ABSTRACT
This paper explores MultiAgent Systems coordination from a socio-psychological point of view. Activity Theory is introduced to explain the coordination among intelligent agents. The hierarchy and motivation thinking from Activity Theory is used to define the motivation driven MultiAgent Systems coordination mechanism. Finally, we apply this mechanism into a health care scenario.

KEYWORDS
MultiAgent Systems, coordination, Activity Theory, hierarchy, motivation, health care

1. INTRODUCTION

Computer agents are believed to be selfish by most of researchers, e.g., Game Theorists (Koller and Pfeffer, 1997), economists (Gibney and Jennings, 1997), ecologist (Tesfatsion, 1998) etc. The selfishness has become a tacit property of agents. When selfish agents interact with each other, MultiAgent Systems (MAS) coordination appears. Coordination is thus considered as an intrinsic property of MAS in performing some activities. Coordination includes cooperation and competition (Weiss, 1999). Cooperation is coordination among non-antagonistic agents, while competition (negotiation) is coordination among competitive agents. Agents either compete through negotiation, or cooperate in a distributed problem-solving scenario. In both cases, agents communicate in some languages that they all understand, e.g., KIF (Genesereth and Ketchpel, 1992), KQML (Finin, 1993), FIPA (FIPA, 2001) etc. No matter it is competition or cooperation, individual agent’s architecture is the start point for discussion. From this start point, agents firstly agree on one communication language, then start to communicate. Individual agents are the focus in this approach.

In many occasions, agents are supposed to work together for one common motivation. For example, in health care system a group of agents work together to take care of one patient. Inside this group, there is no competition but pure cooperation among the agents. They must not be selfish to each other. Thus, there is a contradiction between the selfish agent and the non-selfish group. How should we make a non-selfish group from selfish agents? To deal with this problem, we introduce our approach to start with the whole MAS instead of individual agents. We firstly discuss the relationships among agents on the collective level. Then we define the roles of individual agents. In this paper, we introduce Activity Theory to show a socio-psychological view on MAS coordination.

The paper is organized in fivefold: in the next section, the coordination problem in health care system is introduced; in the third section, Activity Theory from sociology is discussed briefly; in the fourth section, we will discuss MAS coordination with the help of Activity Theory; and in the last section, a possible solution to the coordination problem in health care system is given.

2. COORDINATION PROBLEM IN HEALTH CARE SYSTEM

In this paper, we just focus on the coordination problem in health care system. To start our discussion, we would like to have a brief introduction to the home health care system based on a real story.
2.1 An E-health scenario

Maria (not real name) has several health problems of which one is diabetes of type one. There is a staff nurse\(^1\) from the Home Care Center of County Council, who visits her home twice a day to give her insulin injections. In addition, a personal assistant from the municipal social service helps her do some housework. Maria seems not very concerned about her diabetes, and often eats food and candy that is not good for her. The concentration of blood glucose often goes up steeply. One day the personal assistant called the Home Care Center and reported to the district nurse that Maria did not feel well. The district nurse suspected that Maria had eaten some sweet cookies. The district nurse checked Maria’s record of her recent medical history. Then the nurse went to Maria’s house with a device to measure the blood glucose. After asking several questions to Maria, the nurse took out the device and tried to measure the blood glucose for further decision. However, the nurse was not familiar with this device and could not understand what it showed. After a phone call to the diabetic nurse at the Primary Care Center from hospital, the nurse drew a conclusion that Maria was in an acute situation. Immediately Maria was sent to the doctor.

![Figure 1. Information flow in Home Care Service](image)

The scenario is shown in figure 1. The picture is divided into four parts by three vertical lines. The four parts are primary care from hospital, home care from county council, patient, and home service from municipality respectively. The doctors and three kinds of nurses are also called care-providers. The patient is called care-receiver. There are two different connection lines. The solid lines stand for the normal/everyday connections. For example, the staff nurse and the personal assistant visit the patient everyday. This means that they should have quite good relations with the patient. The dash-dot lines stand for the information flow of the above scenario. The numbers on the dash-dot lines indicate the consequence of the information flow.

2.2 The coordination problems

There are some communication problems in the above scenario. First, the staff nurse is missing in the above information flow. The staff nurse visits the patients’ house twice a day to give injections. She/he knows many details about the patient. All those details are sometimes important for the diagnosis. However, it is impossible to write all of them down into the record. When the district nurse noticed that the patient did not feel well, she/he had no contact with the staff nurse. Additionally, during and after the diagnosis by the district nurse, the staff nurse was not informed of either. This may lead to confusion in her work in future. This implies the communication channels between the nurses are not established.

