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Environmental Inspection using WSANs Based on Multi-agent Coordination Method

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***Abstract*—**In this paper, we focus on the problem of driving and herding a collection of autonomous actors to a given area. Then, a new method based on multi-agent coordination is proposed for solving the problem.

In our proposed method, we assume that the environment is covered by sensors. When an event is occurred, sensors forward information to a sink node. Based on received information, the sink node will estimate the direction and the speed of movement of actors and announce the obtained value to the actors. The actors coordinate to reach the target location.

***Keywords*—**Coordination, Environmental Inspection, Multi-agent systems, Wireless Sensor and Actor Networks (WSANs)

I. Introduction

Wireless sensor and actor networks (WSANs) refer to a group of sensors and actors linked by wireless medium to perform distributed sensing and acting tasks. In such a network, sensors collect information about the physical world, while actors take decisions and then perform appropriate actions upon the environment, which allows a user to efficiently sense and act at a distance [1].

Unlike conventional sensor networks that a central entity was responsible for processing information and division of tasks, in this type of networks processing and decision-making process may be distributed, therefore, coordination plays an important role. In fact, using their communication and processing capabilities, multiple actors can coordinate to decide on appropriate actions based on information received from sensors.

In this paper, we propose a method using coordination concept in multiagent system in order to inspect environments in wireless sensor and actor networks.

Following this introduction, we provide backgrounds of the paper in Section II, describing multiagent definition and WSAN architecture. Then, in Section III, we propose our method, followed by stating some of the related works in Section IV. Finally, in Section V, we end up with conclusion.

II. Backgrounds

In this section, we provide backgrounds of the paper; first, describe multiagent definition and then WSAN architecture.

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A. WSAN and MAS

“Multi-agent Systems (MAS) are systems composed of multiple interacting computing elements, known as agents”[2]. Based on M.Wooldridge definition: “Agents are computer systems with two important capabilities. First, they are at least to some extent capable of autonomous action of deciding for themselves what they need to do in order to satisfy their design objectives. Second, they are capable of interacting with other agents - not simply by exchanging data, but by engaging in analogues of the kind of social activity that we all engage in every day of our lives: cooperation, coordination, negotiation, and the like”[2].

As an intelligent entity, an agent works flexibly and rationally in a variety of environments with useful instruments equipped [3]. Multi-agent systems are one of the best forms of designing a distributed computing system in which information processing is ubiquitous. Agents can be software entities that refer to hardware entities that could be embedded, e.g., mobile robots, cameras, PDAs, laptops, mobile phones, web cameras or any other device.

A sensor or an actor node at least is sensing, processing and communicating equipment and supposed to be enough intelligence to decide what to do, according to sensed and communicated data. Therefore, an individual sensor or actor can be considered as a simple agent.

Wireless sensor networks which belong to distributed systems are self-organizing. Self-organization is a concept that enables systems consisting of huge numbers of autonomously acting subsystems to perform a cooperative task. Moreover, self-organizing systems indicate an overall behavior that cannot easily be predicted or even preprogrammed in a scalable way [4].

Having autonomous agents is one of the central characteristics of a multi-agent system that both actors and sensors have it, thus, wireless sensor and actor networks similarly can be mapped to multi-agent systems. In this way, wireless sensor and actor network can be considered as a kind of multi-agent system that nodes are considered as agents. Usually cooperation and organization is very simple due to autonomous agents [5].

B. WSAN Architecture

WSANs can be classified into two main architectures [1]: automated architecture and semi-automated architecture which in the following we shortly define using Fig. 1 [1].

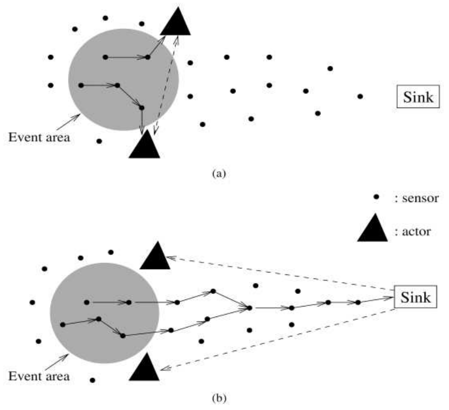

Fig. 1 (a) automated, (b) semi-automated architecture (from page 322 in [1])

Automated architecture: This type of architecture is shown in Fig. 1(a). In this architecture, sensors send their observations to appropriate actors. The actors may coordinate to decide on a right action. Since in this case there is not any central controller, e.g., sink or human interaction, this architecture is named automated. In this circumstance, the observations are distributed among actors and it is necessary for them to coordinate to make decisions.Semi-automated architecture:This type of architecture is shown in Fig. 1(b). In this architecture, the central controller called sink, collects data and coordinates the action process. Sensors detect a route data back to the sink, which might issue action commands to actors.One of these architectures may be applied, based on the type of the application. In this paper, we focus on Semi-automated architecture.

