Cooperative Control for Pursuit Evasion Game

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Cooperative Control for Multi-Vehicle Systems.[Murray:07]

- Cooperative: each vehicle being a dynamic system, and they share a same task without adversarial interference.
- Applications:
  - Military: formation flight, cooperative classification and surveillance, cooperative rendezvous, mixed initiative systems etc.
  - Mobile Sensor Networks: environmental sampling, distributed aperture sampling etc.
  - Transportation Systems: Intelligent highways, air traffic control etc.

[Murray:07] R. Murray, Recent Research in Cooperative Control of Multivehicle Systems, Journal of Dynamic Systems, Measurement, and Control, 2007

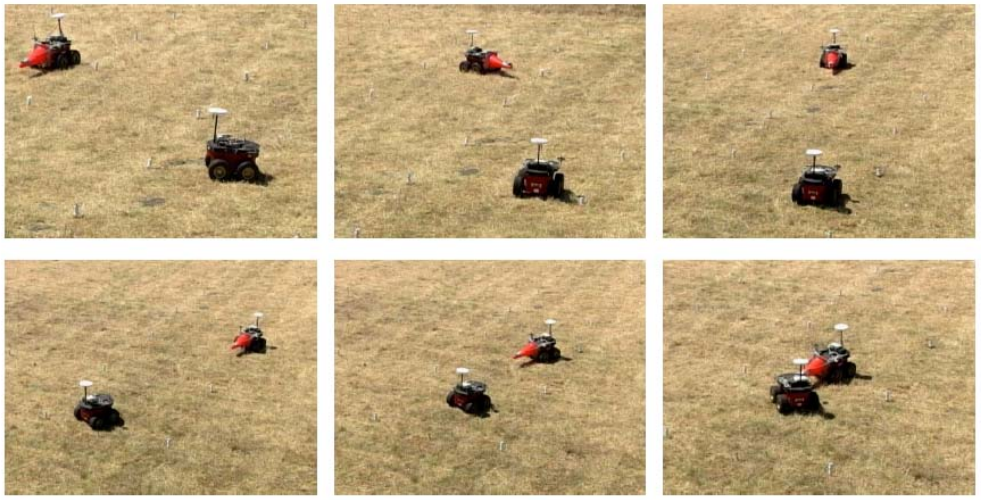
Related PEG Systems

- [Demirbas:03]
  - Evader-Centric: Sensor nodes near the evader maintain a tracking tree dynamically.
  - Pursuer searches the network until it reaches the tracking tree, and then follows the tree to its root in order to catch the evader.
  - Networked Sensors are tunable for tracking speed or energy efficiency
  - Pursuer-Centric Extension: Pursuer sends out agents to find the evader tree, saving energy for locomotion!
  - Small scale experiment: 4 X 4 motes

[Demirbas:03] M Demirbas et al. A pursuit-evasion game for sensor networks, Sixth Symposium on Self-Stabilizing Systems (SSS'03), 2003

Related PEG Systems

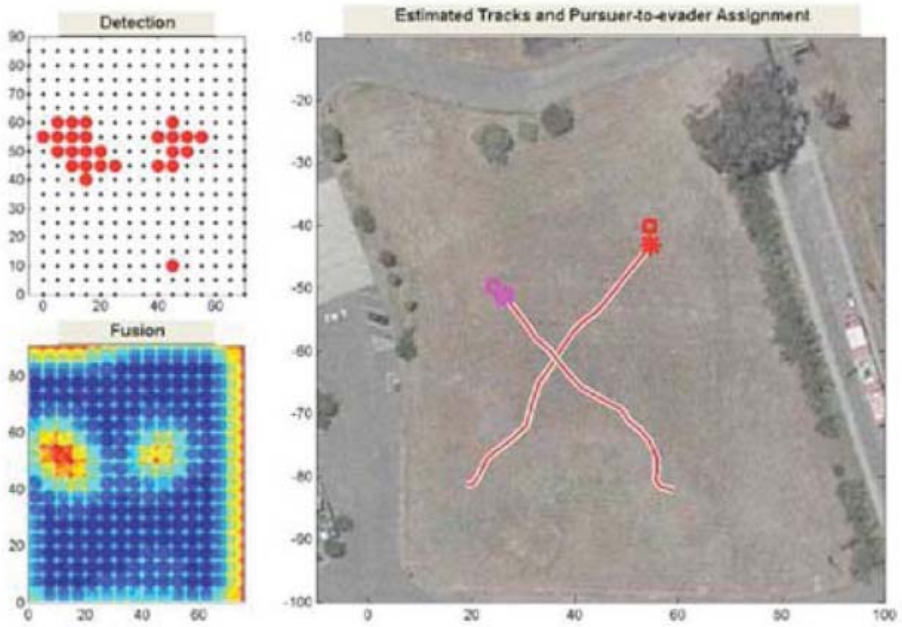
- [Sharp:05] reports an experiment of 100 nodes in a field of 400 square meter.
- Provides physical design experiences a sensor network for detection (Magnetic), routing (landmark)
- Uses GPS to provide pursuer's position



