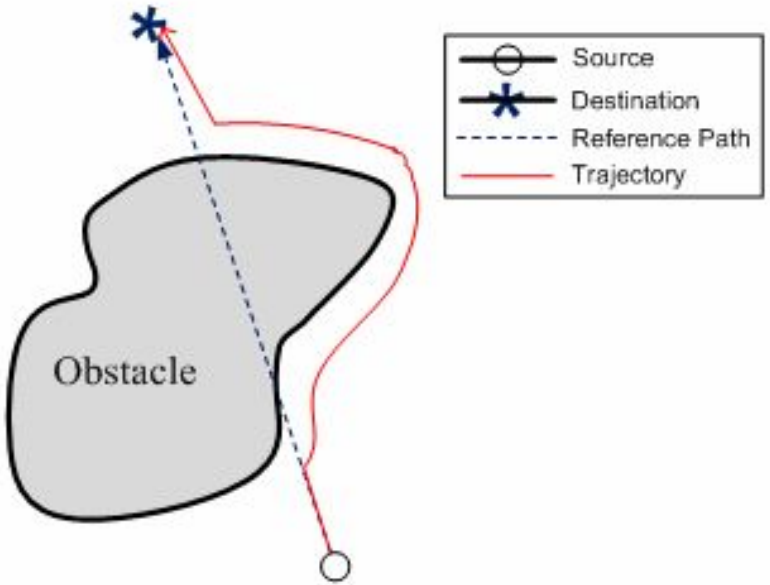
Autonomous Drone Swarms

Danning Yu
CS 35L
26 November 2019

Swarm Robotics: Inspired By Nature

- Social insects (e.g. ants, bees): eusocial behavior
- Researchers at TU Delft, Radboud University of Nijmegen, and University of Liverpool
- 33 g drones, same size as a hand
- **S**warm **G**radient **B**ug **A**lgorithm (SGBA):
  - Follow given direction
  - Wall following
  - Odometry
  - Inter-entity detection
  - Gradient based return
- Results in swarm intelligence and behavior
  - Actions that emerge at a group level



SGBA: Advantages and Tradeoffs

Advantages	Tradeoffs
○ Computationally cheap ○ No expensive processing power needed, so light drones, longer battery life ○ Less susceptible to odometry drift ○ Can work in GPS denied environments (e.g. underground)	○ Cannot precisely navigate from point A to point B (no internal map) ○ Cannot transmit data back in real time: video saved on SD card

Experiment Overview

- Proof of concept using computer simulations - successful
- Real-life tests in an office environment
  - Used up to 6 drones
  - Explored 80% area in 6 min
- Application: search and rescue
  - Able to find victims in 4 minutes