Second, communication problems exist also between the care-providers (doctors and nurses) and the patients’ records. For example, before visiting Maria’s house, the district nurse had to check the patient’s

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\(^1\) There are two different types of nurses in Home Care Center, staff nurse and district nurse. District nurses have more education background and thus more responsibility than the staff nurse. The staff nurse can have at most responsibility to give patients medicine or insulin injections which are delegated by the district nurse.
history record in the office. When the district nurse arrived at Maria’s house, there was no way to access to
the patient’s records. Besides, there are also some problems for different organizations to share information.
For example, the personal assistants from municipality and the nurses from County Council cannot share
their databases with each other.

We consider these as coordination problems in health care system. That is, the doctors and nurses are in
some way working solely without any formal communication channel. Therefore, they are unable to
coordinate their work in a formal way. In reality, phone calls are the most common way for them to
communicate and ask for help. When the nurses get a problem, they ask for help within their personal social
network. That is, they will call those who they know. However, you cannot guarantee that you may find the
right person who can help you out within such a small network.

To improve this situation, we adopt a solution based on Multi-Agent Decision System. In a research
project called Integrated Mobile Information Systems for health care (IMIS), we aim at providing a
communication platform and agent-based services to the users (nurses, doctors and patients) for home care.
This communication platform is constructed as a MAS environment. The users can access to system through
IMIS agents on either stationary PC or pocket PC, which should be able to access to the Internet. Through the
coordination among the IMIS agents, the doctors and nurses are able to work cooperatively. If doctors and
nurses can coordinate their work, the conflicts among their work may be decreased to some extent. Thus, a
well-designed coordination mechanism is the key factor for the system to function well. In the next section,
we introduce Activity Theory, based on which we developed a coordination hierarchy. We use this hierarchy
to define the relationships among the IMIS agents.

3. 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. In
Activity Theory, activity is also understood as context. Context is ‘the complexities of particular situations at
particular times with particular individuals’ (Nardi, 1996). The activity or context consists of six components,
namely object, subject, tool, rule and norms, division of labour, and community (Kuutti, 1996). The
introduction to Activity Theory in this paper is very limited to hierarchy and motivation, which will be
applied into the discussion of MAS coordination. For further details, you can refer to (Engeström, 1999,

3.1 The hierarchy of Activity-action-operation

An important perspective of Activity Theory is the hierarchy of activity-action-operation. (See figure 2) An
activity is always associated with a motivation. An action is performed with immediate, defined goal within
the frame of an activity. Motivation and goal will be discussed in details in the next sub-section. Operation is
understood as ‘routine’ in this case. It is associated with a condition. Activities consist of actions or chains of
actions, which in turn consist of operations (Kuutti, 1996). Activity, action, and operation can transform to
each other, when the associated motivation, goal, and condition change. When the action is practised long
and good enough, the goal of the action can be considered as a condition. Then the action collapses into an
operation. It is similar between an activity and action.

![Activity Hierarchy Diagram](image-url)

Figure 2. Activity hierarchy
3.2 Motivation

Another important perspective of Activity Theory is the motivation. Within an activity, the object motivates the activity and gives it a specific direction (Nardi, 1996). Leont’ev (Leont’ev, 1974) wrote, ‘behind the object, there always stands a need or a desire, to which (the activity) always answers.’ Some researcher called the object as ‘objectified motive’ (Christiansen, 1996). The motivation is always associated with the activity in Activity Theory. This is different from the common understanding in MAS research. In MAS research, motivation is usually considered as a property of individual agents. In this paper, we adopt the definition of motivation from Activity Theory. That is, motivation is the property of a group of agents, who are working together in one activity.

In this paper, we separate goal from motivation with two distinct aspects. First, motivation is on a higher level than goal. Motivation is a collective property of an activity system. Goal is the individual property of an entity or action. For example, the individual agent has its goals to achieve. While the whole MAS aims at a motivation. Motivation generates and is in charge of goals. Second, motivation considers context. Context includes the collective perspectives of the environment and gives them to the motivation. However, goal does not care about the context. It just cares about individual facts.

4. MOTIVATION DRIVEN MAS COORDINATION

Based on Activity Theory, Ricci, Omicini, and Denti (Ricci, et al, 2002) made an approach to discuss MAS coordination onto three levels: co-construction, co-operation, and co-ordination. These three levels are corresponding to activity, action, and operation in Activity Theory. Similar to the activity, the co-construction consists of chains of co-operations, which in turn consists of chains of co-ordinations. In our approach, we map Ricci et al’s model with motivation, goal and condition (in figure 2), and further define these three hierarchies as follows.

