Flocking Navigation in Swarm Robotics

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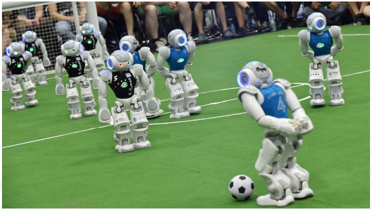
Outline

Swarm Robotics

- multiple autonomous robots
- non central coordination possible
- solve collective tasks

[Bay16]

[dro]



[rob]

Swarm Robotics Motivation

- scalability
- flexibility
- robustness
- parallelism

[CPD+18, MDSD16]

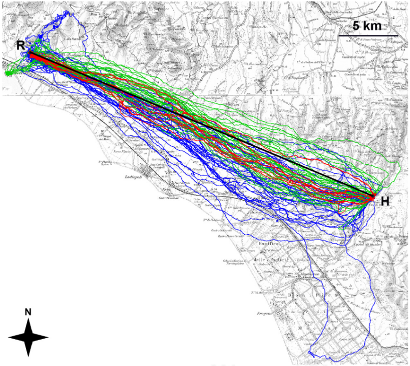
Use-Cases of Swarm Robotics

- Warehouse delivery (carrying objects)
- search and rescue (distributed map building)
- agriculuture (distributed sensing)
- Military (distributed map building and sensing)
- Airspace coordination

[CPD+18]

Navigation Motivation

- each robot needs limited knowledge of environment
- group of animals is more effective for navigational tasks [DDWL08]



Real pigeons flying from R to H. [DDWL08]

Paper

Paper Title: Outdoor flocking and formation flight with autonomous aerial robots
published in: IROS 2014
Authors: G. Vásárhelyi, Cs. Virágh, G. Somorjai, N. Tarcai, T. Szörényi, T. Nepusz, T. Vicsek
"All authors are with the Department of Biological Physics, Eötvös University, Budapest, Hungary" [VVS+14]

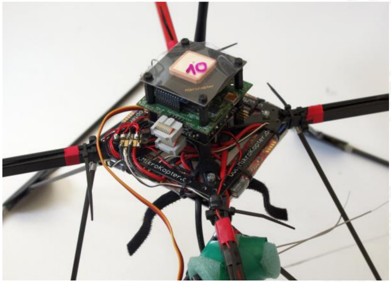
Challenges

- still problems with autonomous flight maneuvers for single drones
- other flock members have to be detected
- delay in detection/communication
- weather

Introduction

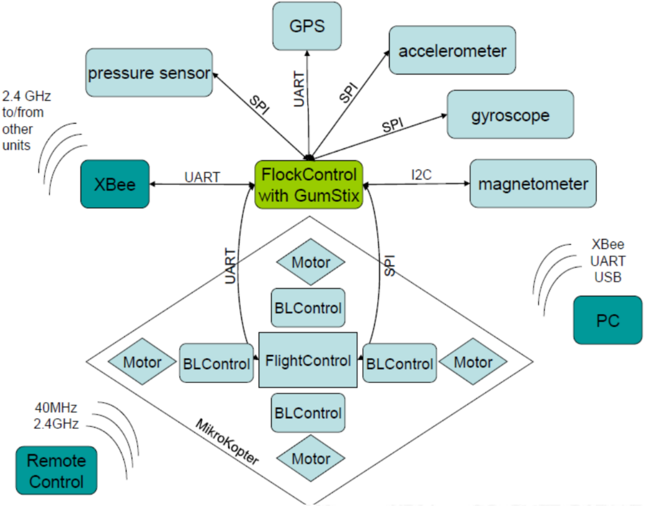
- GPS
- wireless communication
- using 10 Drones
- no central data processing unit

[VVS+14]



The drone used for outdoor flocking and formation flight [VVS+14]

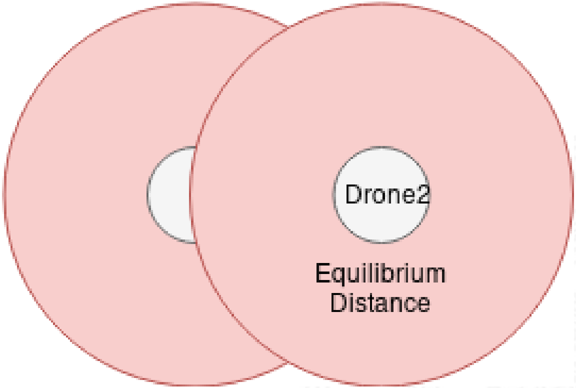
Communication



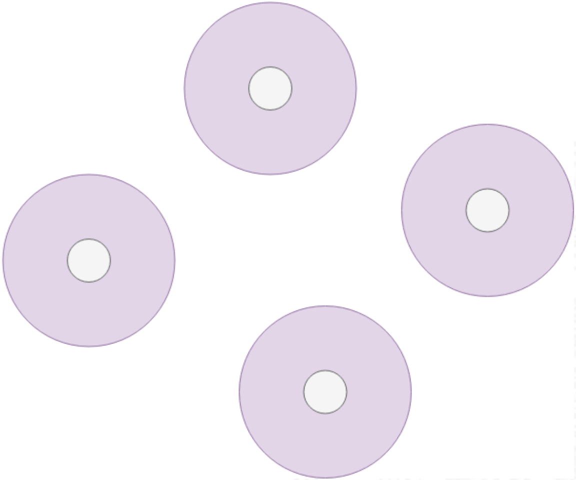
[VVS+14]

