Sensor Placement Algorithm for Rapid Theatre Assessment (SPARTA)

Presented by:

Dr Robert Gordon and Dr Martyn Bull

Introduction

- CB Sensors in Collective Protection Strategies
- Aims of Sensor Placement
- The SPARTA Approach
- Questions

Active Collective Protection Strategies

- Provide early warning of possible CB threat
- Information used to initiate threat response procedures such as
  - **Pre-Verification Actions** – event characterization
    - Source term estimation modeling
    - Hazard prediction modeling
  - **Verification Actions** – confirmation of threat
    - Multiple sensor integration
    - Integration over time
    - Visual observation
  - **Post-Verification Actions** – implementation of full collective protection strategy
  - **Post-Event Actions** – Decontamination / Forensics
    - Sensor data can be used to guide event reconstruction or determine effectiveness of decontamination efforts
- CB Sensors play critical role in Active Collective Protection Strategies

Problem Definition

"To determine how many CB sensors and where to place these CB sensors to provide the required level of protection for key assets while minimising the overall *cost*"

The Art Gallery Problem

- Introduced by Victor Klee in 1973
  - You have just bought an art Gallery and want to protect the contents from theft.
  - Where should the guards be positioned to ensure all assets are protected from theft.
  - What is the minimum number of guards required to provide complete coverage?

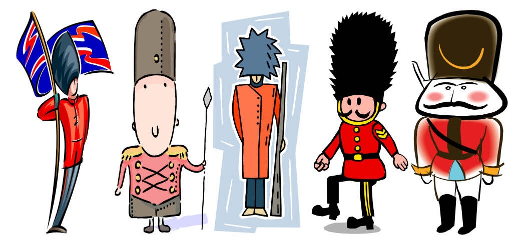
The Art Gallery Problem

- Assumptions
  - Gallery defined as closed polygon
  - Unlimited number of prime quality guards available
  - Guards have continuous 360^{o} vision
  - There are no visitors

- Solution
  - Triangulation to determine maximum number of guards required
  - Optimisation to eliminate unnecessary guards

The Art Gallery Problem

- Closer match to CB sensor placement:
  - The gallery has no defined boundaries
  - Finite number of guards available
  - Each guard has different strengths and weaknesses
  - The guards can be unreliable
  - There are lots of visitors some which like to dress a bit like thief's
  - Assets can relocate
- Conclusion
  - By the time you figure our where best to place your guards, someone has stolen your Mona Lisa!



CB Sensor Placement Problem

- Continuous domain – complex varying environment
- Different sensor type – standoff and point, biological and chemical
- Use different sensing techniques
- Portability and size need to be considered
- Reliability considerations - prone to false alarms and nuisance alarms
- Cost considerations
- Timeliness – balancing the solution with the urgency

Aims of SPARTA Project

- To provide sensor placement capability that
  - Optimises the number and position of CB sensors to provide ‘best’ protection
  - Provides an incremental approach to building the problem complexity
  - Minimises computation times for the initial sensor placement

RiskAware. solutions for life

SPARTA Approach

Key Development Goals

- Key functional requirements
  - Design deployments of multiple co-operating detectors (including detectors of multiple types)
    - Sensors combine to give maximum protection of assets
      - i.e. provide ***maximum probability*** of ***timely*** warning
  - Based on modelling of appropriate fidelity
    - Plume dispersion modelling
    - Sensor modelling
    - Downwind effects modelling

Key Development Goals (2)

