An Extensible Model for the Deployment of Non-Isotropic Sensors

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Presentation Overview

- ✓ Sensor Deployment Problem (SDP)
- ✓ Problem Formulation
- ✓ Optimization Problem
- ✓ Genetic Algorithm Approach
- ✓ SDP Model
- ✓ Case Study, Conclusion, Q & A

Sensor Deployment Problem (SDP)

- ✓ Defining SDP:

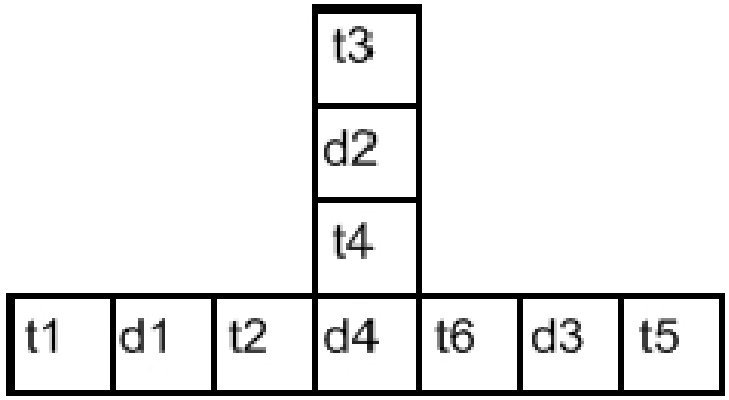
  Given an area to monitor, determining the optimal set of sensors to deploy.

- ✓ Given Heterogeneous, Non-Isotropic Sensors

- ✓ Optimization based on Specific Problem

Problem Formulation

- a_{ij} : zero-one *Coverage Matrix*
- t_i : Target Point (point to cover, rows)
  < x, y, z >
- d_j : Deployment Tuple (sensor tuple, columns)
  < sensor type, deployment point, orientation >



(a)

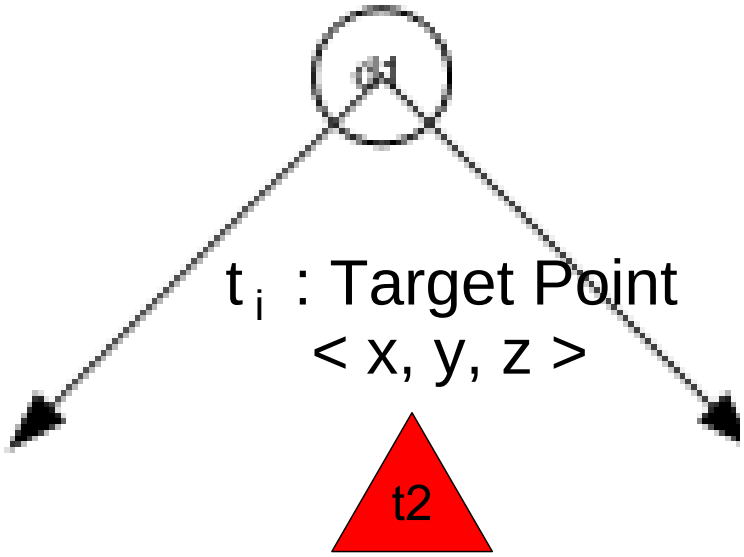
	d1	d2	d3	d4
t1	1	0	0	0
t2	1	0	0	1
t3	0	1	0	0
t4	0	1	0	1
t5	0	0	**1**	0
t6	0	0	**1**	1

