Navigation of Networked Autonomous Underwater Vehicles with Covert Leaders

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Problem Formulation

Motivation:

❖ In real applications, it is impractical to ubiquitously deploy autonomous underwater vehicles (AUVs) due to typically large operating area and high equipment cost. Therefore, it is desired to develop distributed navigation algorithm to control the autonomous underwater vehicles to fulfill the assigned tasks.

❖ Recent advances in biology have uncovered many interaction mechanisms existing in animal swarms, which can lead to complex and optimized behavior in diverse biological systems.

The Problems We Study:

❖ **Autonomous Navigation with Covert Leaders**

Design a distributed algorithm which allows a small subset of AUVs to lead the entire networked AUVs from a starting area to a destination area.

Constraints and Assumptions:

❖ Due to security concerns or equipment constraints, only a small subset of AUVs (leaders) possess extra information guiding the movement of the entire swarm.

❖The guiding information and the identities of these leaders should remain covert.

❖ Each AUV makes decisions on its moving direction by only using the information collected from one-hop neighbors.

Previous Work for Wireless Robots

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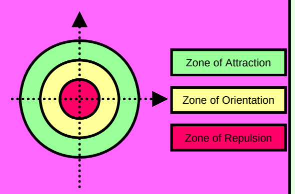
In [1], we extend the swarming model described in [2] and design a distributed navigation algorithm for wireless robot swarms with cover leaders.

Coordination Rules :



❖ Each robot divides its transmission range into three zones, from inside to outside, named zone of repulsion (zor), zone of orientation (zoo) and zone of attraction (zoa).

❖ Each robot calculates three sub-vectors to coordinate its movement with its neighbors in the three zones. Specifically, each robots moves away from its neighbors in zor, or move along with its neighbors in zoo while moving towards its neighbors in zoa.

❖ Each leader adds its own sub-vector toward the destination.

Navigation Algorithm:
1: Each robot asynchronously divides time into slots with equal duration (asynchronous time slots can eliminate communication collisions and enable robots to estimate the real-time positions of their neighbors).
2: Each robot calculates its new moving direction using the coordination rules and broadcast its location and moving direction at the beginning of each time slots.

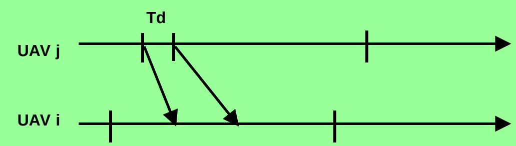
Simulation results in [1] show that a small percentage leaders (below 20%) can effectively lead the entire robot swarms to the destination

Navigation Algorithm for UAVs

New Challenges for Underwater Environment:

❖ Long propagation delay
❖ Obstacles
❖ Kinetic constraints:

Position Estimation with Long Propagation Delay



Remark: Each UAV broadcasts two packets with interval *Td* at the beginning of each time slot. The receivers estimate the propagation delay using the time duration between the two receiving time instances.

Obstacle Avoidance and Kinetic Constraints

❖ Each AUV adds sub-vectors to avoid obstacles within certain avoidance range.
❖ Turning angle is limited by the maximum turning angle allowed by kinetic constraints.

[1] X. Han, L. F. Rossi, C.-C. Shen. "Autonomous Navigation of Wireless Robot Sarms with Covert Leaders," To appear in the First International Conference on Robot Communication and Coordination (ROBOCOMM), Athens, Greece, October 15-17, 2007.
[2] I. Couzin, J. Krause, N. Frank, S. Levin, "Effective Leadership and Decision-making in Animal Groups on the Move," Nature, Vol. 433, No. 7025, pp. 513-516, 2005.

Acknowledgement

This research is supported in part by the National Science Foundation under grant CNS-0347460.

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