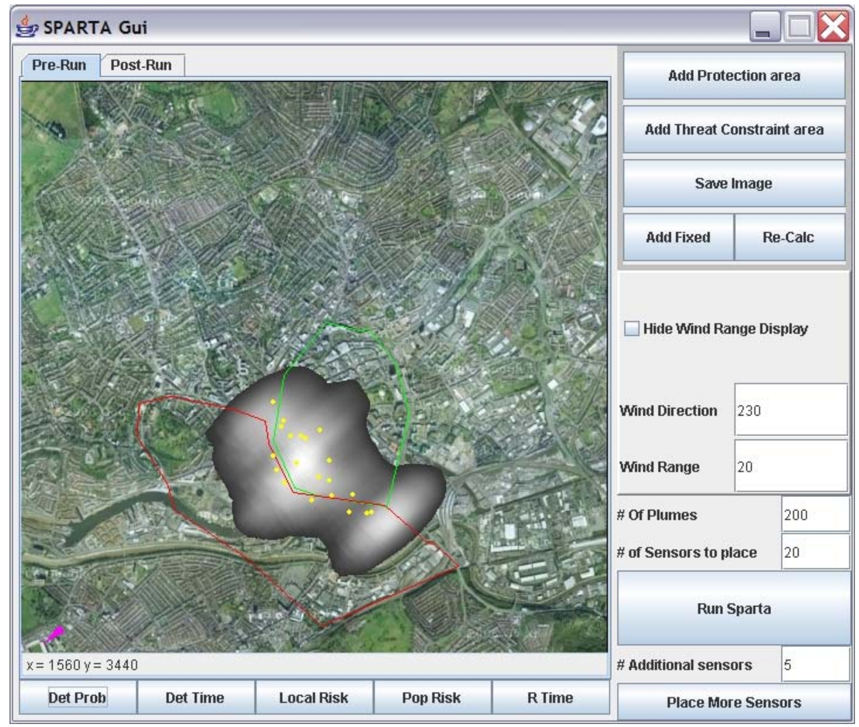
- Key calculation input requirements
  - Spatial information
    - Key asset locations (from vulnerability assessment)
    - Likely threat locations (from threat assessment)
    - Sensor deployment cost information (from geography)
    - Other geographic data
  - Meteorology
    - Wind rose (or spatially varying wind data)

Key Development Goals (3)

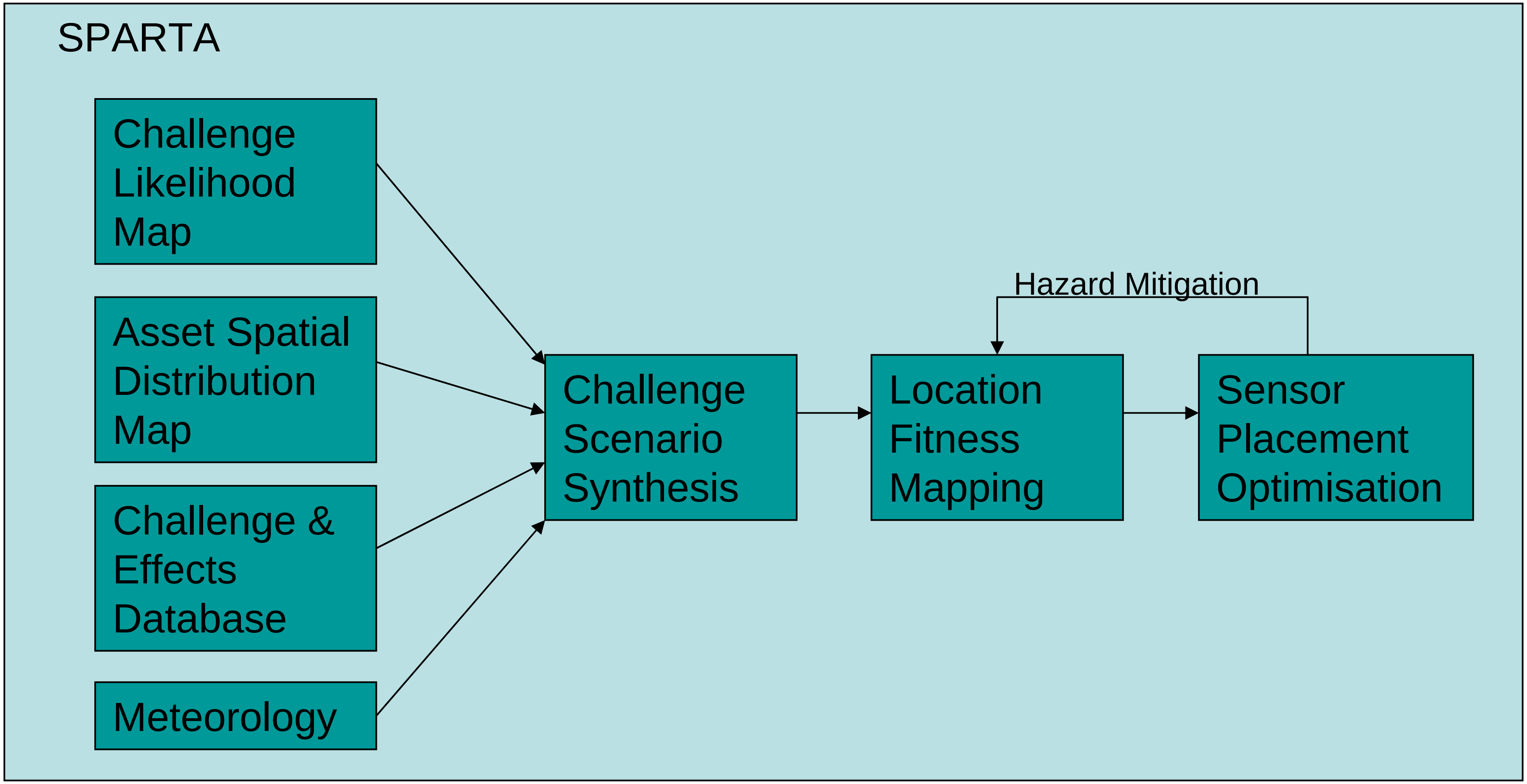
- Key non-functional requirements
  - Rapid computation - 1-5 minute computation
    - (for practical in-theatre deployment)
  - Network-ready modular software design
  - Cross-platform deployment (Windows, Unix, etc.)

