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智慧型機器人手臂研發與應用

Research and Applications of Intelligent Robotic Arms

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Abstract

This study is motivated by robotic applications in healthcare industry. One of the major issues in healthcare industry is the shortage of manpower for caregiving, specifically to the elderly people. Nowadays, the aging societies increasingly growing become globally the serious issue for healthcare. In Taiwan, the birth rate decreasing dramatically results in more seriously the future caregiving issues. Under this circumstance, the autonomous robots with artificial intelligence for healthcare can be developed and involved with resolving this common problem existed globally. Since the latest development in the healthcare information-and-communication technologies (ICT) systems are massively involved with mobile devices, there is a research topic emerging in mobile computing of how to design such an efficient mobile network for intelligent robotic arms. Accordingly, each robotic arm carrying with a set of node devices in a mobile healthcare network can move freely and reestablish connections to its neighboring nodes with wireless links. Therefore, one of our major concerns is how to dynamically route heavy traffic of the health and motion information in the mobile network. In that case, we employ an intelligent-agent system for each node which is able to autonomously maintain the dynamic-routing information. Through both the interaction and collaboration between these agents associated with the mobile nodes, this research focuses on establishing an efficient mobile network protocol to manage dynamic routing of the health and motion information. In this report, a multiagent network is hence designed and applied to connection of the mobile robotic arm in an ICT system.

Keywords: intelligent robotic arm, multiagent network, ICT system, mobile computing, dynamic routing

中 文 摘 要

本研究的動機，源自於機器人在健康照護產業的應用。 近年來，全球正逐漸邁入高齡化與少子化的社會；這將造成健康照護人力需求嚴重短缺。為了能夠有效解決健康照護需求的問題，研發智慧型機器人手臂應用於協助年長者的復健、物理治療、日常起居等健康照護，成為刻不容緩的研究課題。本研究中，智慧型機器人手臂的設計將以移動平台，結合具有人工智慧的資通訊系統。其中，智慧型機器人手臂將能夠具備傳輸生理資訊、移動定位、發出警示訊息等功能。

由於新近的健康照護資通訊系統開發，大量地使用行動裝置，設計有效率的行動健康照護網路成為行動計算的主要研究課題。在一個行動健康照護網路中，每一個智慧型機器人手臂攜帶一組節點裝置，且都能夠自由地移動，同時可以透過無線方式隨時與其鄰近的節點進行動態連線。因此，問題焦點是如何能夠在行動網路中，動態地遶送繁忙的健康照護和移動資訊流量。在此情況下，我們為每個節點導入智慧型代理人系統，自主地維護其動態遶送所需的資訊。本研究專注於透過這些代理人之間的互動與合作，建立一個有效率的行動網路協定，以管理健康照護和移動資訊的動態遶送。在本篇論文中，我們提出一個多代理人網路應用於智慧型機器人手臂的連線，並利用該多代理人網路完成健康照護資通訊系統的設計。

關鍵字：智慧型機器人手臂、多代理人網路、資通訊系統、行動計算、動態遶送

1. Introduction

Robotic research has been a long-term relationship with Artificial Intelligence (AI). This merging development from these two fields brings on more applications in industry. Design of intelligent robots is one of the industrial applications. In this study, the intelligent robots become the mobile agents which form a local multi-agent network to exchange the healthcare information autonomously collected from the elderly people, such as body temperatures, cardiogram signals, blood glucose indices, etc. Eventually, the information will be uploaded to the "medical and healthcare clouds" via Internet.

Meanwhile, information and communication (ICT) systems increase their popularity and importance in wide applications due to the fast development of mobile computing devices with advanced technology in short-range wireless ad hoc networking capability. With dynamic routing protocols, ICT systems become more scalable and efficient. (Wu & Tseng, 2007; Banerjee, Acharya, & Das, 2007) The applications include healthcare ICT systems, rescuing missions, mobile communication between unmanned air vehicles (UAVs) or patrol robots, peacekeeping or law enforcement after disasters, sensor networks, to name a few.

In this study, our concern is to design a mobile healthcare ICT system with intelligent robots which autonomously collecting bio-signals from the elderly people. This system is involved with care-giving to the elderly living in a smart space. Therefore, a sensory system for location-awareness is adopted to autonomously update information from the persons and the space (i.e., environment). (Harle & Hopper, 2008) Each person and the sensory system form a mobile network via wireless communication.

