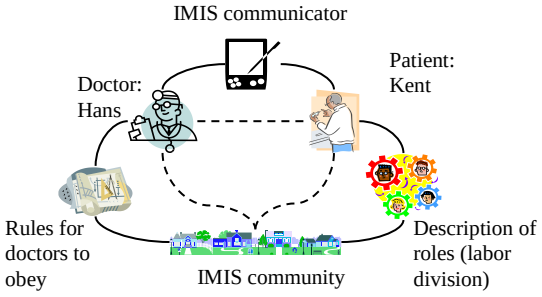

Figure 7 An IMIS activity: doctor gives advices to patients

In the second step, the activity is decomposed based on hierarchy principle. As an example, the activity that doctor gives treatments to the patient can be decomposed into a chain of actions: examine, give diagnosis, injection or other medical treatments, and archive for future examination. The decomposition of activity follows the hierarchy principle of Activity Systems Theory. The actions are performed by action agents (group leader). Actions are continually decomposed into operations. Operations are performed by operation agents (group members). In IMIS system, the operation is the least unit for programming. Operations are functions of agents, as activities are functions of MultiAgent Systems.

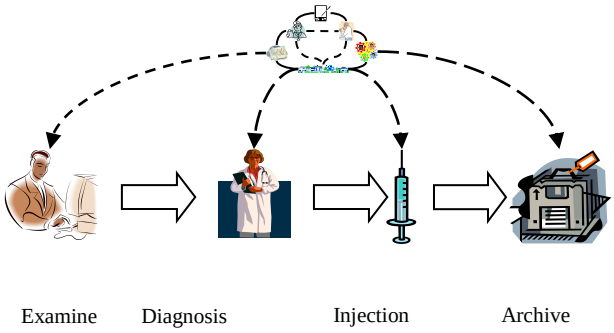

Figure 8 A chain of actions that compose an activity

The last step to define IMIS platform is to define the relations among activities. With the introduction of activity, the diabetic community is much simplified. (See figure 9) What make up the network are not the stakeholders, but the activities. The feedback principle of Activity Systems Theory is represented by the links that connect activities. According to feedback principle, the outcome of an activity must be connected to a destination activity. The destination activity directly or indirectly affects the resource activity in the future. For example, when a doctor finishes the diagnosis to a patient, he/she needs to send the result to the nurses, who will give the treatments to the patient. Meanwhile the doctor sends a feedback to him/herself. This is realized through archiving of the diagnosis for future treatments. As a feedback for the whole IMIS system, the patients also send messages to the doctors when the treatments are done. All of these activities are automatically realized on IMIS platform.

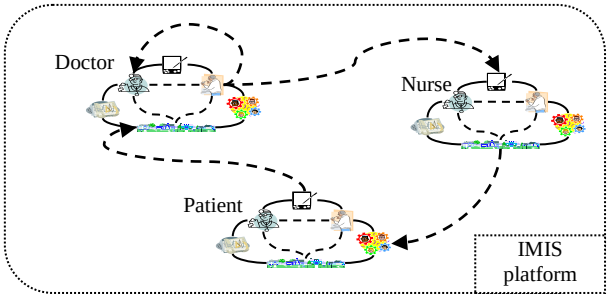

Figure 9 Simplified construction of IMS platform

6. DISCUSSION

Systems thinking can help to simplify the problem, especially when we design a system for a complex situation. Health care involves stakeholders from various organizations, e.g., hospital, county council, municipality, old people's home, patients themselves etc. System thinking helps us to make a clear picture of the problem situation. Activity Theory, from the angle of socio-psychology, provides us with a good analytical method. In our research, we integrate systems thinking and Activity Theory. Principles from both theories contribute to a three-step methodology for IMIS communication platform design. This integration contributes to not only the analysis and design of IMIS platform, but also

the software implementation. Obviously, the E-health MultiAgent Systems can be modeled with CASE tool, e.g. a UML editor.

In the end, this paper mainly approaches Agent Technology in systems science. There is a lot of work left to be done in future. First, the theoretical discussion will continue. Some systems theories will be applied into agent technology for a better design and implementation. Second, the result from the discussion will be applied into practice. A web-based information system will be designed and implemented in order to help the doctors and nurses to improve the quality of their work.

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