Sensor Placement Algorithm for Rapid Theatre Assessments (SPARTA)

- Modular calculation engine programmed in pure Java
  - Cross platform deployment
  - Designed for networked deployment
    - Visualisation via bespoke GUI, GIS, GOOGLE Earth, other options.
  - Based on existing physics-based modelling
    - Uses any suitable dispersion model
- Extensive pre-processing provides very rapid computation
  - 1 minute computation achieved for simple cases
  - Orders of magnitude (2+ orders) faster than “longhand” methods



SPARTA Technical Details – Data Flow



SPARTA Technical Details - Methodology

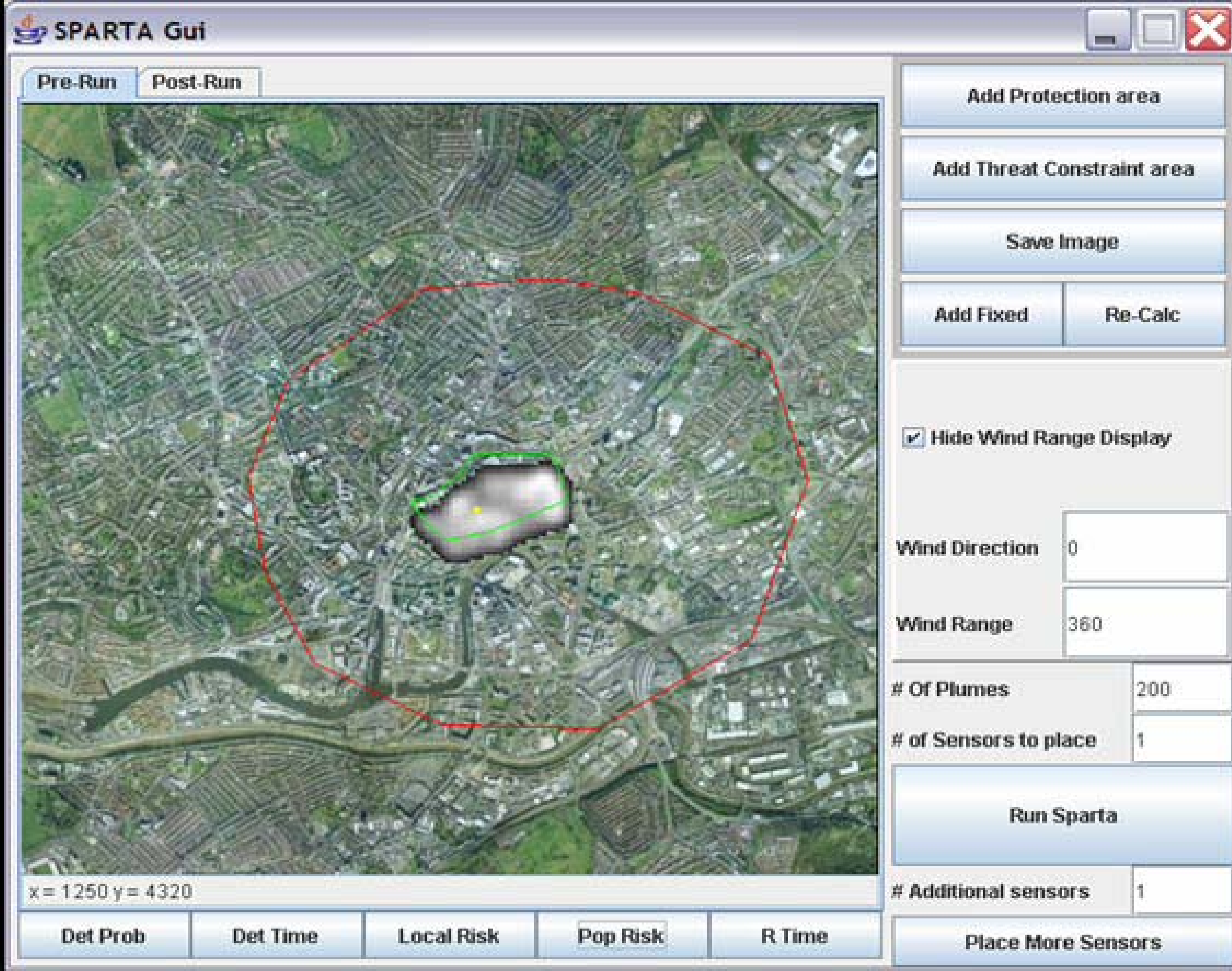
- Challenge/effects database
  - SPARTA uses a database of pre-run and pre-processed plumes from a 2nd order dispersion model such as SCIPUFF
  - Pre-processing ("thin slicing") has been used to extract key information from plume
    - Hazard level map (% casualties)
    - Hazard "impact" time map
    - Detection probability map (for each detector type)
    - Detection timing map (for each detector type)
- Sensor location fitness calculation
  - Monte Carlo method used to create 000's of challenge scenarios
  - **Robust** fitness measure for detector locations calculated
- Sensor placement optimisation
  - Sequential placement algorithm identifies "good" placements

