Evolutionary Algorithms for Fire and Rescue Service Decision Making

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Evolutionary Algorithms for FRS Decision Making

Contents

• Introduction
• Problem scale
• Evolutionary Algorithms
• Software Development
• Conclusions and Future Work
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Introduction

• Strategic (long term) decision making for Fire and Rescue Service Resources
  – Fire Station location
  – Appliance location
  – Crewing types (wholetime or retained)
  – Specialised equipment locations
  – Response types

• Large problem

• Many potential solutions
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Introduction

• Current tools available for strategic decision making
  – Fire Service Emergency Cover toolkit (software) FSEC
  – Measures effectiveness of a particular scenario based on life and property loss
  – Based on statistical incident data
  – Only allows user to evaluate one option at a time
  – Run-times are long (approximately 20-30 minutes for a typical FRS area)

• Is this a problem?
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Problem Scale

• Typical brigade – e.g. South Wales FRS
  – Approximately 50 stations
  – 19 wholetime, 5 day crewed, 26 retained
  – 1000 full time firefighters
  – 600 retained
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Problem Scale

• Assuming 70 station sites (i.e. current 50 sites plus 20 potential sites)

• 50 stations to be placed in suitable locations – how many combinations of 50 stations can be selected from 70 sites?

\[ N_s = \binom{70}{50} = \frac{70!}{50!(70-50)!} \approx 10^{17} \]

• But each station can have a variety of configurations based on crewing type, vehicle allocation etc

• Conservative estimate would suggest 6 different station configurations
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Problem Scale

- Each set of 50 stations can therefore be configured in $6^{50}$ ways ($\approx 10^{38}$)

- Thus total configurations is

$$N = N_s \times N_c = 10^{17} \times 10^{38} = 10^{55}$$

- Some of these configurations may not be feasible, or may include near-duplicates.

- However, it is impossible to even evaluate 10\% of the total number of solutions manually.

- The only feasible way of finding good solutions is via the use of some form of search algorithm

- Evolutionary algorithms have been chosen for this work
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Evolutionary Algorithms

- Bio-inspired search algorithms
  - e.g. Ant colony, particle swarm analysis, genetic algorithms

- Ideal for complex problems
  - do not require fully-defined objective function
  - use a “fitness function” as a means of judging whether one solution is better than another
  - avoid getting stuck on local optima
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Evolutionary Algorithms

- Genetic Algorithms chosen for this work
- Mimic Darwinian evolution (i.e. survival of the fittest)
- Starts with a population of random solutions
- Population gradually evolves by selection, breeding and mutation of the best solutions at each generation
- Only has to sample a small proportion of the total possible solutions
• Genetic algorithm (GA) architecture
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Evolutionary Algorithms

- GA developed for this project
- Tested using simple fitness functions with known solutions
- e.g. maximise $\sin(x)$ where $0 < x < \pi$
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Software Development

• Need a measure of the suitability of potential solutions within the Genetic Algorithm

• A “fitness function”

• Based on methodology from existing software (FSEC)

• Fire Service Emergency Toolkit (FSEC)
  – Based on a Geographical Information System (Wings32)
  – Run-times very long – 27 minutes for a typical brigade
  – Very graphics-intensive
  – Manual model configuration
  – Unsuitable for direct use as fitness function
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Software Development

• FSEC
  – Includes geographical relationships of brigade area
  – Road network
  – Census data
  – Incident data
  – Fire station locations and vehicle / staffing allocations
  – Calculates likely rates of four types of incident
    • Dwellings fires
    • Special Services Incidents (e.g. road traffic incidents)
    • Other buildings fires
    • Major Incidents (e.g. terrorist attack, major rail accidents)
  – Calculates fatalities and property damage based on mathematical relationship between response times and losses
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Software Development

OS Map Data
Road Junction
Road Link
Output Area
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Software Development

- Dwellings
- Special Services
- Other Buildings
- Major Incidents

Statistical Incident Data

Output Area Data

Likely number of Fires or Casualties in Output Area for each incident type

Geographical Data

- Road Network
- Vehicle Data
- Arrival Times
- Fatalities
- Property Loss
Using FSEC as a fitness function

- Fitness function is called multiple times within each generation of the genetic algorithm
- Need for significant reduction in execution times
- Core FSEC calculations re-programmed in Fortran
- Original FSEC used as pre-processor
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Software Development

• Re-coded model achieves significant reduction in execution times:
  – Original full FSEC model for typical brigade 27 min
  – New Fortran FSEC code for same data 18 sec

• All configuration-specific calculations contained within Fortran code

• Pre-processor deals with statistical processing

• Time savings achieved for multiple runs – i.e. to evaluate 500 different resource configurations:
  – Original FSEC 227 hours
  – New Fortran FSEC 3 hours
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Future Work

• Fortran FSEC development
  – Continue testing against range of data sets
  – Include cost effects in Fitness Function

• Link Genetic Algorithm to Fortran FSEC

• Test!!!
Conclusions

- Optimising Fire Service resources is a highly complex problem
- There are a massive number of potential solutions
- It is impossible to manually evaluate all solutions
- Evolutionary algorithms offer many advantages in dealing with complex problems such as this
- A computationally more efficient version of FSEC has been developed for use as a fitness function
- A Genetic Algorithm has been written
- Work is ongoing to couple the two
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Project Website

http://fire.engineering.cf.ac.uk
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Acknowledgements