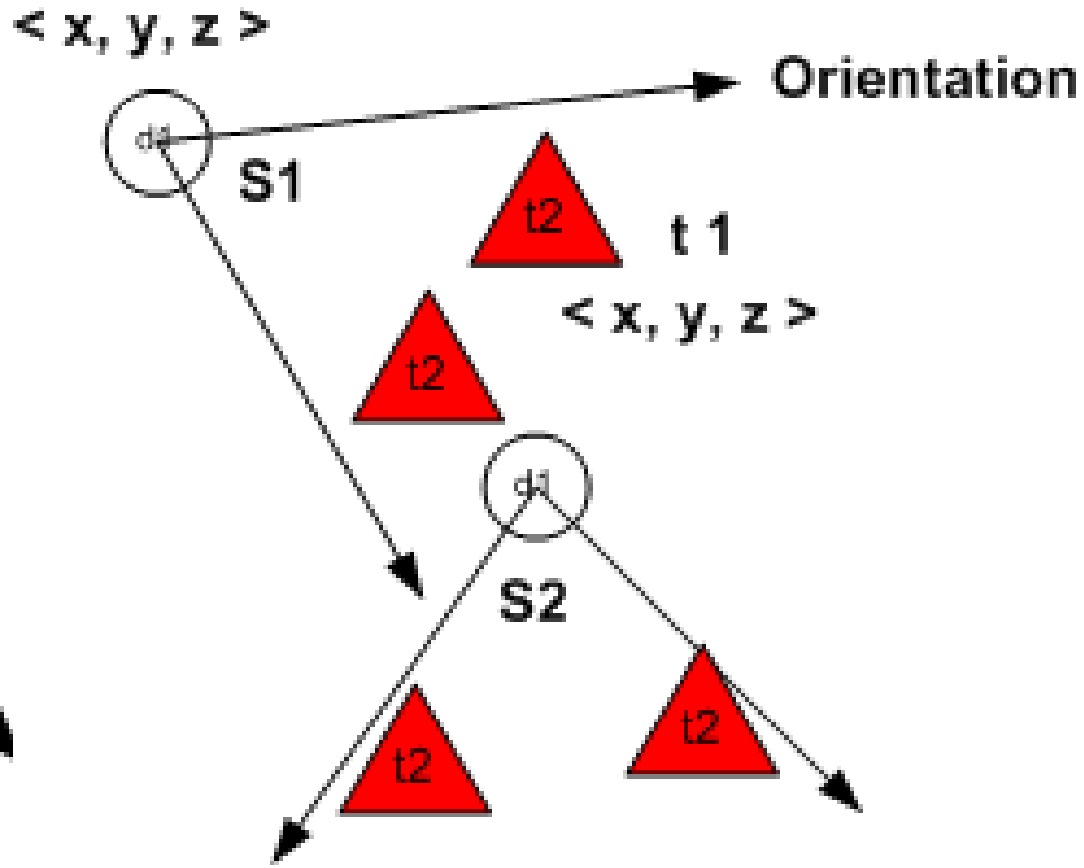
(b)

Non-Isotropic Model

- d_j : Deployment Tuple

< sensor type, deployment point, orientation >





Extensible Model

- Coverage Determination Method:

  Given an area to monitor, determining the optimal set of sensors to deploy. Many different types of sensors with varying abilities.

- Supports different Sensors used in the solution for determining an optimal set.

- Many different target points, many different sensors, with varying abilities.

Building the Coverage Matrix

- ✓ Foundation of the model is building the coverage matrix

	d									
t		1	2	3	4	5	6	7	8	9	10
	1	0	0	0	0	1	1	0	0	0	1
	2	0	0	0	1	0	0	1	1	0	0
	3	0	0	1	0	1	1	0	1	0	1
	4	1	0	1	0	0	1	1	1	0	1
	5	1	0	0	1	0	0	0	1	0	1
	6	0	1	0	1	1	0	1	0	0	0
	7	0	0	0	0	0	1	0	0	1	1
	8	1	0	0	1	0	0	1	1	0	0
	9	0	0	0	0	1	0	0	0	1	1
	10	0	1	0	0	0	1	0	0	0	0
	11	0	1	0	0	0	1	1	0	1	0
	12	0	0	0	1	0	0	0	1	1	0
	13	0	0	0	0	0	0	0	0	1	0
	14	0	1	0	1	0	0	1	0	0	1
	15	0	0	0	0	0	0	0	0	0	1

Optimization Problem

- $x_j = 1$ if d_j is in solution, 0 otherwise
- c_j : cost of deploying d_j
- (n) columns, (m) rows

$$\text{Minimize} \quad \sum_{j=1}^{n} c_j x_j \qquad (1)$$

$$\text{Subject to} \quad \sum_{j=1}^{n} a_{ij} x_j \geq 1, \quad \text{i=1,...,m} \qquad (2)$$