SPARTA Technical Details – Detector Location Fitness

- The following data is used to calculate *smoothly varying* maps of detector location fitness:
  - Impact of each scenario on protected population/assets
    - Considers population density and hazard level
    - Supports raster (graded) or vector definition of protected asset locations
  - Probability of detection at proposed location
  - Timeliness of detection
    - i.e. time between warning and arrival for each protected asset location
  - “Cost” function of sensor location (raster or vector)
- Detector location fitness updated after each detector location is fixed
  - i.e. protected assets have their threat level reduced pro-rata by each sensor

SPARTA Technical Details – Position Optimisation

- A sequential placement scheme is adopted
  - Each successive sensor is placed at the best available location
  - Sensor location fitness is are adjusted via threat reduction
- A final test is performed on the overall placement
  - Weakest sensor locations are moved to better locations
- Sequential scheme is effective because fitness function is smooth and well behaved
- Other algorithms (e.g. Genetic Algorithm) could be added as post-processing stages for use if time allows


SPARTA Gui
Pre-Run
Post-Run
Add Protection area
Add Threat Constraint area
Save Image
Add Fixed
Re-Calc
Hide Wind Range Display
Wind Direction
0
Wind Range
360
Of Plumes
200
# of Sensors to place
1
Run Sparta
Additional sensors
1
Place More Sensors
x = 1250 y = 4320
Det Prob
Det Time
Local Risk
Pop Risk
R Time

SPARTA Summary

- Calculation of sensor placement schemes on a 1-5 minute timescale IS achievable on current computation platforms
- Pre-processed plume database is instrumental in providing required performance gains
- A sequential placement scheme is efficient, and works well in combination with:
  - Smooth fitness function
  - Risk mitigation after each placement.
- Other algorithms (e.g. Genetic Algorithm) could be added as post-processing stages for use if time allows

Questions?

Contacts

Dr Martyn Bull

Tel: +44 (0) 117 9330533

martyn.bull@riskaware.co.uk

Dr Robert Gordon

Tel: +44 (0) 117 9330523

robert.gordon@riskaware.co.uk