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Autonomous multiple teams establishment for mobile sensor networks by SVMs within a potential field

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ABSTRACT

In this work, a new method and algorithm for autonomous teams establishment with mobile sensor network units by SVMs based on task allocations within a potential field is proposed. The sensor network deployed into the environment using the algorithm is composed of robot units with sensing capability of magnetic anomaly of the earth. A new algorithm is developed for task assignment. It is based on the optimization of weights between robots and tasks. The weights are composed of skill ratings of the robots and priorities of the tasks. Multiple teams of mobile units are established in a local area based on these mission vectors. A mission vector is the genetic and gained background information of the mobile units. The genetic background is the inherent structure of their knowledge base in a vector form but it can be dynamically updated with the information gained later on by experience. The mission is performed in a magnetic anomaly environment. The initial values of the mission vectors are loaded by the task assignment algorithm. The mission vectors are updated at the beginning of each sampling period of the motion. Then the teams of robots are created by the support vector machines. A linear optimal hyperplane is calculated by the use of SVM algorithm during training period. Then the robots are classified as teams by use of SVM mechanism embedded in the robots. The support vector machines are implemented in the robots by ordinary op-amps and basic logical gates. Team establishment is tested by simulations and a practical test-bed. Both simulations and the actual operation of the system prove that the system functions satisfactorily.

1. Introduction

In this paper, a new method and algorithm for team establishments within a mobile sensor network (SN) is proposed. The sensor network deployed into the environment using the algorithm is composed of robot units with sensing capability of magnetic anomaly of the earth. They utilize KMZ51 un-isotropic magneto resistive sensors. The sensors are combined to obtain a convolution mask for steepest descent in the magnetic anomaly region. The innovation in this method is to establish more than one team based on tasks available in the region of operation. A task means that it is a magnetic anomaly of earth's magnetic field caused by some dangerous mines. The aim is to detect these mines. There may be several magnetic anomalies within a region. They have to be classified in an intelligent way. This can be achieved in several ways. Why we prefer a new method to identify these sub-regions by multiple robotic teams is that in the previous study [1] it was observed that some of the mobile units had stuck around some sub-regions. For example, in Fig. 1, the three yellow[1] robots swarm into the sub-region where an AT mine is buried, while the other two blue robots approach into another

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[1] For interpretation of color in 1–9 and 14–16, the reader is referred to the web version of this article.

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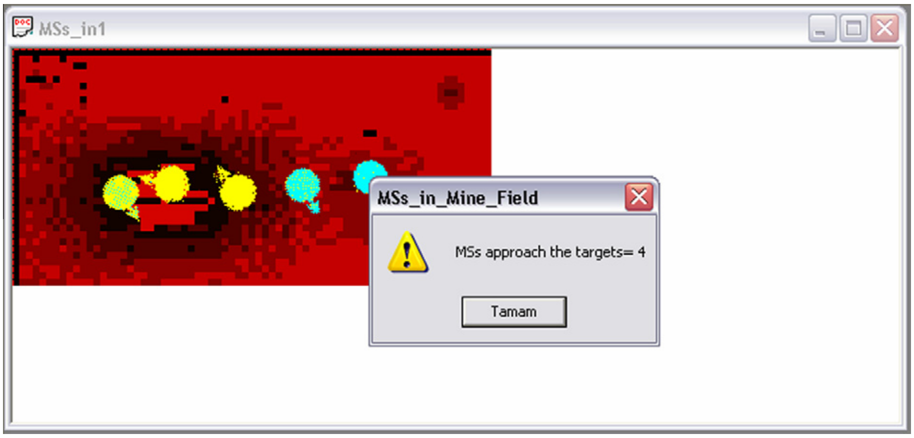

Fig. 1. Groups of robotic units approaching two separate objects.

sub-region where an AP mine is buried. They constituted small groups of robots based on the information gathered by the magneto-resistive sensors mounted on them and calculating the gradient of steepest decent in the magnetic anomalies. There was no external intervention to the motions of the robots. They performed their behavior autonomously. The behavior of the mobile sensor units are synchronized in time by a time division multiple access (TDMA) method [1]. Some of these groups detected important objects but the others could not. The robots within the mobile SN had been separated in an inappropriate manner. This caused a waste of resources in most of the cases. It motivated us to create teams of robotic units in an appropriate way based on the importance of sub-regions. In this paper, we modeled the requirement as a task assignment problem.

In recent years, mobile sensor networks are used in a wide variety of applications such as establishing formations, imitating the behavior of some animals, detecting objects, performing search and rescue activities, area coverage, surveillance and reconnaissance, or controlling streetlights for energy savings. In this study we try to achieve autonomously creation of more than one robot teams allocated into several tasks available within an area of operations where more than one anti-tank (AT) and/or anti-personnel (AP) mines exit. The work is motivated by the detection of these buried mines (anti-personnel and anti-tank) at the border regions for clearing purposes. The mines buried across these regions are hard to find because of the fact that there are no plans available any more or the mines had changed their locations as a result of some geological, natural and/or manmade effects. In our application, an area of several square meters, normally 1.5 m $\times$ 1.5 m, is scanned by magneto-resistive sensors and the buried objects are detected by the anomaly of the measured earth magnetic field.

Within the scanned region, there may be more than one buried objects creating magnetic anomalies. In our previous study, we classified the objects one by one based on the data collected by mobile sensors acting over the region [1]. It was an effective approach for mine detection, but as we observed during operation of the mobile sensor network that some of the robots were grouped around some other buried objects if available within the same region. This is a condition that can frequently been encountered in real applications, therefore we think that we can approach the problem in a different way.

The sensor network deployed into the environment using the algorithm is composed of robot units with sensing capability of magnetic anomaly of the earth. They utilize KMZ51 un-isotropic magneto resistive sensors. The sensors are arranged in a 3 $\times$ 3 sensor matrix to implement a convolution mask for steepest descent in the magnetic anomaly region. The mask is used to determine the gradient of the field as a hardware element. The robots perform rotation and translation motion at the end of each operation period based on the direction of the gradient vector. The mobile units are synchronized by using the method called time division multiple access (TDMA). In this method, a time slot is assigned to each robotic unit to allow them to make movements within its time slot.

We can think of the problem as a task allocation problem which has received significant interest in recent years. As seen in Fig. 2, the objects found in the region can be considered as tasks and the aim will be to assign multiple robots to these tasks based on an appropriate technique.

There are two common methods applied for task allocation, namely, behavior-based [2–5] and market-based approaches [6,7]. One of the earliest behavior-based method is the so called the ALLIANCE Efficiency Problem (AEP) which is an NP-Hard problem [3]. The other famous behavior-based architecture is Broadcast Local Eligibility (BLE) presented in [4]. In general, behavior-based method is a control methodology in which mobile agents are controlled through the principled integration of a set of interacting behaviors in order to achieve desired system-level behavior. Behavior-based approaches are an extension of reactive architectures and also fall between purely reactive and planar-based extremes [5].

The market-based (or frequently called auction-based) approach is another well known method for solving task allocation problem. The famous examples of marked-based methods are the M + system in [6] and the MURDOCH in [7]. These methods are based on or a variant of the well-