Abstract—Computer agent is considered as a technology that may support human beings with automatic functionalities in the social environment. This paper describes an approach to applying agents to diabetic health care. A good health care agent is considered to be able to keep a good balance between individual flexibility and team control. A systemic approach is proposed hereby as a complementation to the current approaches. Multi-agent Systems (MAS) coordination is considered on three levels: collaboration, coordination and communication. In the end, an agent-based computer system—Integrated Mobile Information Systems (IMIS)—is discussed based on the systemic approach.

I. INTRODUCTION

Diabetes is attracting more and more attentions of the researchers from both medical and technical fields. On the one hand, the various complications caused by diabetes require various specialized medical workers to be involved in a single case. On the other hand, new technologies are needed to aid the cooperation among different medical workers. Hereby computer agent is considered to be a good candidate of new technology in this need.

Having been developing for decades, Agent Technology is considered to be of great opportunities in various kinds of approaches. Agent simulation, for example, has been utilized in various areas to help reduce the cost of human decision making [1, 2].

When adopting agents into diabetic health care, several approaches may be taken. Two current dominating approaches are reductionism and constructionism. Each has its advantages and weakness. In the following sections, we will first discuss the above two approaches within the diabetic health care background. Then we will introduce our systemic approach. In the end, we will introduce our project Integrated Mobile Information Systems for diabetic health care (IMIS)—an agent-based system designed for the diabetic health care.

II. MULTI-AGENT SYSTEMS COORDINATION

Agent is considered to be a computer system that is capable of executing some tasks automatically without human beings’ interfere. Computer agents work together towards an expected state of the environment. This cluster of agents forms a Multi-agent System (MAS). The interaction among agents is called coordination. MAS coordination mainly contains two trends, reductionism and constructionism.

A. Reductionism

Reductionism dominates in a sub-area of MAS called Cooperative Distributed Problem Solving (CDPS). CDPS usually takes a top-down solution to the problem solving. Starting with the top-hierarchy, the problem is decomposed into sub-problem, which continues to be decomposed until the sub-problems are able to be solved by individuals. The sub-hierarchy always obey the super-hierarchy. Thus, their interests should comply with the super-hierarchy’s interests, which eventually lead to the top problem. The benevolence assumption is usually considered as a precondition in this area. The benevolence assumption states: the agents in a system implicitly share a common goal, and thus that there is no potential for conflict between them [3]. Benevolence assumption indicates that sacrifice is necessary for every agent when its individual goal is in conflict with the team motivation.

The strong point of reductionism is that it keeps a good tradition from scientific method. Reductionism leads to a good hierarchy in problem solving. In diabetic health care system, such kind of thinking is necessary. For example, a diabetic patient may need to keep in touch with various care providers, since often he or she suffers from more than one kind of complications. There may be many doctors and nurses involved in this case. With reductionism, we can build up a hierarchical MAS, within which the responsibilities of individual agents are specified clearly. The team interest is always considered with the highest priority. There is less possibilities of misunderstandings and mismatches among agents, because all sub-hierarchy agents must comply with their super-hierarchy agents.

However, in the reality, diabetic health care system is flexible in the sense that the patients are usually cared distributedly. The care providers (doctors, nurses) possess
autonomy to some extent. And they must consider the individual patient that they are taking care of as the most important objective. They cannot make a decision to sacrifice one of their patients to optimize the whole team’s interest. Reductionism may optimize the team’s interest, but it will lose the flexibility of agents.

B. Constructionism

The constructionists, compared with the reductionists, concentrate on the individual agents. Individual agents are considered to be self-interested. Individual agent always takes the actions that will optimize their own interests. The team’s (MAS) interests are achieved through the coordination among individual agents under some predefined protocol, e.g., auction. The MAS coordination based on constructionism often leads to competition.

The strongpoint of constructionism is that it gives many details to the agent design and implementation. Agent autonomy is realized through distributing control and resource to individual agents. Individual agents decide their actions, or even their goals. From this point, the MAS is flexible. Often there is a central monitoring unit playing a similar role as server, which monitors and coordinates the agents’ activities.