- Co-construction: about the understanding and reasoning of the MAS activity, based on the motivation;
- Co-operation: about planning what actions to take (by each individual agent), based on some kinds of goals;
- Co-ordination: about enforcing/automating the operations to manage the interactions under some kinds of conditions.

![Figure 3. Motivation driven MAS coordination mechanism, based on Ricci et al. (Ricci, et al, 2002)](image)

The basic idea in this model is hierarchy and motivation driven. Individual agents work on the co-ordination and co-operation level. On these two levels, agents only care about their own utilities. Co-operation decides the goal for an individual agent to achieve. Co-ordination defines the functionalities that can be automated by the agents. Such kind of coordination is driven by the individual goals and conditions. On the co-construction level, agents work together for a common motivation. The motivation in this case is similar to the joint-intention. In some cases, e.g., health care system, a group of agents work in a common activity. The co-construction in this group is driven by the motivation of the activity. The co-construction takes charge of the whole MAS coordination. Since the co-construction is motivated, the whole MAS coordination is also motivated. Co-construction, co-operation, and co-ordination together form the motivation driven MAS coordination mechanism.
5. IMIS COORDINATION MECHANISM

Health care system consists of non-antagonistic agents. These agents should cooperate instead of compete within it. Return to the question we proposed in the beginning: how to build up a motivation driven MAS from selfish agents in health care. An agent is selfish; however, the group of agents should not be selfish in health care system! To become a non-selfish group, the MAS should put some constraints on the individual agents. Thus, the selfish agents are organized to form a coherent and motivated group. This is also how we think IMIS agents should work together.

In health care system, if care-providers have a communication platform on which they can coordinate their work, the efficiency and quality of the home care can be much improved. The IMIS agents coordinate based on the mechanism discussed above. As figure 4 shows, all the stakeholders in the above scenario (figure 1) are connected via the IMIS platform. The dash lines stand for the communication channels that access to Internet through either stationary PC or pocket PC.

On IMS platform, the care providers and receivers are divided onto three levels based on our discussion in the last section. On the co-construction level, there exists a person who is in charge of the patient’s case in general. In most cases of health care, this person is the doctor. The doctor is responsible for the entire health care activity. The patients’ health is the motivation of this activity. The doctor divides the health care activity into actions that are delivered to the nurses. The primary care nurses and district nurses are on the co-operation level. They are responsible for the medical actions, e.g., distributing the medicine, and giving injections etc. The nurses usually are aware of their goals and how to achieve them. Some of the nurses’ work can be delegated to the staff nurses, who are on the co-ordination level. They are those who do most of the work and have good and long-term relations with the patients. The stuff nurses usually just do what they are told, and have no responsibilities to make decisions. Besides, the personal assistants are also on the co-ordination level, although she/he is responsible for the home service instead of home care.

The IMIS system provides different services/agents to the users based on the above coordination mechanism. We hereby only give a general description to the services provided to users, because it is not the focus of this paper to discuss the details. The services that are provided to the doctor are those that help them to monitor/co-construct the whole E-health service. The doctor monitors the patient’s case; but she/he does not have to go to the details, unless something happens and the patient needs a new diagnosis. The services that are provided to the diabetic and district nurses are those that help them co-operate with other nurses and doctors. Such kinds of tasks are usually associated with goals. The services that are provided to the staff nurses are those that help them co-ordinate with others and make their work more autonomous. Based on Activity Theory, these three levels are integrated, which means the co-construction level consists of the co-operation level, which in turn consists of the co-ordination level.
6. DISCUSSIONS AND CONCLUSION

This paper introduces a novel approach on MAS coordination. The discussion focuses on the collective aspects of a MAS. From the perspectives of Activity Theory, motivation does not belong to any individual agent, but is a property of a group of agents who are working together in an activity. The motivation is achieved through the satisfaction of chains of goals, which in turn are achieved through the satisfaction of chains of condition. Based on this hierarchy, MAS coordination is classified into corresponding three levels, namely co-construction, co-operation, and co-ordination. The MAS coordination is motivation driven through the co-construction among agents.

The purpose of this paper is to give the audience a view from the sociology on MAS coordination. Activity Theory, from the socio-psychology, contributes with the thinking of hierarchy and motivation. Hierarchy thinking helps the E-health system to be organized in a structured way. Motivation thinking leads the individual agents to cooperation and the whole MAS to a coherent state. We believe that Activity Theory, as an additional approach, will lead MAS research to a new paradigm.

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