Optimization Problems in Visual Surveillance

M.Sc. Thesis Proposal

by Ahmed Abdelkader

Introduction

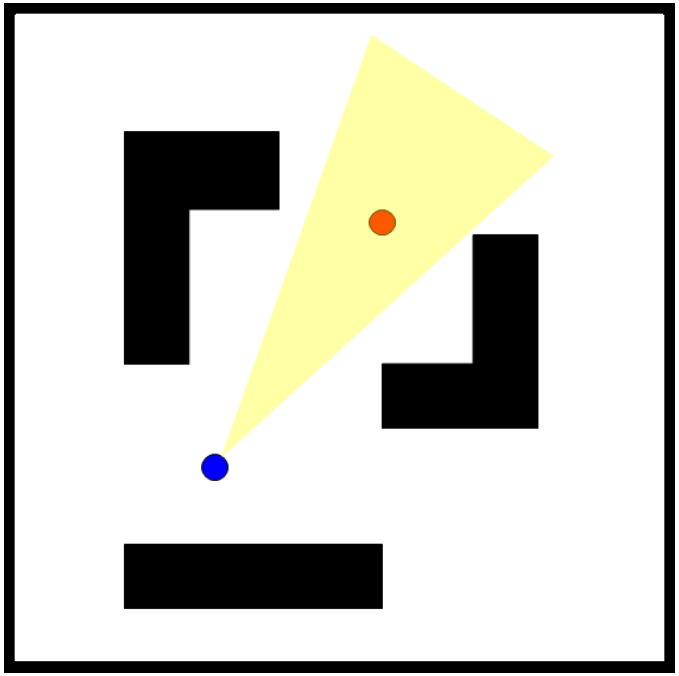
Camera

Target

Two Variants

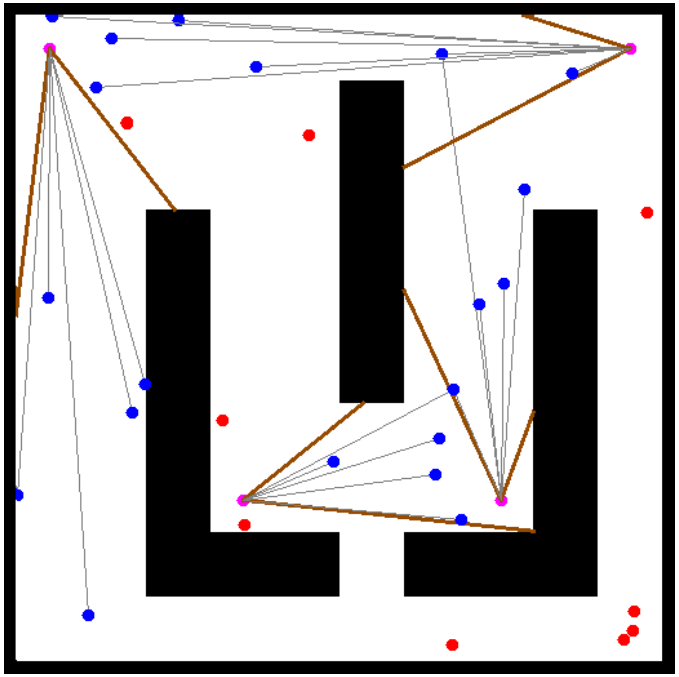
1-on-1

Both Mobile



Many-to-Many

Both Static



Agenda

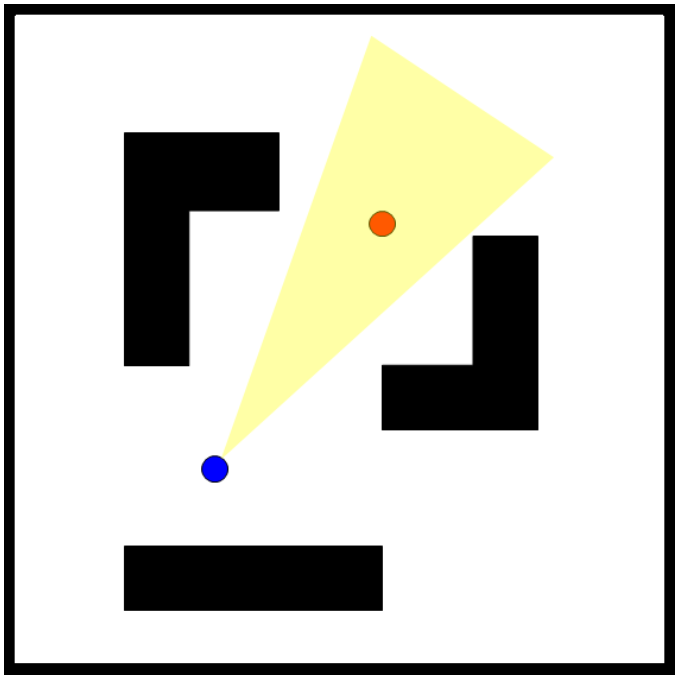
- Introduction
- **Problem(1) Pursuit-Evasion**
- Problem(2) Camera Assignment
- Study Plan

Agenda

- Introduction
- Problem(1) Pursuit-Evasion
  - **Definition**
  - Background
- Problem(2) Camera Assignment
- Study Plan

Visibility-Based Pursuit-Evasion

- Keep evader in sight!
- Omnidirectional vision
- Bounded speed
- Holonomic motion
- General obstacles
- Move in turns
- Complete information



Agenda

- Introduction
- Problem(1) Pursuit-Evasion
  - Definition
  - **Background**
- Problem(2) Camera Assignment
- Study Plan

Background - Pursuit-Evasion

- Continuous - Differential Games