However, decentralized control and resource may not always improve the MAS efficiency. The starting point of constructionism is the self-interest instinct of agents. Thus, it is a difficult issue to make agents cooperate in this case. A famous cooperation protocol is Contract Net (CNET), which is a high-level protocol for achieving efficient cooperation through task sharing in networks of communicating problem solvers [4-6]. In Contract Net, there is no permanent central unit. Every node/agent may become a centre for communication. When there is a task, the task generator becomes the centre/server who will coordinate the coordination among other agents. When the task is achieved, the relationship among the agents will be destroyed at the same time. Thus, the relationship among the agents is dynamic.

In diabetic health care, the relationships among stakeholders/agents are static and stable. The diabetic patients normally keep constant contact with their care providers. Thus, a centralized coordination mechanism may be more efficient than a decentralized one, since there is no need to set up relationship temporally at run time. Besides, in health care area, we cannot let the agents have full autonomy and do whatever they want. A group of self-interested agents may compete among each other and decrease the efficiency and quality of the diabetic health care. In summary, if we take the constructionism, we may give much flexibility to agents, but it is easily to lose the control over agents.

III. SYSTEMIC APPROACH TO MAS COORDINATION

From the above discussion, neither reductionism nor constructionism is realistic in the diabetic health care. A good agent should keep a good balance between individual flexibility and team control. Thus, we believe that we need to find a new way of thinking about MAS coordination in application in diabetic health care.

In this paper, we give some systemic thinking to the MAS coordination. The aim is to find out a general mechanism for MAS coordination, which should give the agents autonomy as much as possible, while keep the general maintainability of MAS at the same time. The systemic thinking hereby indicates that MAS is considered as a holistic system during the analysis. The individual agent is considered as a system element, which has interrelationships with other agents.

Systemic approach, compared with reductionism, allow the system elements to keep autonomy to some extent. That is, the individual agent is considered as self-interested. However, different from constructionism, the individual agent is always part of the whole MAS.

A. Five Parameters to Define MAS

According to [7], there are five parameters that are necessary to define a MAS: 1) level of cooperation among agents, 2) regulations and protocols, 3) number of agents, 4) type of agents, and 5) communication and computation costs.

Computer agents can be designed to be cooperative that they work together to satisfy the same goal. In this case, there is only cooperation in MAS coordination. However, agents are often designed to be self-interested, who try to maximize their own utilities. The coordination among extreme self-interested agents is competition. There are also intermediary cases that self-interested agents coordinate themselves to achieve a joint goal.

Normally the designers of the agents should agree on some regulations for the agents to interact in advance. The regulations often depend on the environment where the agents will work in. The protocols are the languages that agents use to communicate with each other. There are also cases that there are no pre-defined regulations.

The number of agents is an important parameter for MAS. Depending on the size of the MAS, different approaches may be taken to design MAS coordination. For example, if the number of agents is small, game-theoretic and operation research (OR) techniques may be good candidates. If there are a large number of agents in the MAS, game-theoretical approaches may be too time-consuming and complex. A good candidate is the methods of classical mechanics used by physicists to tackle the problem of finding the properties of interaction among many particles [8, 9].

Agents may be classified to several categories depending on the extent to which it is autonomous. Agent can be simply purely reactive to the environment. Agent can also be intelligent to autonomously achieve the tasks without any interfere from human beings. Agent can also be a composition of computer systems and human beings. In this paper, we classify agents into three groups: collaboration/activity agent, coordination/action agent, and communication/operation agent.

Agents communicate and compute in order to achieve their tasks. It costs time and power. If the designers put most of the computation work load on a central server, the agents do not need to communicate a lot. However, the computation cost of the central server will be high. One the contrary, if the designers put the computation work on the individual agents, the computation cost of the server will be highly decreased,
but the communication cost between agents will be increased. Thus, the communication and computation cost should be determined based on the problem situation in the reality. A good balance between computation and communication should be found before the MAS designers decide the MAS architecture.