[Sharp:05] C. Sharp et al, Design and implementation of a sensor network system for vehicle tracking and autonomous interception, *Proc.2nd IEEE European Workshop on Wireless Sensor Networks*, pp. 93-107, 2005.

Related PEG Systems

- [Oh:07] deployed a sensor network system for target tracking with PIR as binary sensors. The main contribution is data association for multiple target tracking.
- Simulations were used to generate the pursuit process. Pursuer is not truly implemented.

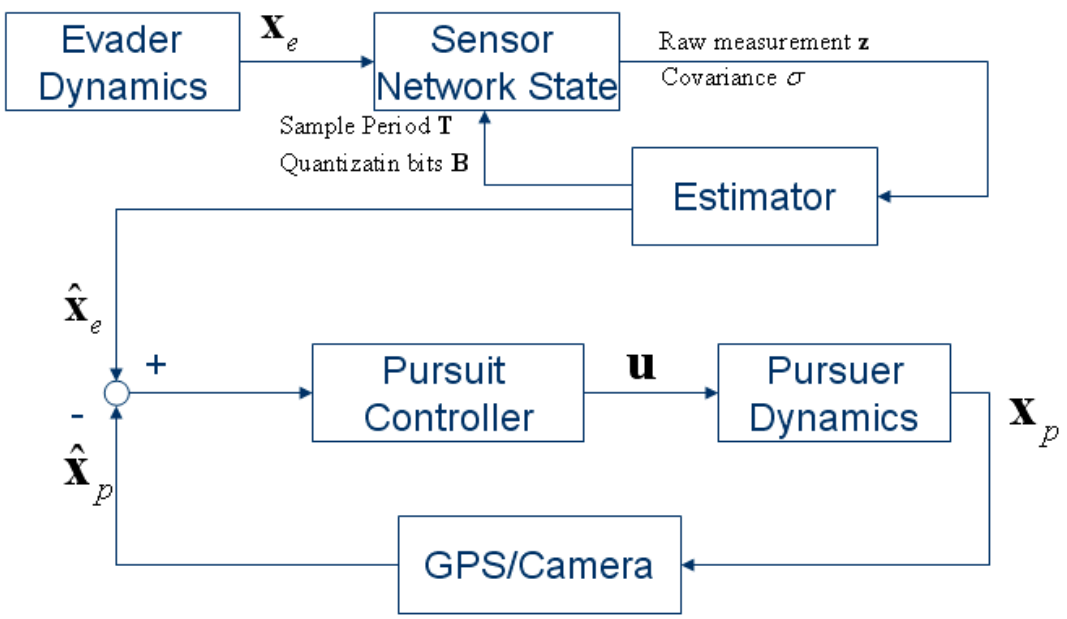


[Oh:07] S. Oh et al. Tracking and Coordination of Multiple Agents Using Sensor Networks: System Design, Algorithms and Experiments. Proceedings of the IEEE, Vol. 95, No. 1, 2007

