Evolutionary Approaches for Resilient Surveillance Management

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BioSTAR Workshop, 2017
Surveillance Systems

- Growing interest in surveillance systems
  - Decreased camera costs make these systems affordable
  - Applications include monitoring security and improving safety

- Management has become more complex
  - Given a set of cameras how should they be deployed?
  - What happens if the environment changes?
Art Gallery Problem

- Determining camera locations and orientations is a well known problem
  - Art Gallery Problem (AGP) originally introduced in 1973
    Locate guards (cameras) in an art gallery (polygonal space) such that every interior wall was observed by at least one guard.

- Heuristics exist for AGP, but assume everything is static
Surveillance Problem

- Let’s consider a variation of the AGP

- Assume cameras are already located within the floor space
  - Each camera has fixed view angle $\alpha$ and adjustable rotation angle $\beta$
  - Can also turn a camera on or off

**Objective:** Determine the smallest set of cameras and their orientation that maximizes wall coverage
Configuration Search

- Consider all the possible configurations for a floor plan and camera set.

- Can apply a search algorithm, but perhaps not a traditional approach.
Surveillance Resilience

- Cameras and/or obstacles may be introduced and/or removed

Management should automatically adjust to changes
Evolving Surveillance Management

- Evolutionary Algorithms (EAs) are used as search heuristics
  - Better solutions are created from good solutions
- EAs have the ability to constantly search
  - If the problem changes, then the EA can adapt the solution
Evolutionary Algorithm Components

- Chromosome – a model for a solution to the problem
- Fitness – value for ranking, we seek *better solutions*
- Processes – combining solutions to create new one
- Pool – set of chromosomes (*also called a population*)
Chromosomes and Fitness

- A chromosome is a solution to the problem
  - Camera $i$ has two settings: $p_i = \{1, 0\}$ and $\beta_i = (0, 360)$

\[
s = \{\{1, 95\}_0, \{0, 0\}_1, \{1, 80\}_2\}
\]

- Therefore a surveillance configuration $s$ is a chromosome

- Fitness consists of two objectives
  - Maximize the coverage (percentage of the wall space observed)
  - Maximize the number of inactive (unused) cameras
  - Use Pareto ranking to determine the best configuration
Evolutionary Algorithm Processes

- Selection identifies parents for new chromosomes (configurations)
- Crossover combines selected chromosome to create new chromosomes
- Randomly change traits (camera settings)
System Operation

Continually iterates and updates configurations based on environment.
**EA + Beam = Hybrid**

- Beam search is another search heuristic that maintains a population
  - Explores only the best $x\%$ solutions in the current generation
  - Best $x\%$ mutated to create next generation
  - Beam can focus on a specific area within the search space
- Combining EA and Beam may provide better search breadth and depth
  - Combining can be easily done across generations

- Provides refinement and exploration (if the environment changes)
Experimental Results

- Considered 40-sided orthogonal polygonal floor plans
  - 10 different 40-sided orthogonal polygons generated
  - 80 cameras were randomly located within the floor plan
- Interested in evaluating the resiliency of surveillance management
  - Considered random camera add/removal and obstacle add/removal
  - EA, beam search, and hybrid management approaches compared
- Seek high coverage and high inactive camera percentages
Adding and Dropping Cameras

- 4 Drop (D) events followed by 4 Add (A) events

![Graph 1: Average Coverage percentage](image1)

![Graph 2: Average Inactive camera percentage](image2)

- Evolutionary-based adapted better than beam search
- Hybrid performs slightly better than EA
Obstacles

- Four 4-sided obstacles introduced at generation 300

- Evolutionary-based adapted better than beam search

- Coverage is similar; however, evolutionary-based used fewer cameras
Conclusions and Future Work

- Camera-based surveillance systems are increasing in popularity
  - Providing resilient management is difficult (Art Gallery Problem)
  - Most heuristics do not consider dynamic conditions
- Evolutionary-based management algorithms have several advantages
  - Able to dynamically adjust to changing system conditions
- Several areas for future work
  - More experiments are needed to better understand hybrid operation
  - Experiment with complex events (camera changes and obstacles)
  - Prefer the technique to be more distributed
Turn back, you’ve gone too far
Multi-Objective and Pareto Optimal

- Weighted sum can be used to scalarize multi-objective values
  - All solutions that yield an good average are considered equal

A configuration \( s_i \) said to dominate the another solution \( s_j \): if the solution \( s_i \) is no worse than \( s_j \) in both objectives and the solution \( s_i \) is strictly better than \( s_j \) for at least one objective.