Synthetic Flocking and Bioinspiration

MERIT FAIR
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Objective

To understand how local interactions between pigeons give rise to seemingly coordinated behavior for an entire flock of pigeons.

http://hal.elte.hu/pigeonflocks/

Motivation

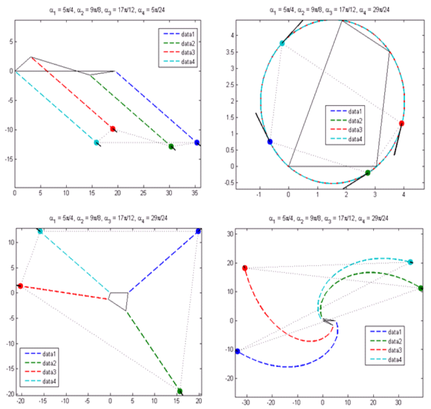
Distributed control of multi-robot systems.

Applications

- Search and rescue
- Self-assembly
- Space colonization?

http://www.outerspaceuniverse.org/ice-water-discovered-moon-lcross-successful.html

Theoretical Background



Figures courtesy of K.S. Galloway, Ph.D. Thesis

- Figures show trajectories of particles implementing a distributed control algorithm called cyclic constant-bearing pursuit.
- Observations about the collective give the impression there is a prescribed behavior for the entire group. However, each particle uses a feedback control law which only uses state information about one other particle.

Constant-Bearing (CB) Pursuit

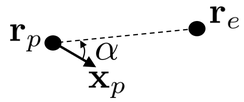


Figure courtesy of K.S. Galloway

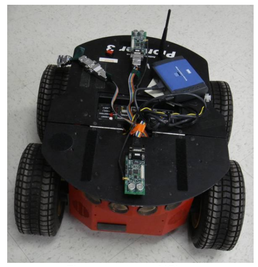
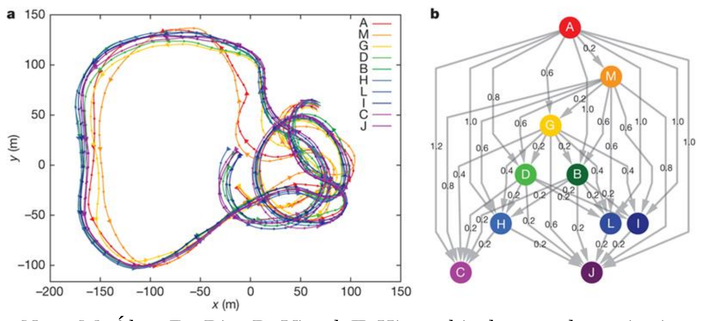


Figure courtesy of ISL

- Intuitive pursuit strategy observed in nature (e.g. falcons pursuing prey).
- Has shown potential to be a building block for collective motion planning (see figures to the lower left).
- Successfully implemented on mobile robots in the Intelligent Servosystems Lab.

Pigeon Flock Experiment

- 10 pigeons were equipped with GPS-loggers.
- Position data was collected during free flight every 0.2 sec.
- Evidence of a leader-follower hierarchy?



Nagy M, Ákos Zs, Biro D, Vicsek T: Hierarchical group dynamics in pigeon flocks, *Nature* **464**, 890-893 (2010).

Hypotheses

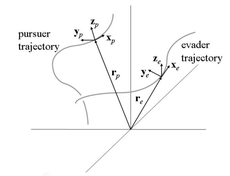
- Underlying mechanism that governs local interactions between pigeons is CB pursuit.
- Leader-follower hierarchy proposed by Nagy et al. is consistent with CB pursuit.

Methodology

- Curve estimation: use steepest descent method to minimize cost:

$$J = \sum_{j=1}^{n} ||\gamma(t_j) - \gamma_j||^2 + \lambda \int_0^{t_n} \left(\hat{u}^2(\sigma) + \hat{v}^2(\sigma) + \hat{\nu}^2(\sigma)\right) d\sigma$$

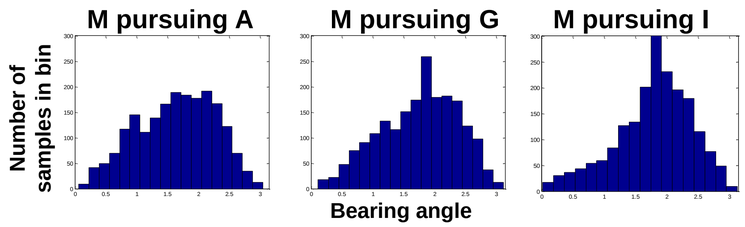
- Use cross validation to find λ.
- From estimated velocities, compute offset angles and examine their distributions.



$$\begin{aligned}
\dot{\mathbf{r}}_p &= \nu_p \mathbf{x}_p, \\
\dot{\mathbf{x}}_p &= \nu_p(\mathbf{y}_p u_p + \mathbf{z}_p v_p), \\
\dot{\mathbf{y}}_p &= -\nu_p \mathbf{x}_p u_p, \\
\dot{\mathbf{z}}_p &= -\nu_p \mathbf{x}_p v_p,
\end{aligned}$$

Preliminary Results

- Cost function is non-convex, so the curve estimation algorithm did not reliably converge. Instead, we used velocities estimated by Nagy et al.
- Hierarchy proposed by Nagy et al. does not follow CB pursuit.
- Select pairs of pigeons support hypothesis of CB pursuit.
- Results might allow an alternative hierarchy, where followers do not necessarily follow a unique pigeon for an entire flight.



Future Work

- Modify curve estimation algorithm to improve performance.
- Examine shorter durations of flight and try to find direct evidence of a follower that switches between leaders.
- Consider alternative pursuit strategies as mechanism governing the behavior of the pigeon flock.

Acknowledgements

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