Drone networks

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1 Overview

This presentation will illustrate a survey of the most recent developments about drone networks, swarms and air pollution monitoring systems.

2 Air pollution and low-cost sensors

Thanks to the release of low-cost sensors, air pollution analysis received a boost in popularity. Only big agencies could afford complex and costly sensors in the past and not much data was shared. Low-cost sensors are really inexpensive and portable, but lack in three aspects: accuracy, data interpretation and maintenance, especially because of their untrained users. Low-cost sensors are useful to scan for abnormal situation. Many drones mounting sensors are already commercially available. The two showed here were developed to collect air samples.

2.1 Sensor networks

There are three main categories of sensor networks. In Static Sensor Networks, sensors are located in stationary devices. They are accurate and usually not subject to physical constraints. They can also be deployed on walls and traffic lights. Unfortunately, immobility and coverage are major weaknesses, so they can only be employed in specific situations. In Community Sensor Networks, sensors are attached to personal devices, thus they are less expensive and are as mobile as the host, achieving good coverage. At the same time the movements are unpredictable and usually not well maintained, so the accuracy is low. In Vehicle Sensor Networks, sensors are embedded in public transportation. The mobility and coverage are decent, but a little redundant. Constraints are loose and accuracy is good but the temporal resolution is low. All three categories lack 3dimensional sampling and adaptive behaviour. Maintenance is somewhat of an issue as well. Those aspects are innate strengths of UAVs and possible integrations with sensor networks would be really beneficial.

2.1.1 Drone networks

A set of drones interconnected is called a network. The main limitation is the absence of adequate algorithms and protocols for routing. Wi-Fi doesn't account for height and most of searching algorithms to avoid loops doesn't work in 3D environments. A paper found that locating an UAV was not affected by its speed, while data gathering was greatly affected (using CSMA/CA). Communication is far more prone to errors when considering drones. Non-uniformity of drone distribution in the sky is a major issue when working in graph theory. Specific scenarios require specific countermeasures, there is no standard solution for every need. Battery power is a huge impairment in missions. Wireless Power Transfer could be a solution, but imposes additional constraints, such as static or flying charging stations acting in line-of-sight and close range.

2.2 Drone systems

A set of drones working on the same task is called a system. Centralized approaches make use of a motion capture system to locate UAVs in a controlled environment. A central controller elaborates data and commands the units, relieving them from hard computations. A study about sowing through UAV using a centralized system showed many aspects about efficiency and scalability. There is a threshold to the number, after that the risk of collision is too high and performance degrades. The system was stable even after unit malfunction. Decentralized systems rely on ad-hoc networks and communication between units. Their field of application is greater but many issues emerge.

2.3 Drone swarms

A set of drones coordinating movements and cooperating on a task is called swarm. In a paper, a leader UAV was deployed from a base station. Whenever the leader needed to travel outside the network range, another UAV would take off, acting as a bridge, while forming an horizontal chain. A platform to test swarming algorithms is Paparazzi SDK, allowing to connect multiple AR Drones to a Ground Station Controller. A theoretical proposal defined different categories of swarms. Artificial can match velocity of the swarm, avoid collision and avoid getting too far. Continuous are regulated by short-range repulsion and long-range attraction. Discrete loop through the steps of look, compute, move.

2.4 Drone sensing

Compared to classical sensing and monitoring, drones can benefit from their flying prowess, low cost and possibility of adaptation through software. On the other side, sensors are not accurate enough and weather simply renders them useless. In AIRWISE, a 39x39 area was monitored. The battery power lasted less than three iteration, for a total of 12 minutes of flight time. Worst of all, UAV networks are extremely unreliable because of speed and altitude causing high error rates. An issue mentioned only in one study, was the influence of rotor's wind on the measurements.

2.5 Drone movement

Drone movement focuses on coordination, spatial management and collision avoidance. Coordination is required to efficiently perform a specific task. AIRWISE divided the monitored area in cubes, implementing two algorithms. The first covering all the areas each iteration cycle, The second computing stability of areas, and monitoring more frequently those with low stability. The A* algorithms was chosen in planning a path for a wheeled robot, using an aerial map gathered by an UAV. Collision avoidance is arguably the most difficult aspect to improve. At close quarter, only centralized systems can guarantee sufficient precision.

2.6 Data dissemination

Data dissemination improves the efficiency and the adaptability of a network. Forecasting UAV paths guarantees robust and timely data delivery, while not penalizing bandwidth. In ADDSEN, knowledge items were broadcasted with swarm ID, drone ID and awareness parameters. Additionally each drone locally stores sentto, senderList, awareAll, senttoAll. If a drone broadcasts a knowledge item to neighbor drones and then cannot find its ID in the senderList of the rebroadcasted knowledge items from some neighbor drones after a period, the drone will determine the loss of the knowledge item.

3 Conclusion

In conclusion, drones are effective only on specific scenarios. The most cumbersome challenges are energy autonomy and weather conditions. A good amount of algorithms and protocols are currently being researched, progressively overcoming obstacles, but standards will still not be available in the near future.