B. Three Levels of MAS Coordination

The systemic approach considers MAS coordination on three levels, communication, coordination, and collaboration [10]. When designing MAS coordination protocol/mechanism, these three levels should be considered.

Communication level is the basic level. On this level, agents are able to exchange message among each other. The realization of this level requires a common ontology among agents. Agent Communication Languages (ACL), for example, KIF [11], KQML [12], are enough to realize this level. Normally, ACL are message based language for agent communication.

Coordination level is where agents exchange goals, while communication level is where agents exchange information. The goals hereby mean the intentions owned by individual agents. Once an agent decides its goal, it should commit to it and should not give it up easily. Thus, it is very important for the individual agent to coordinate their goals to avoid the conflicts to the lowest level. A possible solution is to define the agents’ goals carefully in advance. In a relatively static environment, e.g. diabetic health care, this can be done through specify agents’ roles according to health care labour division.

On the collaboration level, agents should consider the motivation of the MAS activity. Motivation belongs to a group of agents who are performing one activity. All the individual agents in one activity work to achieve the same motivation. Thus, even though the individual agents have different goals, they still collaborate to achieve the same objective/motivation.

C. Systemic Approach to Design

To start designing the MAS coordination mechanism, systemic approach should give a definition to the target MAS according to the five parameters. Then, the collaboration level should be considered firstly. This is a general design of the MAS construction. Main activities are defined. Secondly, the coordination is designed in order to perform the activities. The relationship among agents are defined. Thirdly, the communication language is chosen for the agents to exchange message/information.

IV. CASE: INTEGRATED MOBILE INFORMATION SYSTEM (IMIS)

In this section, we will apply our systemic approach to design an agent-based computer system – IMIS. IMIS is designed to support the diabetic workers with agent-based services.

A. IMIS Definition

We consider IMIS as a MAS. We define this MAS according to the five parameters introduced above.

The cooperation among IMIS agents exists on three levels: collaboration, coordination and communication. On collaboration level, IMIS agents focus on the cooperation among health care organization. On the coordination level, IMIS agents are considered to be self-interested. The reason that we design IMIS agents to be self-interested instead of cooperative is that we want to give as much as possible autonomy to the agents. Cooperative agents can work smoothly with each other. But this will loose the point of autonomy, which is necessary in diabetic health care.

The regulations of IMIS agents are mostly based on the practical situation of diabetic health care system. Nowadays, the Swedish health care involves various formal and informal organizations. Hospital, Municipality and County Council are formally involved in the health care with their corresponding health care services. There are also some informal organizations involved, e.g. shopping, taxi, etc. IMIS cannot change anything about the regulation in these organizations. What we can do is to apply and reflect the existing regulations to the MAS coordination design.

IMIS will start from a small area for testing purpose. However, during the process of development and application, a broader area will be applied. A systemic approach is taken to consider IMIS design. Three levels or steps in this approach will be discussed later.

IMIS is an Internet-based system. The IMIS agents are considered as Information Agent [13]. In diabetic health care analysis, we consider the whole system on three levels: activity/collaboration, coordination/mechanism and operation/communication. Correspondingly, we classify IMIS agents into three groups: collaboration agent, coordination agent and communication agent. The communication might use the ACL, e.g. KIF, KQML, or standard information exchanging language on Internet, e.g. XML.

An important aspect of diabetic health care is the distribution [14]. The IMIS agents work at the edges of the system. Thus, we put most of the computation work load on the distributed individual agents. The work load of the IMIS server is decreased to the most extent. The computation is thus distributed.

B. IMIS Coordination Mechanism

Based on the above definition, IMIS coordination design is considered on three levels: collaboration, coordination and communication. The IMIS agents are classified by their roles in the coordination.

