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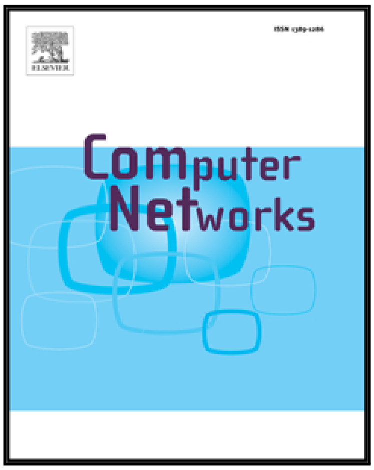

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Quantum-Inspired Algorithm for Cyber-Physical Visual Surveillance Deployment Systems

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***Abstract*—With recent advances in camera and visual computing technology, visual surveillance is playing a significant role in wireless sensor networks (WSNs) and cyber-physical systems (CPSs). It can be used in civilian areas for traffic control and security monitoring. Deployment is an important and fundamental issue in a WSN/CPS. Many issues, such as the quality of service, energy efficiency, and lifetime, are based on the placement of sensors. Different heuristic and deterministic methods have been proposed to achieve optimal deployment. In this paper, we propose a novel algorithm, called the Quantum-inspired Tabu Search algorithm with Entanglement (QTSwE), which is based on both the Quantum-inspired Tabu Search (QTS) algorithm and quantum entanglement feature. QTSwE is applied to a deployment problem to determine the minimum number of sensors required and their locations. This paper analyzes the property of the deployment problem and calls this phenomenon dependency. It uses the concept of quantum entanglement to build the initial positions of sensors to tackle the dependency of variables. The QTS is then used to find better solutions iteratively. Moreover, we use local search to enhance the search capability of QTS and to avoid being trapped in local optima. The experiment results showed that QTSwE outperformed other deployment approaches and used the least number of sensors to satisfy the monitoring requirement and topology connectivity. With QTSwE, the performance of surveillance system deployment has improved further.**

***Index Terms*—Cyber-Physical Systems, Visual Surveillance, Quantum-Inspired Tabu Search, Entanglement, Deployment.**

I. Introduction

VISUAL surveillance plays a significant role in wireless/wired sensor networks (WSNs) and cyber-physical systems (CPSs). Traditional sensors can only measure temperature, pressure, ambient light, etc. With recent advances in camera and visual computing technology, visual surveillance can be applied to traffic monitoring, parking control, intrusion detection, visual-type fire detection, and in a variety of visual monitoring systems. Distributed surveillance and sensors can be deployed to build a WSN/CPS. These sensors are placed in a sensing field to monitor the environment to collect information; they can communicate with each other via a wireless channel to transport data to the data sink. The use of a WSN/CPS is efficient for performing measurements in inaccessible environments.

WSN originated in battlefield surveillance and other military applications. At present, WSN has attracted much attention worldwide; it can be widely employed in civilian areas, for environmental and ecological monitoring, home automation, and traffic control. WSN/CPS applications utilize different types of visual technologies. For environmental applications, they can use colors and shadows to detect fire; in home automation, they can recognize the spatial behavior of humans, such as falling persons; for traffic monitoring, they can recognize the license plates of stolen cars and detect pedestrians, traffic-flow, etc.

In a WSN/CPS, each sensor may have limited computational resources, power, and channel bandwidth. Based on these constraints, several researches have focused on issues such as energy minimization, quality of service, efficient routing protocol, data aggregation, and localization [1]–[4]. However, all these researches on WSNs were based on the placement of sensors. If any sensor location is slightly changed or a sensor is removed from the topology, the performance of the upper layer will be affected. Deployment systems not only involve the determination of the number of sensors, but also encounter problems related to coverage, connectivity, and topology lifetime. A well-designed deployment method may reduce the complexity of several parameters in a WSN/CPS, such as routing, communication, and lifetime. The topology in a WSN/CPS is fundamental and significant. Hence, in this study, we will focus on static deployment, which is the most important issue in a WSN/CPS.

The deployment problem is formulated as a combinatorial optimization problem, which has been proven an NP-complete problem [5]. When the geographical environments (sensing field) become huge, the complexity of the deployment problem grows exponentially, making this problem difficult to solve. Traditional methods are unable to cope with such high computational complexity. Therefore, we propose an efficient and effective evolutionary algorithm, called the Quantum-inspired Tabu Search algorithm with Entanglement (QTSwE), as the core of our deployment system.

QTSwE is based on the Quantum-inspired Tabu Search (QTS) algorithm and the quantum entanglement state, which is a significant characteristic of quantum computing. The QTS