UAV Swarm with Mesh Radios: Development Update

Sondre Engebråten, Olav Rune Nummedal, Don Gilbreath, Oleg Yakimenko and Kyrre Glette

October 31, 2019

UAV swarm with mesh radios: development update

Sondre A. Engebråten [12†], Olav Rune Nummedal [1], and Don Gilbreath [3], Oleg Yakimenko [4] and Kyrre Glette [12]

[1] Norwegian Defence Research Establishment, P.O. Box 25, 2027 Kjeller, Norway.
(E-mail: Sondre.Engebraten@ffi.no)
[2] University of Oslo, P.O. Box 1080, Blindern, 0316 Oslo, Norway
[3] Rajant Corporation, 200 Chesterfield Parkway, Malvern PA 19355, USA
[4] Naval Postgraduate School, 1 University Circle, Monterey, CA 93943, USA

Abstract: Many of the swarms demonstrated today lack a key piece in order to be useful in the real-world: communication. Our most basic and commonly used communication infrastructure such as cellular networks and WiFi, assume that communication is facilitated by a centralized actor or controller. This falls short in a swarm setting. We demonstrate that the technology exists to take swarms to the next level and enable new fully decentralized swarms for novel applications.

Keywords: Swarm, UAV, Mesh, Communication, Distributed-control

1. INTRODUCTION

Swarm systems have been a research topic for over thirty years starting with the early simulator experiments on emulating the behavior of natural swarm such as birds or fish [5]. As technology and miniaturization advances to the required level, we now see the advent of real-world swarms and multi-agent systems [1–3].

Using a simulator allows fast experimentation, but a simulator is also the definition of a perfectly controlled environment with no outside influence. As such, success is likely. When taking a simulated swarm into the real-world there is a number of challenges that have to be tackled. Most notable is perhaps the flow of information.

A fundamental premise of a true swarm system is the ability for its agents (actors in the swarm) to interact in some meaningful way in order to collaborate, solve tasks, adapt to the environment or compete. Without this interaction the swarm breaks down and becomes little more than several independent agents, and therefore, any potential emergent behavior or interaction on a macro-level is lost. Hence, a true swarm system relies on the ability to communicate or interact.

This abstract addresses the problem of communication in a true swarm system, and presents recent advancements allowing to push past previous boundaries in terms of the number of agents and limits of the command and control architecture while developing a multi-function multirotor drone swarm [3].

2. HARDWARE AND SOFTWARE

As reported earlier [3] the current platform used for the development is the 3DR Solo commercial-of-the-shelf (COTS) quadrotor. The Solo is uniquely suited for a swarm platform in that it allows third-party integrations while still featuring a reasonable cost (MSRP $1000). To enabling swarming, a communication payload talking to Pixhawk autopilot is added to each platform. While the previous efforts relied on the COTS WiFi gear [3], this was detrimental to the concept of a swarm because it went against the principle of decentralized control by introducing a centralized failure/weak point. The current payload consists of a connection board, for interfacing with the 3DR Solo, a companion computer (Odroid C2) and a Rajant InstaMesh radio (Fig. 1).

Fig. 1 A swarm payload added to a COTS drone

The companion computer employs Ubuntu 16.04, Robot Operating System (ROS) along with the MAVROS packages to interface with the autopilot on the Solo drone. Early experiments indicated that in order to make use of many agents in a swarm collisions would quickly become an issue. Therefore, a software solution was developed that operates independently and transparently to both MAVROS and the swarm behaviors. This collisions avoidance software package rely on artificial potential fields [6]. Artificial potential fields allow potential collisions to be handled gracefully by applying a repulsive force between the agents. As agents get closer to each other this force increases in strength which leads to natural equilibriums in most practical use-cases. An example of how the collision avoidance operates can be found on YouTube [1].

On top of the reactive collision-avoidance swarming

† Sondre A. Engebråten is the presenter of this paper.

[1] `https://youtu.be/8mcNE_TYCa4`

behaviors can be built and tested without having to consider potential collisions. The developed swarm behavior framework is a type of Physicomimetics [7] and allow defining a variety of swarming behaviors. Each controller consists of a set of parameters affecting the behavior of an agent. By tweaking the parameters a swarming behavior for multiple concurrent tasks can automatically be generated, thus enabling a multi-function swarm [4].