The collaboration level of IMIS is also the most intelligent level where agents can serve. IMIS collaboration is conducted by collaboration agents. The main task of collaboration agents is to collaborate health care organizations. In IMIS we define several organizations like hospital, home services, patient homes, and other services providers (shopping etc.). These health care organizations conduct their corresponding health care activities. The responsible agent for each activity is called collaboration agent. Collaboration agent defines the role/activity and the responsibility of each organization. Another important task that the collaboration agents conduct is to decompose the activities into actions and delegate them to the sub-level agents, which are considered as coordination
agent. As Figure 1 illustrates, collaboration agents are responsible for the health care organizations, e.g. hospital, home service, other services providers and patient homes. These agents coordination through the IMIS server.

The coordination level of IMIS is responsible by coordination agents. From the collaboration agents, health care activities are decomposed into smaller tasks/actions that can be performed by coordination agents. Coordination agents mainly conduct two kinds of actions, depending on whether the two coordination agents are within one health care organization or not. For example, in Figure 2, agent 2 and 3 both work in home care organization from County Council. They may be involved in one health care activity – taking care of one patient. Thus, to achieve this task they need to coordinate their work. In another case, agent 3 and 4 work for Home Service from Municipality. They also may work in the same health care activity. In this case, cross boundary coordination is needed. The latter coordination is the most important role that the coordination agent should play in the reality. There exist many misunderstanding, mismatches between different health care organizations. These misunderstanding and mismatches are considered as ‘Grey Zone’ in our IMIS. Thus, the most important task of IMIS coordination agents is to work within the Grey Zone and make a good connection between different organizations. We have described the Grey Zone problems in [15].

The communication level on IMIS platform is the technical level. Nowadays, the nurses use mobile as the main tool for communication with each other. Some other tools like fax, email, SMS are also used. These different communication channels are not guaranteed to be working in a synchronizing way. IMIS platform is itself a common communication platform. Care providers and care receivers can share their information on this common platform. This avoids the mismatch and desynchronization problem that might caused with the mobile communication. With information sharing, the IMIS agents can work on either stationary computer or mobile devices. The care providers can visit the IMIS system at anytime anywhere to access the most updated information of the patients, and upload the new information of the patients to let other care providers to browse.

![IMIS Server](image)

**Figure 1. IMIS collaboration**

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![IMIS Coordination](image)

**Figure 2. IMIS Coordination**

We define IMIS to be a MAS that is: 1) made of self-interested agents, 2) regulated by difference organizations, 3) expanding size, 4) made up of Information Agent and 5) distributed computation. The IMIS coordination is realized by on three levels via three categories of agents. The whole IMIS system is considered as a MAS. The IMIS coordination is classified into three levels, on which corresponding agents are taking the responsibilities. See Table 1.

**TABLE I**

<table>
<thead>
<tr>
<th>MAS Coordination levels</th>
<th>Collaboration</th>
<th>Coordination</th>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent type</td>
<td>Activity agent</td>
<td>Action agent</td>
<td>Operation agent</td>
</tr>
<tr>
<td>Objectives</td>
<td>Collaborate big health care organizations.</td>
<td>Coordinate agents within one activity.</td>
<td>Smallest unit of IMS.</td>
</tr>
<tr>
<td></td>
<td>Decompose activities and delegate to action agent</td>
<td>Decompose actions and delegate to operation agents</td>
<td>Communicate with each other on technical level based on standard protocols.</td>
</tr>
<tr>
<td>Example</td>
<td>Task delegation</td>
<td>Organization coordination</td>
<td>Information sharing</td>
</tr>
</tbody>
</table>

Compared with reductionism, systemic approach gives much more autonomy to the individual agents. In reductionism, individual agents are considered as sub-unit
that must obey their super-hierarchies. On the coordination level, individual agents are allowed to possess individual goals or intentions. Thus, the agents can make their own decisions and try to maximize their own utilities. This gives much freedom to the agents.

Compared with constructionism, systemic approach starts with the whole MAS. It gives a holistic view on the MAS coordination via the collaboration design. MAS activities are designed in the first stage. Based on the MAS activities, individual agents are assigned with actions, which compose of activities. Although, individual agents have the autonomy to take any actions, the actions cannot be inconsistency with the MAS activity.

In summary, through a balance between MAS collaboration and agent coordination, a balance between team control and individual autonomy is realized.

REFERENCES