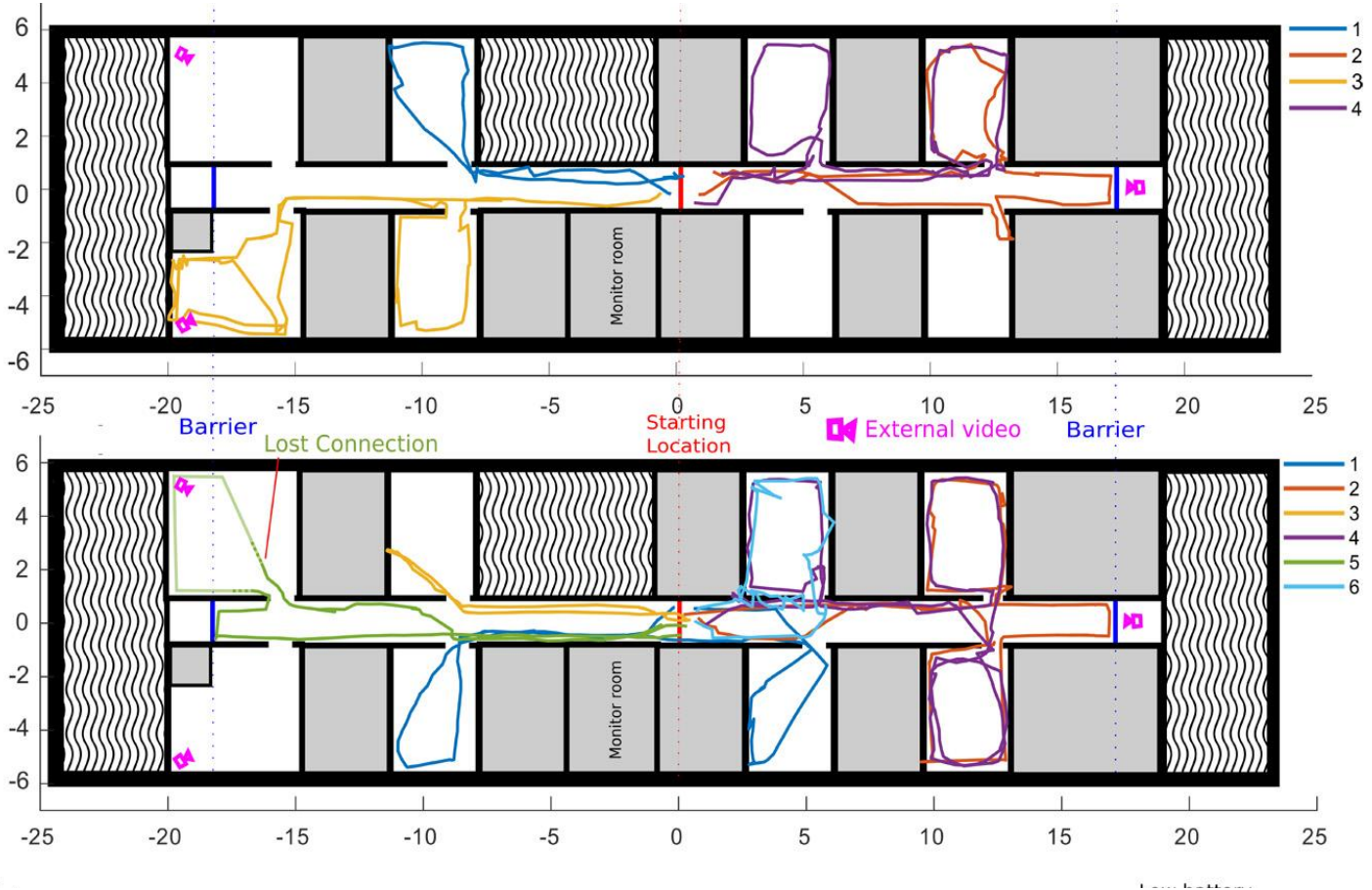
Real Life Experiment: Setup

- Crazyflie 2.0 drones
  - Laser rangers for obstacle detection and wall following
  - Flow deck for odometry (visual, time of flight sensors)
  - Wi-Fi module for communication
- Setting: empty hallways with offices
- Experiments with 2, 4, and 6 drones
- Start from home beacon, return with 2/3rds of battery left (~2 min)