$$x_j \in \{0, 1\}, \quad \text{j=1,...,n} \qquad (3)$$

Genetic Algorithm Approach

- ✓ Microbial Genetic Algorithm

1. Define binary Vector v_i (chromosome)

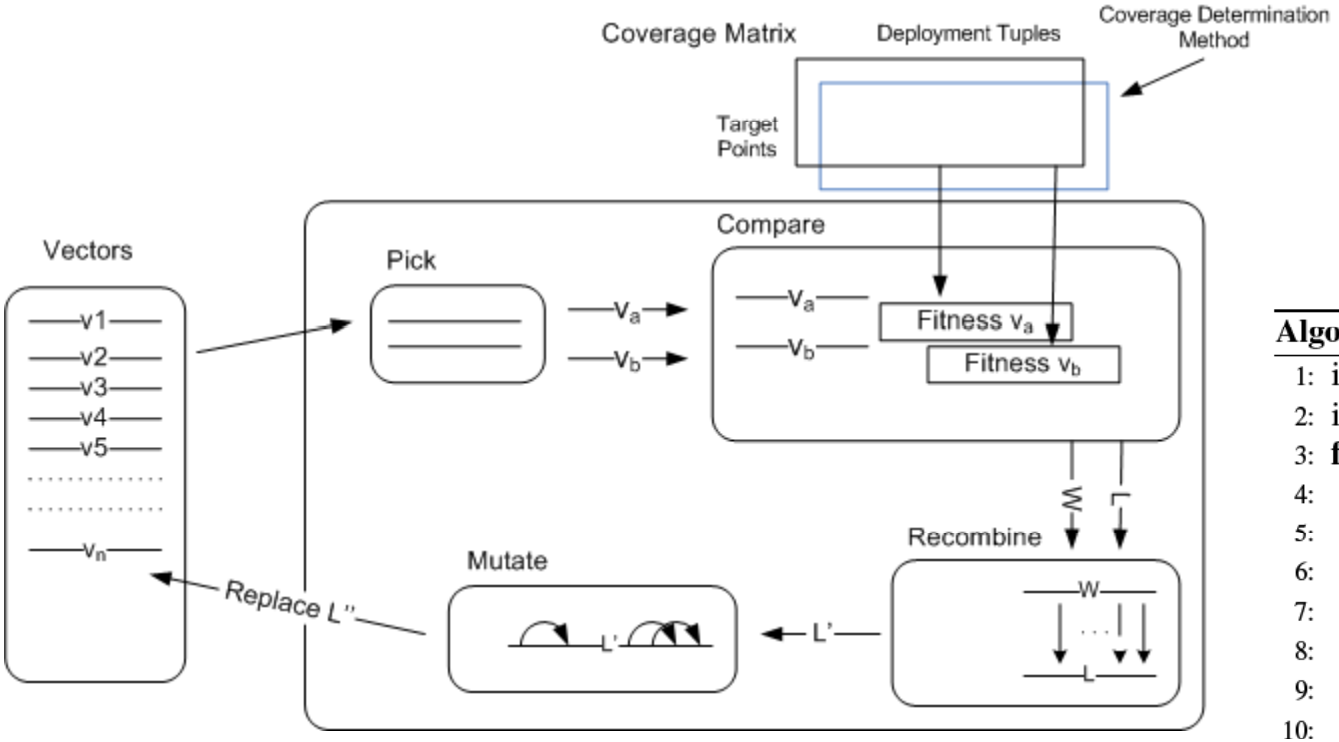
   - select a subset of the deployment-tuples
   v_1 = (1110), use of d_1, d_2, d_3, exclude d_4