A wireless network which consists of subgroups of connected hosts is shown in Fig. 1. These hosts can be *static* sensors at fixed positions. If carried by the intelligent robots, they also can possess mobility and dynamically regroup themselves as loosely connected hosts within such a wireless network. In other words, these hosts are decentralized as a distributed network system. Moreover, each subgroup in the network forms a sub-network system and could potentially execute search in parallel rather than sitting idle. Accordingly, there exists a dynamic-graph problem with such mobile hosts as networking nodes. If we adopt intelligent agents for individual hosts, a multiagent system can be used to dynamic routing for communication between connected hosts. (Pearce, Tambe, & Maheswaran, 2008; Modi, Shen, Tambe, & Yokoo, 2005)

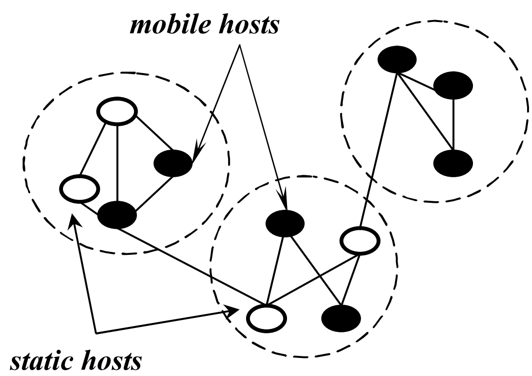

Fig. 1 A wireless network with subgroups of connected hosts.

An intelligent agent for each node in a dynamic graph usually consists of two parts. One is the *agent's architecture* which includes *sensors* for percepts and *actuators* for actions while the other is the *agent program* which performs mapping from the percepts to the actions. (Russell & Norvig, 2003) Accordingly, each agent can percept and interact with its *neighbors* in its environment. This forms local sub-networks for smaller multiagent systems. From the networking viewpoint, a wireless network, as shown in Fig. 1, can be re-illustrated as a group of multiagent sub-networks interacting with their environment in Fig. 2. (Wooldridge, 2002; Zambonelli, Jennings, & Wooldridge, 2003)

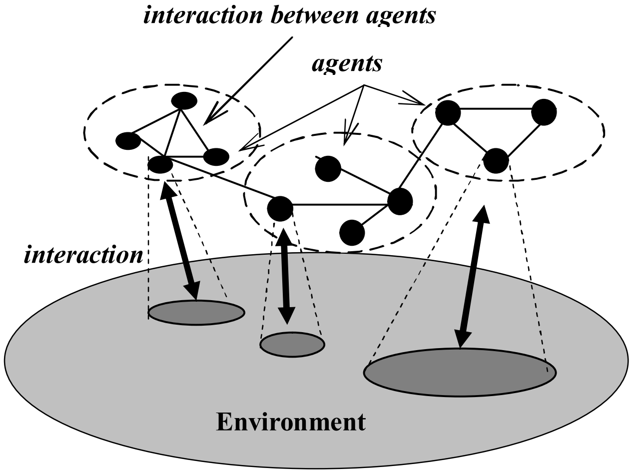

Fig. 2   Agents interacting within multiagent networks and with their environment.

Fig. 2 shows interactions among agents within the multiagent networks. These agents also interact with their environment individually. When the effects of interactions between the agents and their environment can be ignored by comparison, the local interactions within a multiagent network usually depend only on actions from the agents in such a network. At this circumstance, this graph-based multiagent system can be hence solved through a *distributed constraint optimization problem* (DCOP). (Pearce et al., 2008; Modi et al., 2005)

A DCOP includes a set of variables, each corresponding to an agent. Values of the variables indicate individual actions taken by the agents. There exist constraints between subsets of these variables that determine penalties and rewards to the multiagent network from the actions taken by their respective agents. Some researchers, such as Modi *et al.* with a complete algorithm named Adopt, obtained a global optimal solution to DCOPs. When the size of the problem domain scales up, it definitely increases computation and communication costs.

Since local interaction is a major feature in such multiagent networks, an agent only interacts locally with its neighbors, i.e. the other agents within the same network. In other words, incomplete algorithms for local agents forming sub-networks in order to easily optimize inside their subnets. This can easily assist the dynamic routing in a large-scale network. On this behalf, an approach called *k-optimality* can be adopted for DCOPs. It should be noted that complete algorithms are guaranteed to reach a globally optimal solution while incomplete algorithms reach a local optimum and do not provide guarantees on solution quality. (Pearce et al., 2008)

This project is attempting to design intelligent robotic arms to accommodate themselves to a multiagent-based mobile healthcare network. It has to be involved with appropriate location-awareness for robotic arms via intelligent agents in order to exchange the health and motion information. The location-aware system architecture is employed and modified from Harle and Hopper's work (2008). Insomuch as this system is based on the multiagent approach, we hence adopt a hybrid *k*-optimal method as our approach to solving multiagent networks for DCOPs. Our approach focuses on how to appropriately decide the local *k*-optima for DCOPs as mobile agents dynamically regroup themselves to form new subnets as time being. The rest of the report is organized as follows. In Section 2, the location-aware system architecture is delineated. Then, the original *k*-optimal approach and our current approach will be described in Section 3. Requirements for designing such mobile intelligent robotic arms are discussed in Section 4. The concluding remarks and future work will be given in the last section.