Our Current System

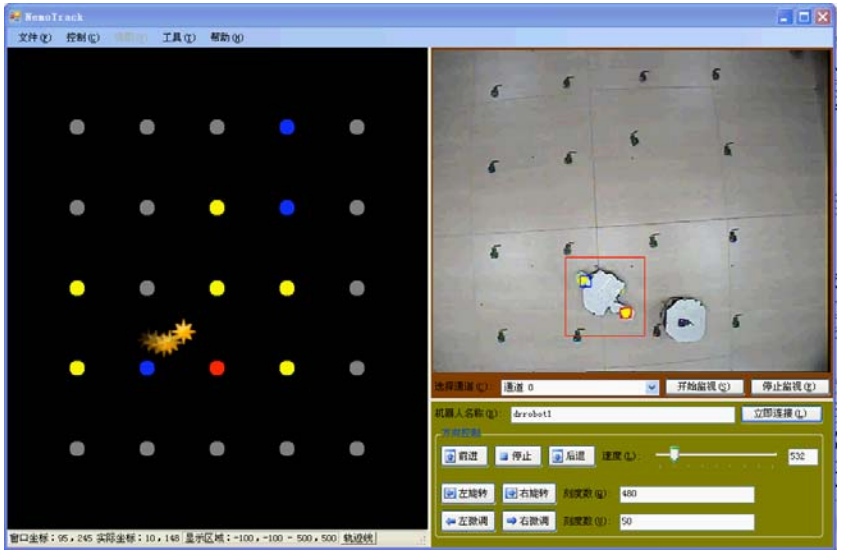
- Follows an architecture similar to [Sharp:05]
- As an Indoor test bed, we use a Camera feedback system to take the place of GPS

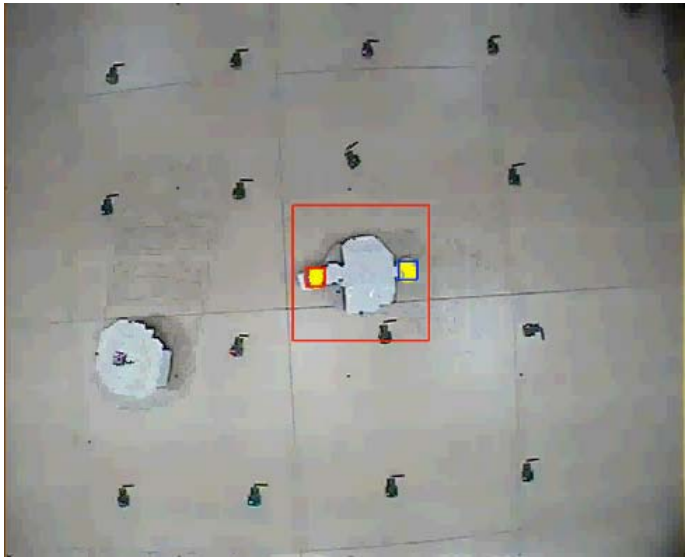
- We tested two different distributed sensor network coordination method:
  - Group management
  - Cluster-based



Our Current System

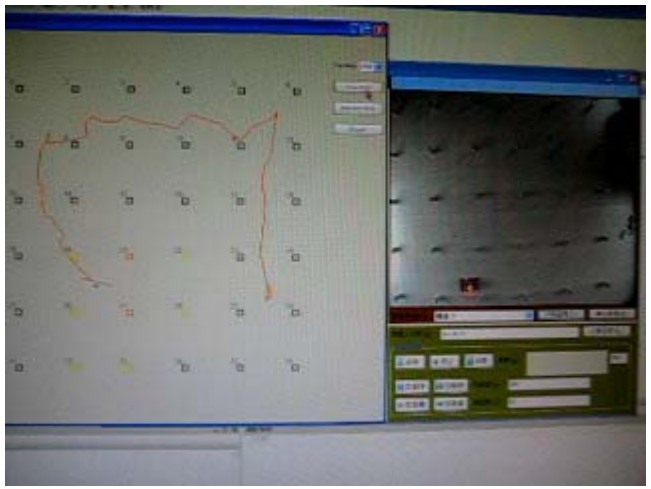
- Demo One:
  - Distributed Group Management.
  - HW: MICAz compatible motes, use RSSI to detect evader and calculate the location estimates.

