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Enabling Technologies to Support Emerging UAV-Swarms

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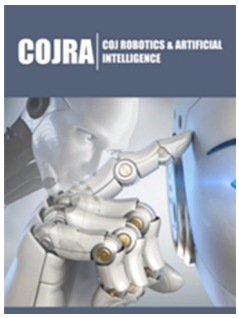

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Abstract

Swarm robotics is a promising research area with a great number of applications both in the civilian and the military domain. However, in order to be fully operational, systems deploying swarm robots depend on a number of other technological features to support them. Of a particular interest, Unmanned Aerial Vehicle (UAV) swarms, represent an important area of development in this subject, not only due to the increasing applications of these flying platforms, but also due to the whole spectrum of technology around this type of system. Within this landscape, this paper provides an overview of the emerging technologies to support the development of emerging UAV-Swarms systems, as well as the main challenges ahead.

Introduction

Swam robotics is a research area focused on the designing self-coordinated groups of robots that are able to jointly perform tasks that are not able to be done (or not with the desired quality parameters) by an individual robot or that would be too costly in this case. This approach relies on the idea that from the individual behaviors of each of the swarm group members, a collective behavior emerges, addressing the desired goal. This means that there is no central entity coordinating the group members, but that all of them know what has to be done to achieve the goal, which is grounded in the swarm intelligence principles [1].

The literature already surveyed numerous applications indicating the advantage in using swarm robotics systems both in military and civilian domains, such as in defense systems for area monitoring, search and rescue after catastrophic events, crowd monitoring and control, precision agriculture among many other [2]. Recently, these many of the before envisioned applications are coming to the reality, with a particular highlight to those based on aerial robots [3]. Unmanned Aerial Vehicle (UAV) swarms are of particular interest as the three-dimensional movement ability of these aerial robots expand the possibilities in using this type of system to a great number of applications.

Despite the promising applications of UAV-Swarms systems, the successful development and deployment of these systems depend much on associate enable technologies, which provide support for different needs behind the autonomous work performed by each UAV. These needs go from basic functionality such as location and communication networking to more sophisticated and application-specific ones as distributed task allocation and payload intelligence, such as advanced embedded image processing [4]. Observing this landscape, this short paper provides a brief overview on some recent advances in these technological advances that are making possible the emerging deployments of UAV-Swarms systems applications.

Reviewing Key Technological Advances Enabling UAV-Swarms Systems

Considering the employment of UAV teams performing cooperative task, one of the major concerns is related to flight formation and collision avoidance capabilities. However, in order to instantiate this type of service, a more basic one is necessary, which is the location. The

concern is not just related to the location awareness of each UAV, but a more general service that provides this information about all UAV members' locations to the entire group.

Recent works are tackling this issue, as the one reported in [5]. This work presents a multipurpose localization service for cooperative multi-UAV systems, which is able to support the necessary location upper-layer services such as collision avoidance and coordinated flight formation.

One of the main contributions of this work is the integration of a position estimation algorithm that copes with problems related to incomplete of outdated information from some UAVs in the team. Related to the above discussed location awareness needs, there is the need of a stable network to provide support to data exchange among the UAVs that compose a cooperative team. Regarding this issue, the communication network is an important asset to the UAVs that cooperatively work to accomplish different types of tasks. There are many approaches addressing UAV-Networks handling the problem from different perspectives, from physical layer communication technologies to medium access and networking protocols. The latest advances in these areas are surveyed in [6] providing information of state-of-the-art technology such as 5G and 6G. Particularly, these two technologies are very promising for massive UAV-teams, as the provided high-speed and broadband communication enable robust and reliable communication needed for the emerging UAV-swarms systems.

Another important topic that is mandatory when it comes to a discussion on UAV-Swarms is task allocation. Distributing the workload of a given mission to UAVs in a team is challenging, particularly when the UAV members have different capabilities. The work reported in [7] sheds light on this issue, surveying relevant work about this issue and proposing a lightweight distributed protocol for task allocation in cooperative UAV-Swarms. On top of this protocol, another work tackles a higher-level service demanded by UAV-Swarms to efficiently perform their operations, which is the construction and maintenance of a common map the environment being explored by the UAV-Team [8]. The importance in having a shared common understanding of the explored environment is of crucial importance to avoid unnecessary coverage overlap as well as to provide a comprehensive overview of the target area.

Conclusion and Challenges Ahead

This paper provided a very brief overview of the main technologies that support advanced UAV-Swarm systems. It does not have the ambition to exhaust the discussion, but only to provide initial pointers to key technologies that are being developed in this domain, such advanced communication, positioning, and task allocation techniques. Despite the advances so far, there are many challenges that need to be addressed, such as more efficient positioning estimation algorithms, computer vision support to collision avoidance, and more efficient exploration of 5/6G technology to support emerging approaches on edge processing offload and distributed decision making.

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