Short Range Repulsion

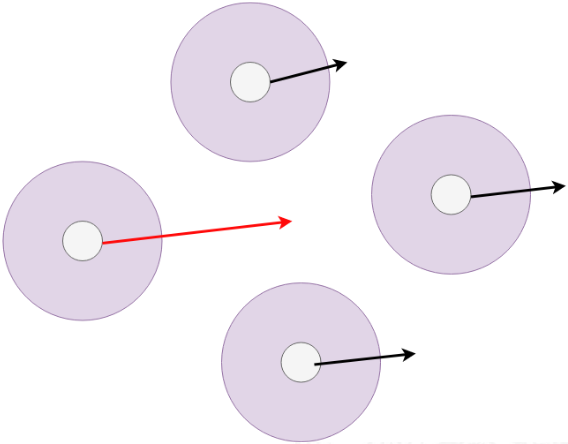
Short Range Repulsion



Middle range Velocity Alignment



Middle range Velocity Alignment



length of arrow indicating speed

Global positional constraints

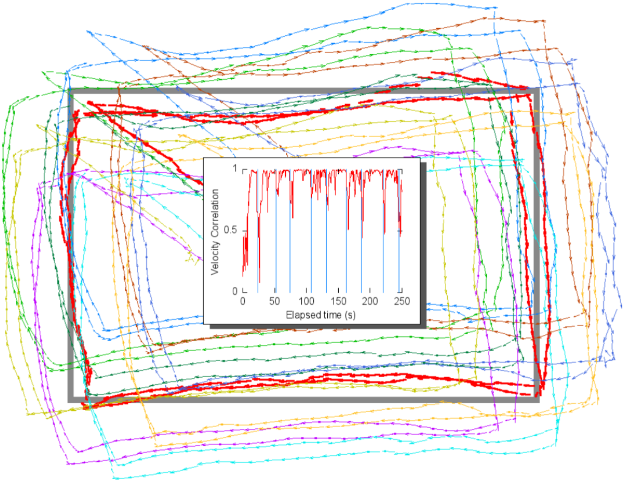
- Flocking
  - defined walls constrain movement
  - walls implemented as virtual agents
- Formation Flights
  - flying around global reference target
  - for grid: heuristic for smallest circle

[VVS+14]

- 10 Drones

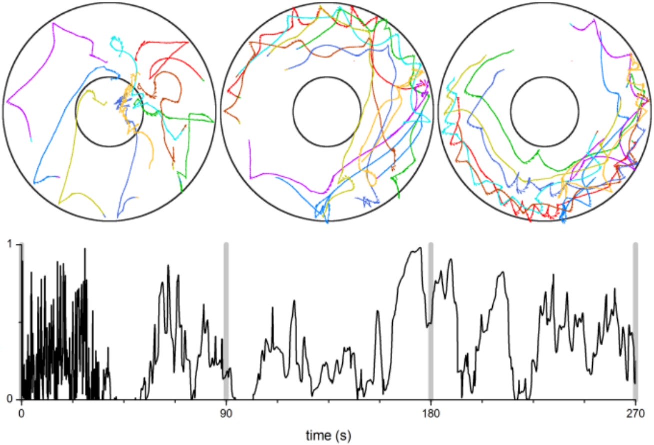
[VVS+14]

Result Tracklogs Rectangle



[VVS+14]

Result Tracklogs Circle



[VVS+14]

Conclusion

- presented method used gps to get relative position, velocity, attitude information
  - other systems outputting these informations could work with the same algorithms
- simulations showed larger numbers would be possible
- oscillation time could be improved
- real time os could help with delays

[VVS+14]

[Bay16] Levent Bayındır.
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[rob] Image of robocup.
https://guardian.ng/wp-content/uploads/2017/07/RoboCup.jpg.

[VVS+14] Gábor Vásárhelyi, Cs Virágh, Gergo Somorjai, Norbert Tarcai, Tamás Szörényi, Tamás Nepusz, and Tamás Vicsek.
Outdoor flocking and formation flight with autonomous aerial robots.
In *2014 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 3866–3873. IEEE, 2014.

Short Range Repulsion

$$a_{pot}^{\rightarrow i} = \begin{cases} -D \sum_{j \neq i} min(r_1, r_0 - |x^{\rightarrow ij}|) \frac{x^{\rightarrow ij}}{|x^{\rightarrow ij}|} & if\,|x^{\rightarrow ij}| < r_0 \\ 0 \text{ otherwise} \end{cases}$$

$D \rightarrow$ spring constant of a repulsive half-spring

$x^{\rightarrow ij} = x^{\rightarrow j} - x^{\rightarrow i}$

$r_0 \rightarrow$ equilibrium distance

$r_1 \rightarrow$ upper treshold for repulsion

[VVS+14]

Middle range Velocity Alignment

$$a_{slip}^{\rightarrow i} = C_{frict} \sum_{j \neq i} \frac{v^{\rightarrow ij}}{(max(|x^{\rightarrow ij}| - (r_0 - r_2), r_1))^2}$$

$C_{frict} \rightarrow$ viscous friction coefficient
$v^{\rightarrow ij} = v^{\rightarrow j} - v^{\rightarrow i}$
$r_0 \rightarrow$ equilibrium distance
$r_2 \rightarrow$ constant slope around equilibrium distance
$r_1 \rightarrow$ lower threshold
[VVS+14]