2. Define Initial Population, set of vectors

3. Define Fitness Function

$$f(x) = \sum_{j=1}^{n} c_j x_j + w(m - coverage) \qquad (4)$$

SDP Model

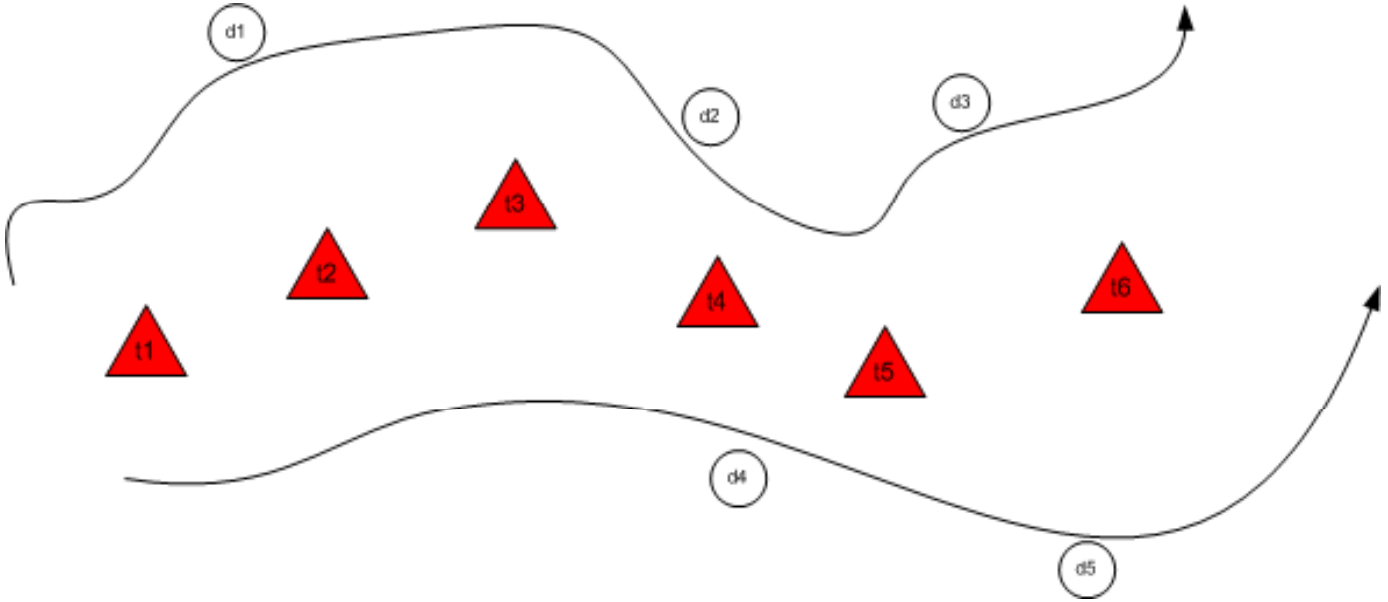


Algorithm 1 GA for Non-Isotropic SDPs

1: input: a_{ij}
2: initialize $P = \{v_i : i = 1..POP\}$
3: **for** $i = 1$ to $TOURS$ **do**
4: a=rnd(1..POP)
5: do b=rnd(1..POP) while (a==b)
6: **if** evaluate(v_a) > evaluate(v_b) **then**
7: $w = a, l = b$
8: **else**
9: $w = b, l = a$;
10: **end if**
11: **for** $j = 1$ to n **do**
12: if(rnd $< p_c$) $v_l[j]$ = $v_w[j]$
13: **end for**
14: **for** $j = 1$ to n **do**
15: if(rnd $< p_m$) $v_l[j]$ = 1 - $v_l[j]$
16: **end for**
17: **end for**
18: output: v_{max}

Case Study

- **Along a road or riverbed**



$$d1 =< s_1, d_1, S >,$$
$$d2 =< s_2, d_1, S >,$$
$$d3 =< s_1, d_2, S >,$$
$$d4 =< s_2, d_2, S >,$$
$$d5 =< s_1, d_3, S >,$$
$$d6 =< s_2, d_3, S >,$$
$$d7 =< s_1, d_4, N >,$$
$$d8 =< s_2, d_4, N >,$$
$$d9 =< s_1, d_5, N >,$$
$$d10 =< s_2, d_5, N >$$