III. Our Proposed Approach

Here we describe our proposed approach for coordinating in a wireless sensor and actor network mapped with multiagent mechanism.

Our coordination mechanism aims to guide a group of agents inspecting an environment, where inspecting means removing harmful objects from environment. Thus, it is important to keep information about environment always updated.

In our scenario, there exists an environment covered by sensors, and there are also some actors in the environment.

Sensors would forward information to sink node, then according to received data, sink node will specify the movement direction of actors. Actors classified into two groups: leaders and followers. The sink node communicates with leader actors and sends them information about direction and speed of movement. Leader actors have duty to coordinate with each other and keep follower ones in the inspection area.

The main applications of this approach would be, for example, in removing harmful chemicals and clearing minefield in military applications. In this paper, we consider the problem of removing chemicals.

In this case, several applications are required:

1- Monitoring the environment, the direction and speed propagation of chemicals. In this application, sensors send the sink information about the source of leakage and the new zones polluted by the chemicals.

2- Using the received information, the sink node estimates the direction and speed of propagation of leakage and will direct the leader actors to the polluted area.

3- The leader actors should herd the follower actors to the area determined by sink in order to investigate the area. To do so, according to the received data from sink, the leader actors will communicate with each other and decide to herd the follower actors to the area after coordination.

According to this description, we can identify three required actions: first, data aggregation, second, estimation, and third coordination.

For data aggregation the conventional approaches such as the approach in [10] can be used. Obtained data can be used to estimation. The aim of third item is to lead and maintain the actors in the inspection area. For achieving this goal, the approaches of containment problem are used.

The containment problem is to drive a collection of autonomous mobile agents to a given target location while guaranteeing that their motion satisfy certain geometric constraints [11]. It is shown in [11] that as long as the interaction graph is connected and the leaders are stationary, the followers will always converge to locations in convex hull spanned by the leaders.

One of the other main problems is consensus problem. The consensus problem is basically a problem including having multiple agents reaching an agreement over a network. This problem is a canonical problem in decentralized coordination and it can be solved quite sophisticatedly using algebraic graph theory [12].We note that, as shown in [13], consensus problem is realized as long as the network stays connected; it means all agents will converge to the static leader (or anchor) agent. This fact essentially allows us to control the network by moving the leader agent around. In fact, as long as it moves slowly enough (as compared to the convergence rate of the consensus equation) we can expect the other agents to follow the leader agent rather closely. Moreover, if we have a number of stationary leader agents, it was shown in [11] that the remaining agents will in fact converge to the convex hull spanned by the leader agents. In order to get more information, we refer readers to [11], [12] and [13].

IV. Related Works

In recent years, WSANs are increasingly applied to many scenarios such as wide-area monitoring, security, target tracking and etc. Because of similarity in WSAN and MAS, many MAS mechanisms are applied to WSANs.

In [6], some implemented example of sensor networks based on agent technologies has been described.

A survey of agent technologies for wireless sensor networks has been done in [7], where agents are classified into three classes, mobile software agents, mobile hardware agents and sensor nodes as agents.

In [3],[8], a number of methods has been proposed for target tracking based on WSNs which in both papers multi-agent coordination mechanisms are used.

In [9], the authors studied the team coordination problem, between a set of vehicles. The main role of the vehicles is to penetrate into dangerous areas, to gather information and send them back to the incident commander. The vehicle's team leader is remotely controlled by the incident commander, while each team member coordinates with it, to define its direction and speed.

V. CONCLUSION

In this paper, we proposed a multi-agent approach in order to inspect environments. When an event occurs in the environment, the sensors communicate with sink node and the sink node will drive the actors to the event area to inspect. The actors coordinate based on a multi-agent approach to get to the target location.

Our future work will be based on proposing coordination mechanism on automated architecture which means omitting the sink node. In such architecture, the multi-agent negotiation approaches should be used to determine the target location.

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