3. EXPERIMENTS

Fig. 2 Experiment setup at Camp Roberts, CA

All tests were conducted in a restricted airspace R-2504 in Central California. (Performing tests within a restricted airspace is an advantage as it allows us to test concepts that might otherwise not be possible or permitted.) A compact area of approximately 100m-by-100m was utilized (Fig. 2).

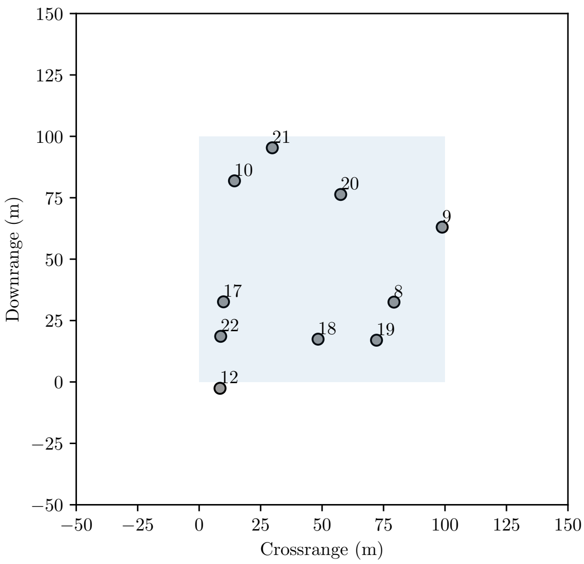

Fig. 3 A birds eye view during a 10 UAVs flight test

The overall goal of the test series conducted in May of 2019 was to verify performance of a new payload based on Rajant InstaMesh radio. First, reliability of agent-to-agent communication links was tested with UAVs were stationary, and then the full multi-function capability was evaluated with the new payload. Fig. 2 shows an example of a flight test employing ten (out of twenty) UAVs with reactive collision avoidance, mesh radios and decentralized swarm control algorithms, while Fig. 4 shows an example of mesh networking status monitoring.

Fig. 4 A snapshot of mesh network health monitoring

4. CONCLUSION

During the latest field experimentation campaign it was found that the mesh radios were successful in serving a means of communication for a swarm of UAVs. With some adaptations in software the reactive collision avoidance algorithms developed earlier were successfully employed. That enabled further testing of exploratory swarming behaviors. That is considered as a significant step towards enabling more real-world UAVs swarm. Further development will address both hardware, software and practical challenges that were revealed during the tests.

REFERENCES

[1] A. Bürkle, F. Segor, and M. Kollmann. Towards autonomous micro UAV swarms. *Journal of intelligent & robotic systems*, 61(1-4):339–353, 2011.

[2] M. Duarte, V. Costa, J. Gomes, T. Rodrigues, F. Silva, S. M. Oliveira, and A. L. Christensen. Evolution of collective behaviors for a real swarm of aquatic surface robots. *PloS one*, 11(3):e0151834, 2016.

[3] S. Engebråten, K. Glette, and O. Yakimenko. Field-Testing of High-Level Decentralized Controllers for a Multi-Function Drone Swarm. In *2018 IEEE 14th International Conference on Control and Automation (ICCA)*, pages 379–386. IEEE, 2018.

[4] S. A. Engebråten, J. Moen, O. Yakimenko, and K. Glette. Evolving a Repertoire of Controllers for a Multi-Function Swarm. In *European Conference on the Applications of Evolutionary Computation*. Springer, 2018.

[5] C. W. Reynolds. *Flocks, herds and schools: A distributed behavioral model*, volume 21. ACM, 1987.

[6] E. Rimon and D. E. Koditschek. Exact robot navigation using artificial potential functions. *Departmental Papers (ESE)*, page 323, 1992.

[7] W. M. Spears, D. F. Spears, R. Heil, W. Kerr, and S. Hettiarachchi. An overview of physicomimetics. In *International Workshop on Swarm Robotics*, pages 84–97. Springer, 2004.