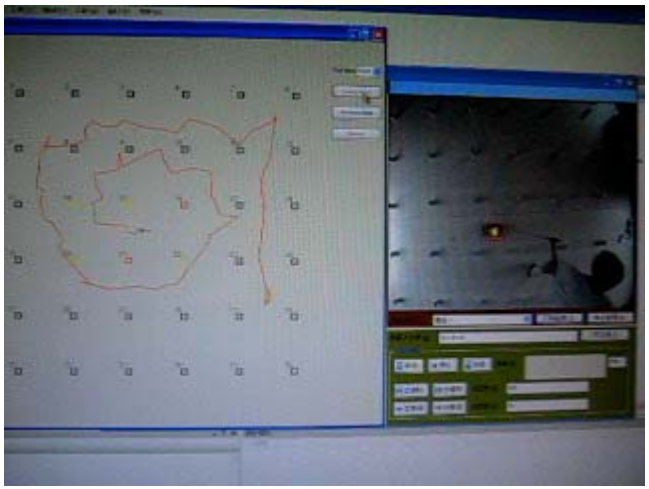




Our Current System

- Demo Two:
  - Single Cluster Management: Nodes are activated only when needed.
  - HW: IRIS motes
    - No longer provides RSSI.
    - Could be used as binary sensors



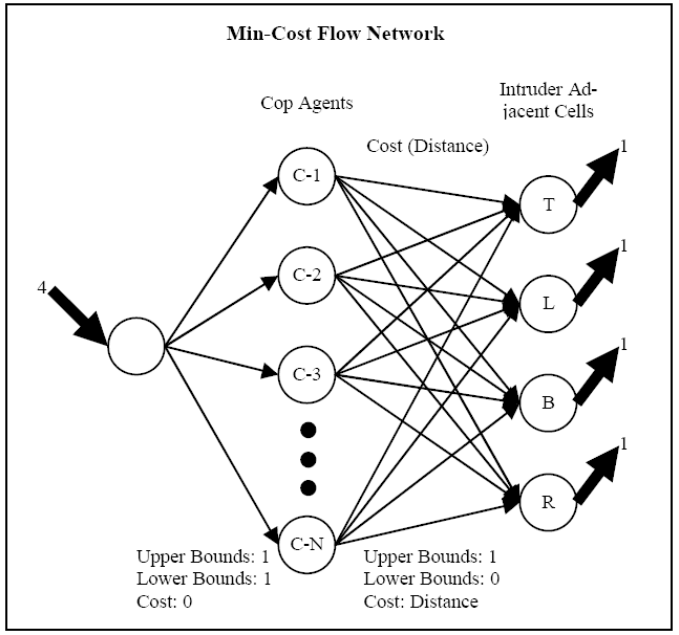


Where is the GAME?

- The Tracking and Pursuit is decoupled by the sensor network!
- It is unfair to provide the pursuers with global information and leave the evaders nothing.
- Need more general settings that make the game interesting:
  - Tunable information availability for evader/pursuer and tunable moving speed.
  - Task assignment and collision avoidance for pursuers.
  - Consider faulty network transmission with unpredictable latency.

PE Game in Sensor Networks

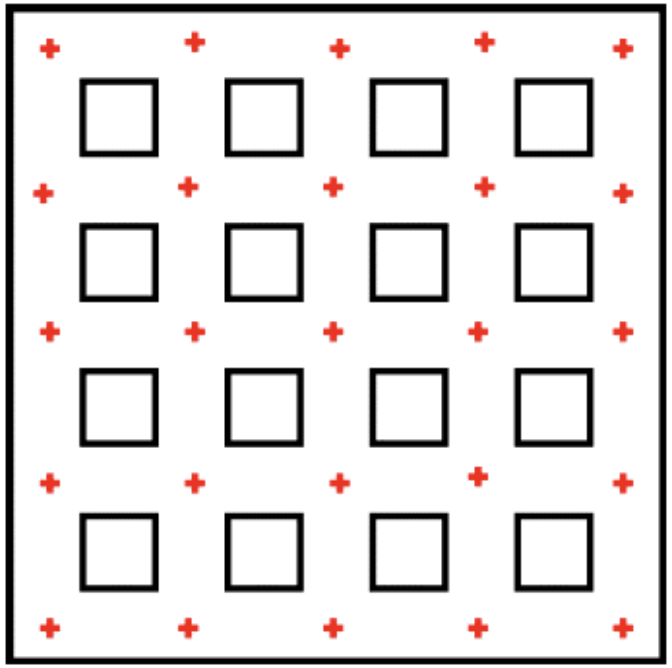
- [P. Beling] developed a simulation-based test bed for researchers to compare the performance of PEG strategies.
- Formulate the RoboCop problem as a min-cost flow network problem