  - Isaacs conditions ~ Pontryagin's principle [1]

    Characterize the Hamiltonian of the system along optimal trajectories

$$H(\mathbf{x}, \nabla J, u, v) = \nabla J \cdot f(\mathbf{x}, u, v) + L(\mathbf{x}, u, v)$$

$$(u_e^*, \theta_e^*, u_p^*, \theta_p^*) = \min_{u_e, \theta_e} \max_{u_p, \theta_p} H(x, \nabla J, u, v)$$

$$H(\mathbf{x}, \nabla J, u^*, v^*) = 0$$

- Discrete - Graph Search
  - Cops and Robbers [2]

$$\ell(c_{xy}) := 1 + \min\{\ell(r_{x'y}) : x' \in N^+(x)\}$$

$$\ell(r_{xy}) := \max\{\ell(c_{xy'}) : y' \in N^+(y)\}$$

[1] S. Bhattacharya, S. Hutchinson, *On the Existence of Nash Equilibrium for a Two-player Pursuit-Evasion Game with Visibility Constraints*, IJR, 2010

[2] Geňa Hahn, Gary MacGillivray, *A note on k-cop, l-robber games on graphs*, Discrete Mathematics, 2006

Agenda

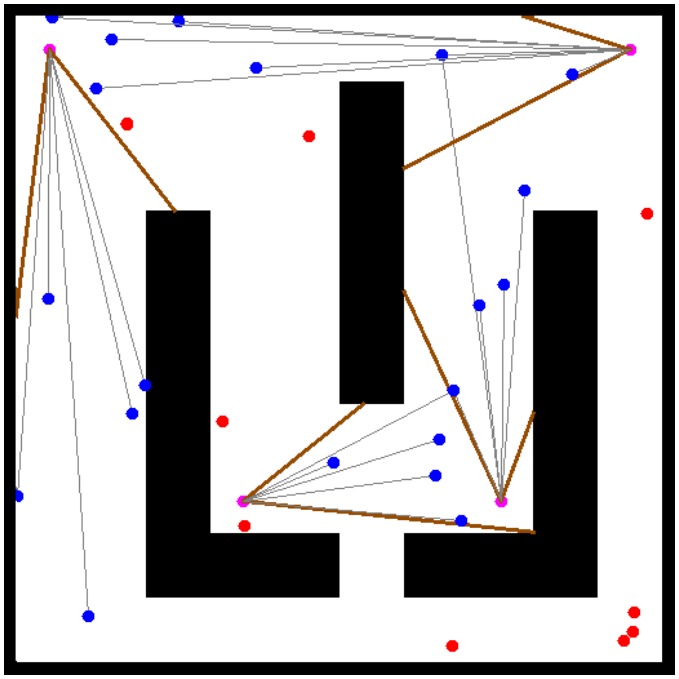
- Introduction
- Problem(1) Pursuit-Evasion
- **Problem(2) Camera Assignment**
- Study Plan

