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A Hybridization of Gravitational Search Algorithm and Particle Swarm Optimization for Odor Source Localization

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ABSTRACT

This paper concerns with the problem of odor source localization by a team of mobile robots. The authors propose two methods for odor source localization which are largely inspired from gravitational search algorithm and particle swarm optimization. The intensity of odor across the plume area is assumed to follow the Gaussian distribution. As robots enter in the vicinity of plume area they form groups using K-nearest neighbor algorithm. The problem of local optima is handled through the use of search counter concept. The proposed approaches are tested and validated through simulation.

KEYWORDS

Gravitational Search Algorithm, Multi-Robot Coordination, Multi-Robot Systems, Odor Source Localization, Particle Swarm Optimization, Plume Traversal

INTRODUCTION

The ability of a multi-robot system to detect, locate or follow a target either in known or unknown area, has various valuable applications in real life. Applications of target searching include search and rescue after disaster, toxic gas detection, narcotics or explosives localization and so on. For instance, the use of autonomous robots for search task in dangerous environment has been receiving consistent attention. Searching using a team of mobile robots, instead of a single robot has potential advantages (viz. fault tolerance, accuracy) and also has numerous challenges (viz.coordination, communication, collision avoidance). Information of odor is widely used by animals for information exchange, finding mates and searching for food in nature. Advancement in the area of robotics and sensor technology has motivated researchers to use robots for odor source localization in environment harmful for human beings. The process of odor source localization can be divided into three phases: odor plume finding, plume following and odor source declaration.

Nature inspired paradigms have been used consistently in robotics for control, decision making and learning. Simple control rules drawn by the study of social insects and animals have been found suitable for multi-robot systems. We have proposed two approaches for odor source localization. The first approach is inspired from gravitational search algorithm, GSA (Esmao Rashedi et al., 2009) and the second approach uses a hybrid of Gravitational Search Algorithm and Particle Swarm Optimization, PSO (Eberhart & Kennedy, 1995) proposed by Kennedy and Ebarhart in 1995.

This paper discusses an approach which minimizes the time required to locate the odor source, by utilizing the strengths of GSA and PSO.

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This paper is organized as follows: Section Related work provides a brief review of target searching methods. Section Methodology discusses the proposed target localization approaches. Simulation setup details and results are discussed in section Simulation setup and Simulation results. Section Conclusion concludes the paper with a discussion on possible future work.

RELATED WORK

Target search is the process of localizing an object of interest on the basis of current information available about the environment. This problem has been studied under various scenarios such as static or dynamic target, constant or variable plume intensity, single or multiple targets etc. Depending on the target, a broader spectrum of target locating problems has emerged. For instance, odor source localization (Jatmiko et al. 2011), target localization and tracking (Ramya et al., 2012), search and rescue (Liu & Nejat, 2013) and so on.

Research on locating the odor source using robots began in 1990s (Sandini et al., 1993). Problem of odor source localization has already been studied by many researchers (Russell et al., 2003; Marques et al., 2006; Jatmiko et al., 2011; Marjovi et al., 2011) Several methods have been proposed namely: Hex-path algorithm (Russell, 2003; Lilienthal et al., 2003), Gradient following (Li et al., 2007), the Zigzag path search strategy (Holland & Melhuish, 1996), rule based strategy (Zarzhitsky et al., 2004), Fluxotaxis (Gong et al., 2011), Odor tracking

(Vergassola et al., 2007), Infotaxis (Kuwana & Shimoyama, 1998), combination of Chemotaxis and Anemotaxis (Hayes et al. 2002), cooperation based on swarm intelligence (Hayes et al., 2003), etc.

Li et al. (Li et al. 2007) has proposed a gradient-based method to locate the odor source. In this approach, robots make the use of the concentration-gradient information and apply global stochastic strategy to decide the next move. But the cooperation mechanism employed among robots does not utilize the complete information available from other robots. Marques et al. (Marques et al., 2006) proposed a new PSO inspired cooperative algorithm which is based on the exchange of information among neighboring agents for searching odor sources across large search spaces. The spreading of the agents across the large search space is made possible through modeling and implementation of repulsive forces among the agents and crosswind biased motion. Marques et al. (Marques et al., 2002) proposed a method for odor source localization by multiple robots. This method is based on genetic algorithms. The fitness computed for each robot is the measure of odor concentration. The algorithm aims to increase the ability to explore the area by applying crossover, mutation and selection operation. Convergence of this algorithm is poor if there is no random initialization of robots in the search space. Hayes et al. (Hayes et al., 2003), have presented a collaborative spiral surge approach on the basis of swarm intelligence and a control algorithm to localize the odor source by a team of autonomous robots. Marjovi and Marques (Marjovi & Marques, 2011) proposed a cooperative approach to locate odor source in unknown structured environments. Theirs is a frontier-based-decentralized approach and it uses the concentration of odor source and flow of air at each frontier to decide the next move. Jatmiko et al. (Jatmiko et al., 2009) have proposed a cooperative approach for odor source localization based on niche PSO. Zhang et al. (Zhang et al., 2013) have proposed a multi-robot cooperation strategy based on the virtual physics force which incorporates four different forces, structure formation force, repulsion force, goal force and rotary force. They have introduced a new method using rotary force to avoid the tracing of single target by more than one group of robots. Meng et al. (Meng et al., 2012) have presented a cooperative search approach to realize odor source localization. Their method uses the upwind search algorithm and ant colony optimization, ACO algorithm. Couceiro et al. (Couceiro et al., 2011) have proposed two approaches namely Robotic PSO, RPSO and Robotic Darwinian PSO,