[Beling:05] P. Beling et al. Dynamic Multi-Agent Coordination: RoboCop, Proceedings of the 2005 Systems and Information Engineering Design Symposium

PE Game in Sensor Networks

- [Sert] considers chessboard like network (with clustered sensors). Information Available to both pursuer/evader.
- Pursuit considerations
  - Shortest-path pursuit
  - Non-Collaborative Assignment
  - Collaborative Assignment
  - Obstacle Avoidance (not included in the optimization formulation)
- Evader has greedy policy: Maximize the distance between the nearest pursuer at each instance.



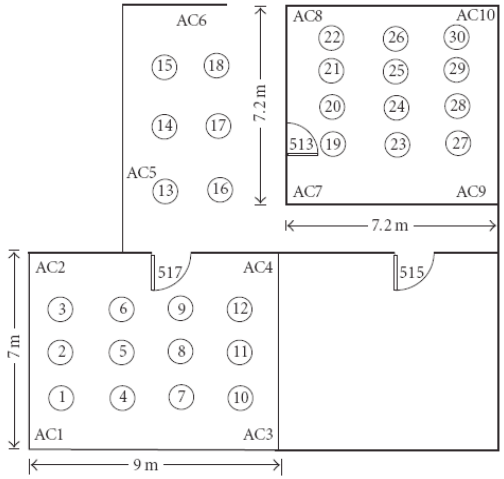
[Sert] O.Sert et al. A Discrete Model for a Differential Pursuit-Evasion Game Using a Hierarchical Sensor Network, http://cres.usc.edu/pubdb_html/files_upload/525.pdf

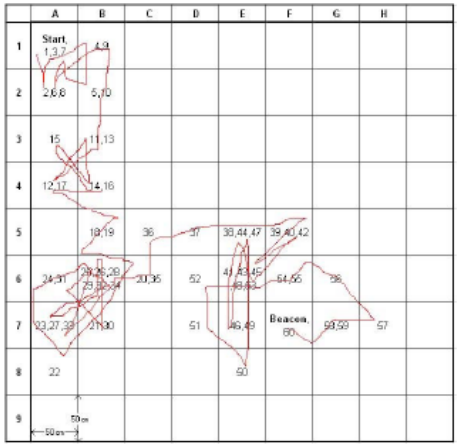
Possible Research Directions

- Dynamic Target Assignment
  - Methods: Scheduling, Optimization.
- Pursuers Formation Control (For Multi-On-One)
  - Methods: Flocking (when searching the evader), Rendezvous/Capture (when evader targeted)
- Pursuit-Evasion Strategy
  - Use prediction schemes to counteract different evader mobility models.
  - Take into account network latency.
- All Could Be Categorized into Multi-Robot Cooperative Control Problem

Integration with previous research

- Extend the PEG in Aisle Environment:
  - Utilize indoor positioning technique to detect evaders. [Li:08a]
  - Utilize static sensors to guide pursuers. [Li:08b]





[Li:08a] H. Li et al. INEMO: Distributed RF-based Indoor Location Determination with Confidence Indicator. EURASIP Journal on Advances in Signal Processing, vol. 2008
[Li:08b] H. Li et al. Connectivity-Aware Motion Control among Autonomous Mobile Units. IEEE International Symposium on Industrial Embedded Systems (SIES) 2008.