2. System Architecture

When a robotic arm enters a smart space by wearing a mobile device which can transmit personal health as well as motion information via wireless communication, the receiving sensory system on a mobile intelligent robotic arm will autonomously update information due to the environmental change. Therefore, we will not only build up a mobile network system but also a location-aware system. It becomes important to identify some healthcare-related situations with location awareness. For example, a person with severe dementia who needs continuing reminders can survive in such a location-aware smart space. (Mihailidis & Fernie, 2002)

In the following, a location-aware system architecture introduced in Harle and Hopper's work (2008) will be modified and adopted to fulfill the requirements in this study. Harle and Hopper adopted a high-accuracy, pervasive, ultrasonic location system called the *Bat system*. The system was used to monitor and update the inconsistencies in the world model which is constructed from the percepts of the sensory system. The monitor framework is accomplished by inputting percepts from the sensory system into a series of *filters* which generate the coarse representation of the world.

In this project, we introduce the intelligent-agent system for the moving robotic arm and each static sensor node. When the robotic-arm activities cause the environmental change detected by an intelligent agent, the sensory system on the person will collaborate with the mobile device on each node of the robotic arm to update the change. The system architecture is illustrated in Fig. 3.

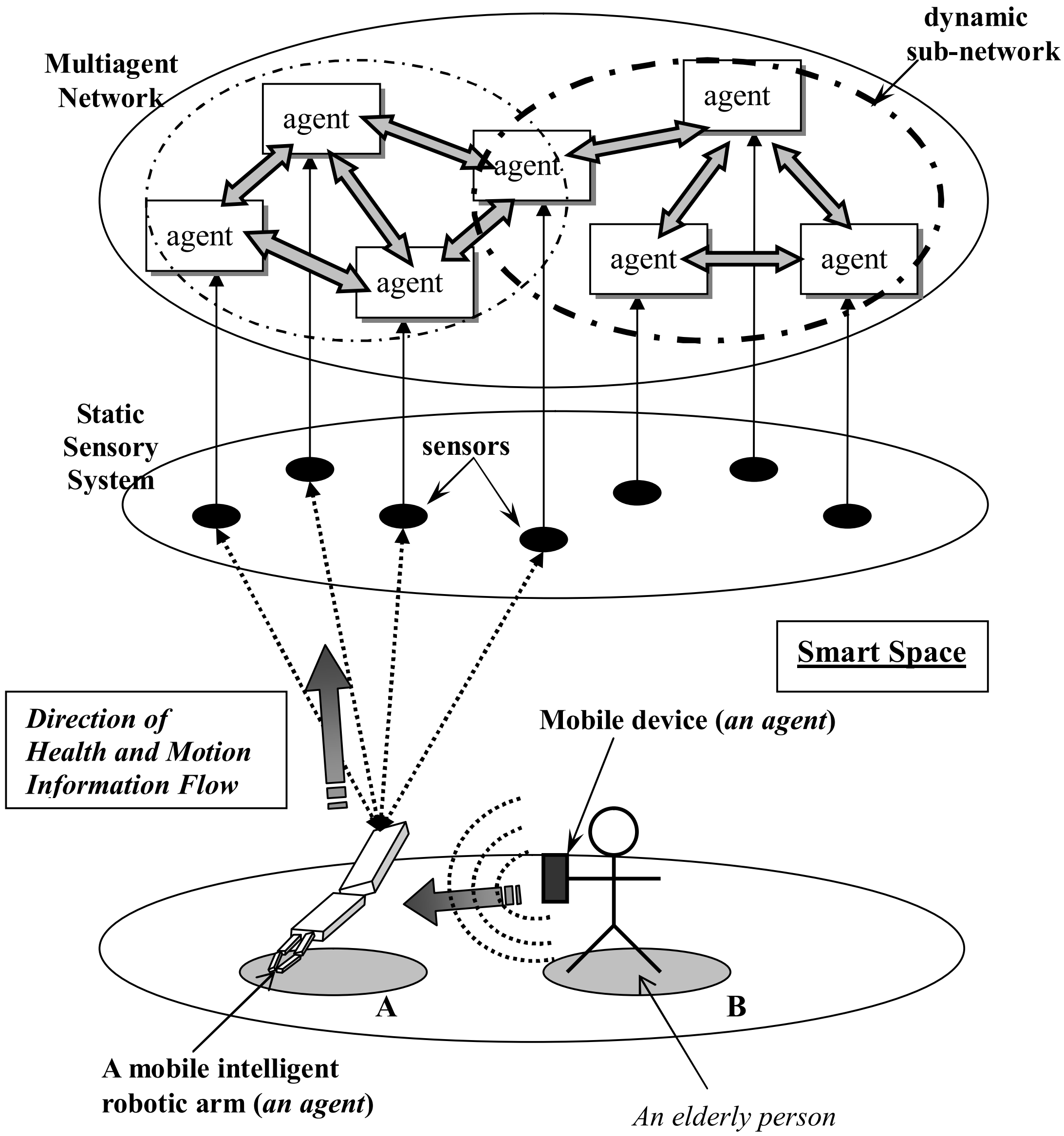

Fig. 3 An illustration of a multiagent-based location-aware network for mobile ICT-systems