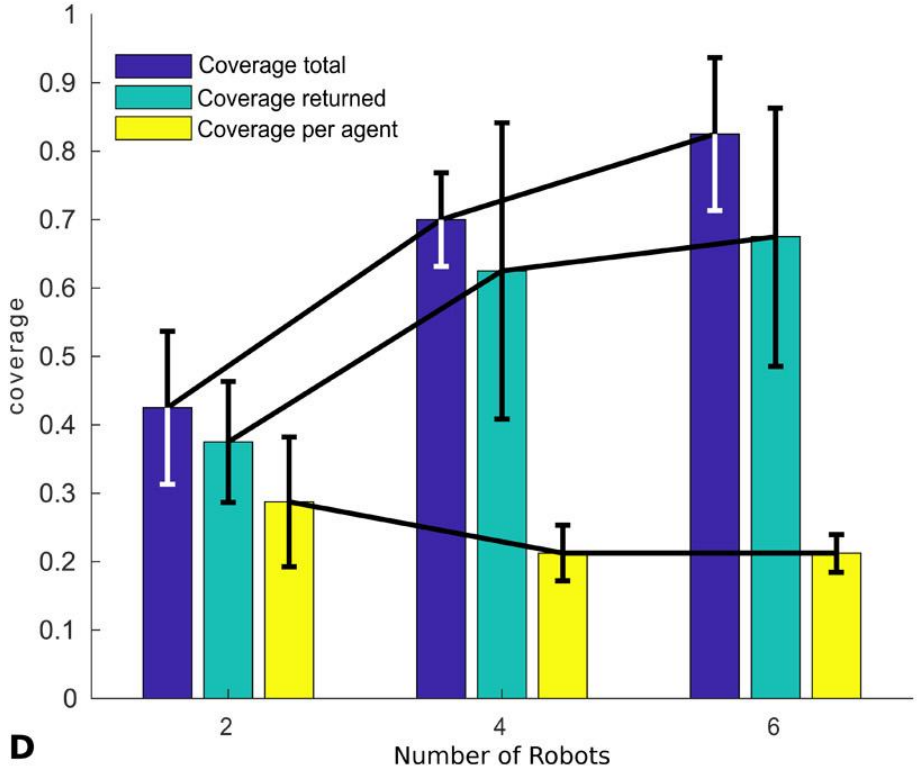
Real Life Results

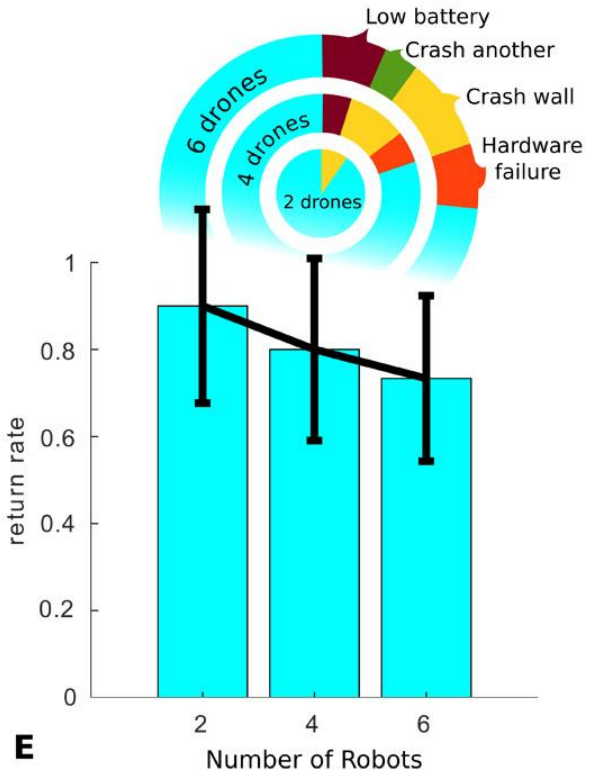
4 drones

6 drones



Real Life Results

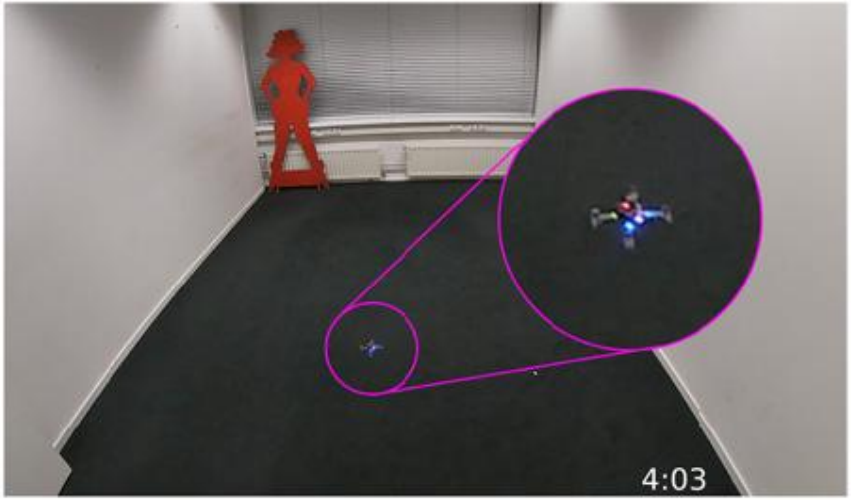




- Coverage area increases; area per drone stays constant
- Return rate goes down as number of drones increases

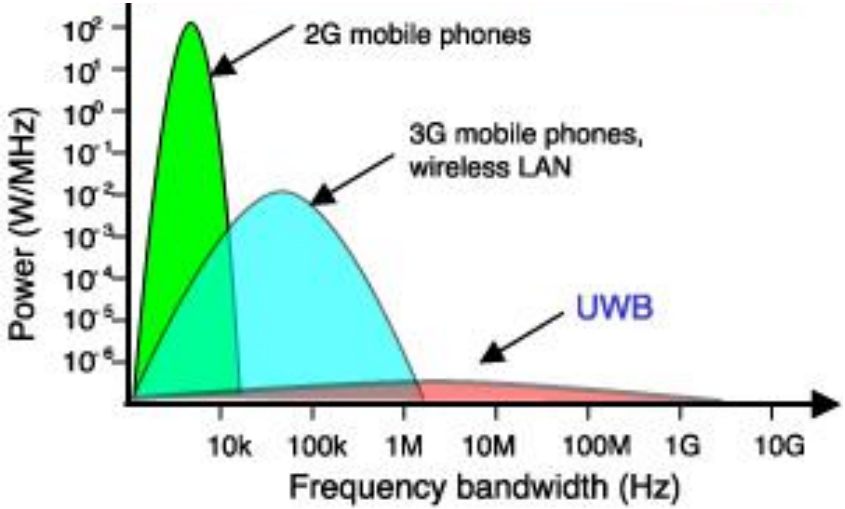
Search and Rescue

- 2 simulated victims placed in rooms
- Drones were able to find both victims quickly
  - 1 drone failed but other drone capture a picture as well
- Can backwards analyze videos to generate a detailed map using simultaneous localization and mapping (SLAM) techniques



