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Localization Algorithm Based on a Spring Particle Model (LASPM) for Large-Scale Unmanned Aerial Vehicle Swarm (UAVs)

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ABSTRACT

A new localization algorithm based on large scale unmanned aerial vehicle swarm (UAVs) is proposed in the paper. The localization algorithm is based on a spring particle model (LASPM). It simulates the dynamic process of physical spring particle system. The UAVs form a special mobile wireless sensor network. Each UAV works as a highly-dynamic mobile sensor node. Only a few mobile sensor nodes are equipped with GPS localization devices, which are anchor nodes, and the other nodes are blind nodes. The mobile sensor nodes are set as particles with masses and connected with neighbor nodes by virtual springs. The virtual springs will force the particles to move to the original positions. The blind nodes' position can be inferred with the LASPM algorithm. The computational and communication complexity doesn't increase with the network scale size. The proposed algorithm can not only reduce the computational complexity, but also maintain the localization accuracy. The simulation results show the algorithm is effective.

KEYWORDS

Computation Complexity, Localization Algorithm, Mobile Adhoc Network, Spring Particle Model, Unmanned Aerial Vehicle Swarm

INTRODUCTION

The development of unmanned aerial vehicle (UAV) swarm poses a great challenge to the localization system of the UAVs (Chen et al., 2021). To swarming UAVs, their positions are essential for a variety of collaborative operations, including navigation(Chen et al., 2022), motion control(Wu et al.,2021), and mission completion (Gupta et al., 2016; Villas et al., 2013). There are a number of localization schemes(Moon et al., 2022; Mozaffari et al., 2019; Xiong et al., 2021), among which the global positioning system (GPS) is one of the most representative technologies

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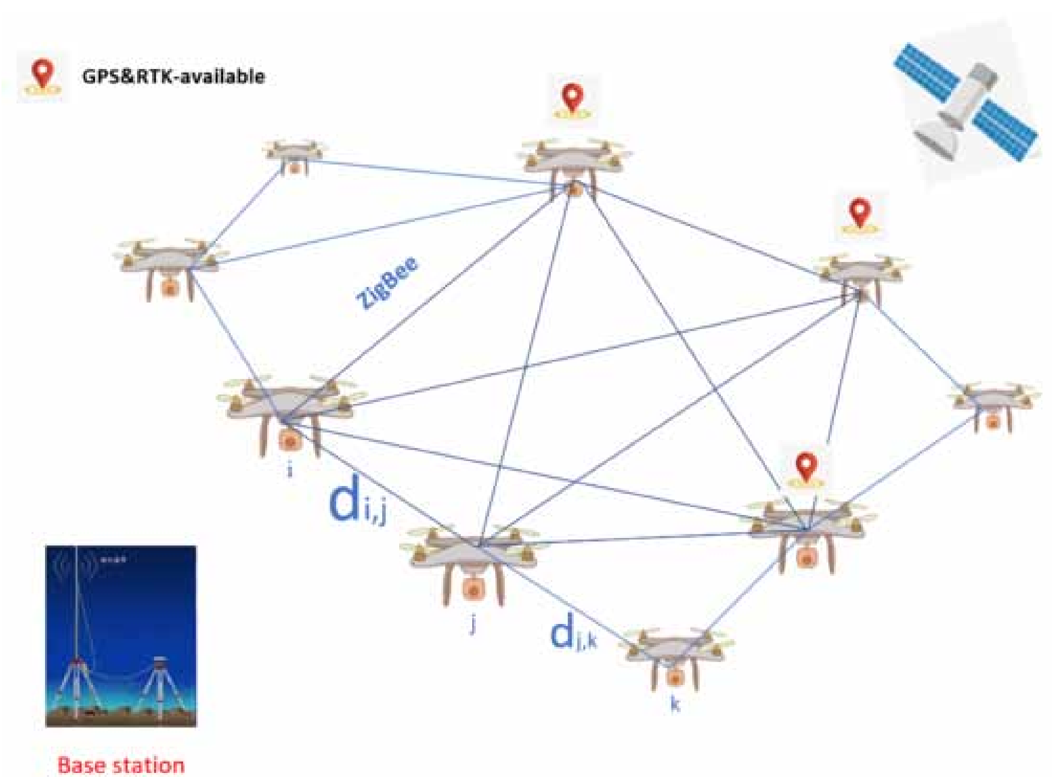
(Youn et al., 2021; Goel et al., 2017). However, the location estimation performance of GPS has been found to be unreliable in some closed and isolated environments(Qi et al., 2020), such as urban canyons and indoor spaces (Zhou et al., 2019). The other localization and navigation methods, such as inertia navigation (Svacha et al., 2020), have large error accumulations that cannot be used in long-distance navigation (Gribben et al., 2014). Wireless sensor network technologies can be used for the UAVs' localization and navigation (Chen, et al., 2017). The wireless sensor nodes are deployed with the UAVs(Alzenad et al., 2017; Yang et al., 2017) . However, with the increase of operation area and scale of UAVs, a large number of sensor nodes need to be deployed(Alzenad et al., 2018;Kim et al., 2010), thereby constituting a large-scale wireless sensor network(Chen et al., 2018;Gao et al., 2021). A large-scale sensor network contains thousands of sensor nodes, and the complexity of the network becomes very sensitive to the sensors' scale(Yin et al., 2020). Examples include computational complexity, time complexity, and communication complexity. Now developing a low-complexity and high-energy efficient localization algorithm for large-scale sensor networks on UAVs is very urgent.

To solve these problems, we propose a UAV system with some movable Ultra Wideband (UWB) anchors. A base station controls several anchor UAVs. Each anchor UAV is equipped with a UWB anchor and real-time kinematic (RTK)-GPS capabilities. The blind nodes are equipped with CC2431 chips, which can be determined from the proposed LASPM algorithm by calculating the related forces with the neighbor anchor nodes. The diagram of a localization model for swarming UAVs is shown in Figure 1.

The LASPM localization algorithm is based on a spring model that is suitable for large-scale sensor networks. The complexity of each sensor node is O(1), which does not increase proportionally

Figure 1. The diagram of localization model for swarming UAVs



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