In Fig. 3, it shows that when a person with a mobile device moves in a smart space, the device keeps on transferring health and motion information to the static sensory system. The input data will be processed by the attached multiagent system. Meanwhile, the world model will also be updated in order to locate the person for further information.

In the next section, a hybrid *k*-optimal method for solving DCOPs will be introduced to accommodate to the multiagent system for updating the world model.

3. Approach

In this section, the concept of k-optimality for DCOPs will be introduced first. Then our approach regarding a hybrid k-optimal method will be described. Let us begin with defining a distributed constraint optimization problem.

Distributed Constraint Optimization Problem

A DCOP consists of n variables $X = \{x_1,\ldots, x_n\}$ and a set of domains $\mathrm{D} = \{\mathrm{D}_1,\ldots, \mathrm{D}_n\}$, where the i^{th} variable, x_i, takes value a_i in D_i. We denote the joint action (or assignment) of a subgroup of agents $S \subset X$ by a_s and the joint action of the multiagent team by $a = [a_1,\ldots, a_n]$.

A reward function $R(a_s)$ is defined for a constraint on S, which represents the reward to the team generated by the constraint on S when the agents take assignment a_s. By minimality of the reward $R(a_s)$ obtained by the subset of agents, these subsets S are so-called the *constraints* and the functions $R(\cdot)$ the *constraint reward functions*.

k-Optimality

According to DCOPs aforementioned, for two joint actions, for example, assignments a_i and a_j, we define a deviating group, $D(a_i, a_j)$ which represents the set of agents whose actions in both assignment a_i and a_j are different.

If we decide the distance between assignments a_i and a_j, $d(a_i, a_j)$, as the number of agents with different actions, i.e. the so-called *cardinality* of the deviating group, then the *relative reward* of a_i with respect to a_j is written as

$$\delta(a_i, a_j) = R(a_i) - R(a_j).$$

Thus we can define the local k-optimum as follows:

“If $\delta(a_i, a_j) \geq 0 \ \forall \ a_j \ni d(a_i, a_j) \leq k$, then the assignment a_i is called a *k-optimal assignment* or *k-optimum*.”

Accordingly, if a k-optimum has been reached, there is no subgroup of cardinality k or less being able to improve the overall reward by choosing different actions.

A Hybrid k-Optimal Method

Our approach for a hybrid k-optimal method is dynamically selecting k value based on the mobility of local agents. Since the 1-, 2- and 3-optimal algorithms have been investigated (Pearce et al., 2008), we can take advantage of these algorithms with locally centralized multiagent networks. The results of incomplete algorithms will be implemented in agents who will serve as masters for their team. Then, when each subnet adds or loses agents, the master agent will dynamically update its neighbors’ information, as shown in Fig. 3. Hence it will find the most appropriate k-optimal algorithm for mobile communication in a multiagent network.

4. Design Requirements of Intelligent Robotic Arms

Based on both the system architecture and approach, the mobile intelligent robotic arms should be designed in order to fulfill the following requirements:

- possessing a *sensory system* for receiving both the health information (or bio-signals, such as body temperatures, cardiogram signals, blood glucose indices, etc.) as well as motion information from the elderly person;
- possessing a *transmitting device* to transfer the received health and motion information to the ICT system;
- possessing a *location-aware sensory system* to track the robotic-arm motion;
- possessing a *navigation system* for mobility to following the robotic arm.

5. Concluding Remarks

The current study for a multiagent-system application to a mobile network has been designed for intelligent robotic arms in an ICT system. Globally, we adopt a location-aware system for smart space implementation. For the functions of the multiagent system, we introduce the concept of *k*-optimality for a possible solution for both global and local solutions for DCOPs. The global network still remains decentralized. However, the multiagent networks are locally centralized by assigning a certain agent as a master for each subnet. This will provide mobility for the entire mobile network and reduce complexity of computation. In the light of both the system architecture and approach, the requirements for designing the mobile intelligent robotic arms hence have been identified.

The future work will continue focusing on implementing the intelligent robotic arms and realizing the hybrid *k*-optimality method to DCOPs for ICT systems as well.

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