Agenda

- Introduction
- Problem(1) Pursuit-Evasion
- Problem(2) Camera Assignment
  - **Definition**
  - Background
- Study Plan

Camera-Target Assignment

- Cover max. no. of targets!
- Cameras rotate freely
- Fixed field of view
- General obstacles

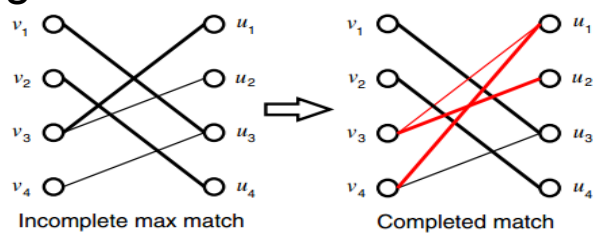


Agenda

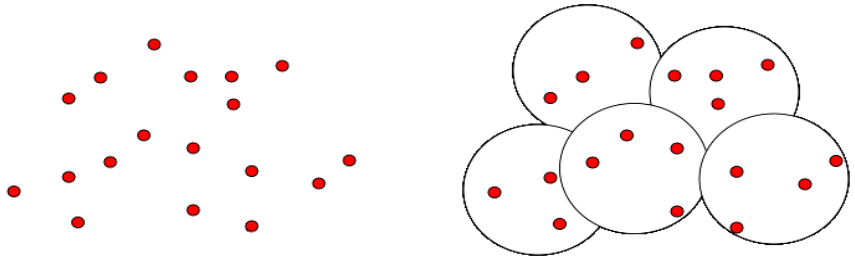
- Introduction
- Problem(1) Pursuit-Evasion
- Problem(2) Camera Assignment
  - Definition
  - **Background**
- Study Plan

Background - Camera Assignment

- Assignment Problems [3]
  - Bipartite Matching



- Geometric Set Cover
  - Coverage by unit disks, NP-hard [4]

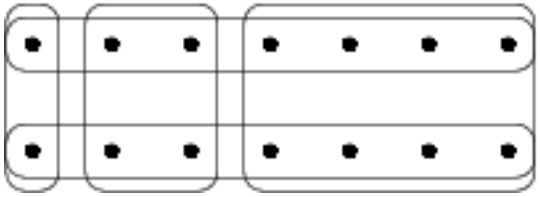


[3] David Pentico, *Assignment problems: A golden anniversary survey*, European Journal of Operational Research, 2007

[4] Robert Fowler, Michael Paterson, Steven Tanimoto, *Optimal packing and covering in the plane are NP-complete*, Information Processing Letters, 1981

Background - Camera Assignment

- Greedy Heuristics
  - Approximation of Set Cover
  - $\Omega(\log n)$ - *unless NP has quasi-polynomial time algorithms [5]*



- Game Theory
  - Welfare Games [6]
    - Nash Equilibrium
    - Price of Anarchy

[5] Uriel Feige, *A threshold of ln n for approximating set cover*, JACM, 1998

[6] Jason Marden, Adam Wierman, *Distributed welfare games with applications to sensor coverage*, CDC 2008

Agenda

- Introduction
- Problem(1) Pursuit-Evasion
- Problem(2) Camera Assignment
- **Study Plan**

Study Plan - Pursuit-Evasion

- Theoretical foundations
  - Escape conditions
  - Graph models
- Solution methods
  - Star regions
  - Recurrences
- Practical considerations
  - Feasible computation
  - Motion continuity
  - Online planning

Study Plan - Camera Assignment

- Theoretical foundations
  - Assignment models
  - Linear programming relaxation
  - Geometric set cover
  - Game theory
- Solution methods
  - Greedy heuristics
  - Approximation algorithms
- Practical considerations
  - Quality of coverage e.g. zooming
  - Target mobility

Thank You

Questions?

abdelkader@alexu.edu.eg