CASE STUDY COVERAGE MATRIX

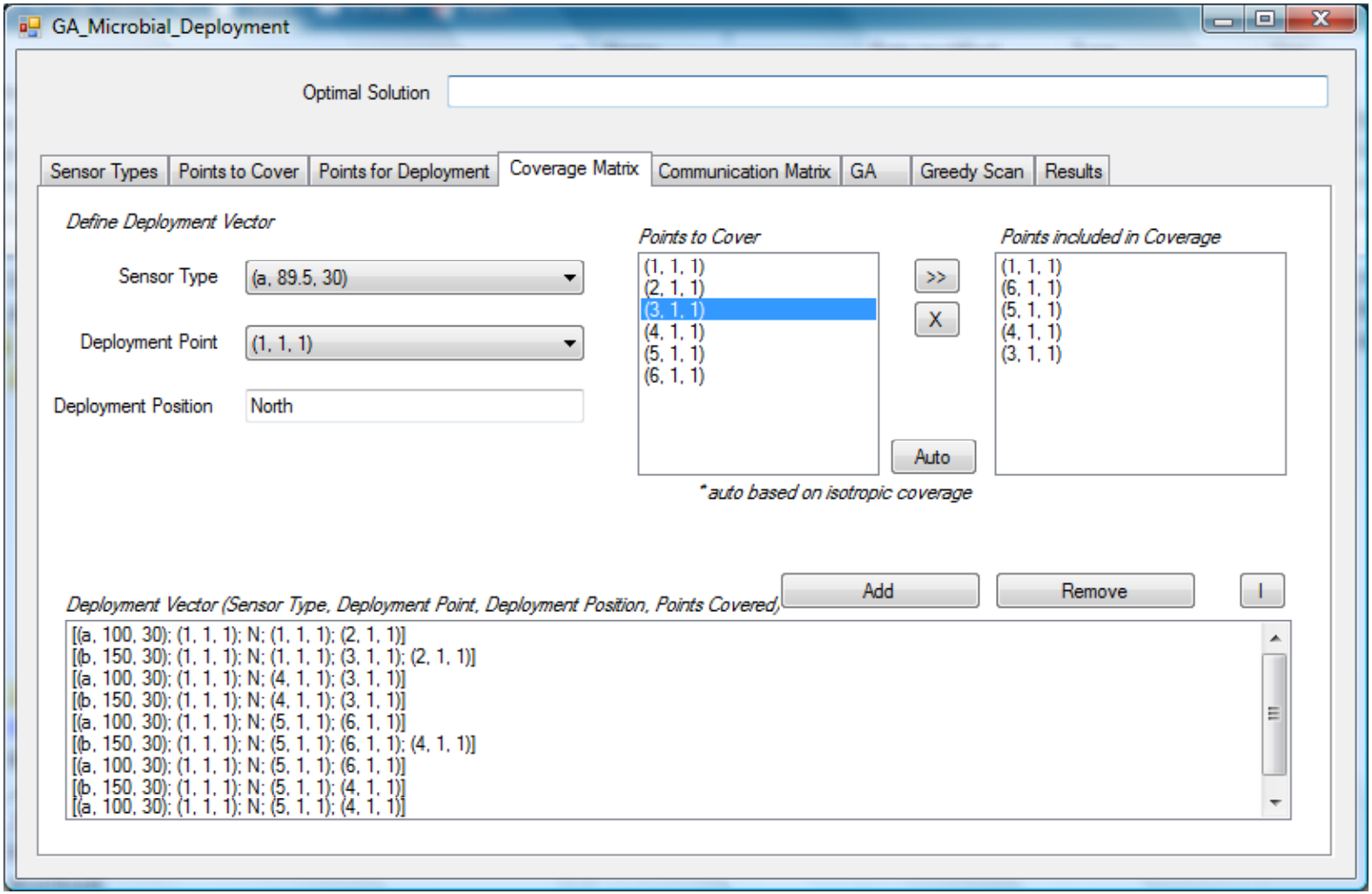
CP	d1	d2	d3	d4	d5	d6	d7	d8	d9	d10
1	1	1	0	0	0	0	0	0	0	0
2	1	1	1	0	0	0	0	0	0	0
3	0	1	1	1	0	0	0	0	0	0
4	0	0	1	1	0	1	0	1	1	1
5	0	0	0	0	1	1	1	1	1	1
6	0	0	0	0	1	1	1	0	0	1

- **Vectors satisfy constraints**

(0100000001)

(0100010000)

Simulation


GA_Microbial_Deployment
Optimal Solution
Sensor Types
Points to Cover
Points for Deployment
Coverage Matrix
Communication Matrix
GA
Greedy Scan
Results
Define Deployment Vector
Sensor Type
(a, 89.5, 30)
Deployment Point
(1, 1, 1)
Deployment Position
North
Points to Cover
(1, 1, 1)
(2, 1, 1)
(3, 1, 1)
(4, 1, 1)
(5, 1, 1)
(6, 1, 1)
>>
X
Auto
Points included in Coverage
(1, 1, 1)
(6, 1, 1)
(5, 1, 1)
(4, 1, 1)
(3, 1, 1)
*auto based on isotropic coverage
Add
Remove
Deployment Vector (Sensor Type, Deployment Point, Deployment Position, Points Covered)
[(a, 100, 30); (1, 1, 1); N; (1, 1, 1); (2, 1, 1)]
[(b, 150, 30); (1, 1, 1); N; (1, 1, 1); (3, 1, 1); (2, 1, 1)]
[(a, 100, 30); (1, 1, 1); N; (4, 1, 1); (3, 1, 1)]
[(b, 150, 30); (1, 1, 1); N; (4, 1, 1); (3, 1, 1)]
[(a, 100, 30); (1, 1, 1); N; (5, 1, 1); (6, 1, 1)]
[(b, 150, 30); (1, 1, 1); N; (5, 1, 1); (6, 1, 1); (4, 1, 1)]
[(a, 100, 30); (1, 1, 1); N; (5, 1, 1); (6, 1, 1)]
[(b, 150, 30); (1, 1, 1); N; (5, 1, 1); (4, 1, 1)]
[(a, 100, 30); (1, 1, 1); N; (5, 1, 1); (4, 1, 1)]

Q & A

- Next Steps
  - *probabilistic Coverage Matrix*
  - *Case Studies*
- Questions/Discussion
- Contact Information
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