Future Improvement

- Using ultra wide band: less communications interference
- Improved obstacle detection: eliminate blind spots
- Different sensors: sonar/radar for smoke filled rooms

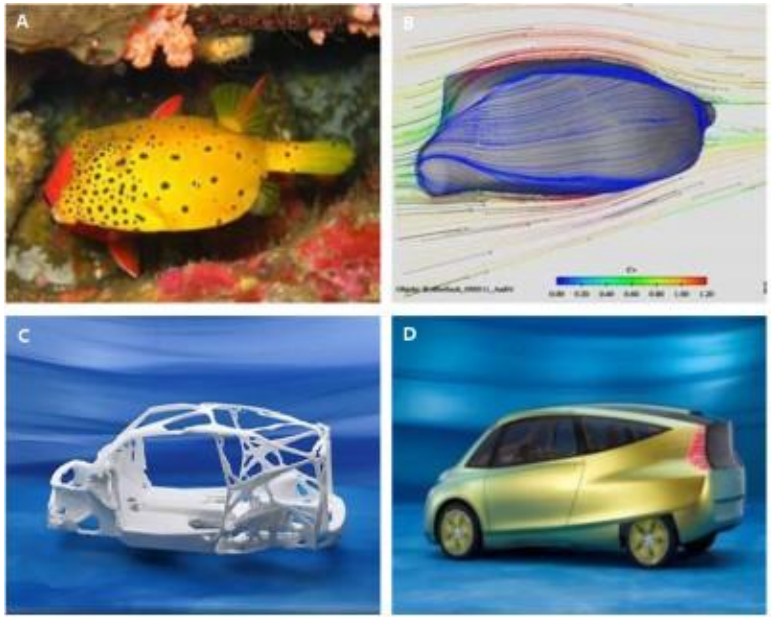


Applications

- Well suited for any of the following environments
  - Dangerous, requires unknown amount of resources, large, unstructured, rapidly changing
- Quickly adapt to changing situations
- Tolerate the loss of individual members
- Examples: toxic spill cleanups, buildings at risk of collapse, search and rescue, geographical exploration, disaster recovery

My Reactions

- Cool example of biomimetics
- Large potential due to reduced cost, easy deployability
- Dependent on hardware: main limitation is battery size and computing power



Works Cited

[1] McGuire KN, De Wagter C, Tuyls K, Kappen HJ, de Croon GE. Minimal navigation solution for a swarm of tiny flying robots to explore an unknown environment. Sci. Robot. 2019 Oct 23;4(35). doi:10.1126/scirobotics.aaw9710.

[2] Reid CR, Sumpter DT, Beekman M. Optimisation in a natural system: Argentine ants solve the Towers of Hanoi. J. Exp. Biol. 2011;214:50-8. doi:10.1242/jeb.048173.

[3] Mondada F, Gambardella LM, Floreano D, Nolfi S, Deneuborg JL, Dorigo M. The cooperation of swarm-bots: physical interactions in collective robotics. IEEE Robot. Autom. Mag. 2005;12(2):21-8. doi:10.1109/MRA.2005.1458313.

[4] Dorigo M, Birattari M, Brambilla M. Swarm robotics. Scholarpedia. 2014;9(1):1463. doi:10.4249/scholarpedia.1463.

[5] Bitcraze AB. Crazyflie 2.0. Sweden: Bitcraze AB; 2019.

[6] Fuentes J, Ruiz-Ascencio J, Rendon-Mancha JM. Visual simultaneous localization and mapping: a survey. Artificial Intelligence Review. 2015 Jan;43(1):55-81. doi:10.1007/s10462-012-9365-8.

[7] Hwang J, Jeong Y, Park JM, Lee KH, Hong JW, Choi J. Biomimetics: forecasting the future of science, engineering, and medicine. Int. J. Nanomedicine. 2015 Sep 8;10:5701-13. doi:10.2147/IJN.S83642.