The 19th MED – June 20-23 2011, Corfu, Greece

Search Methodologies for Node Recovery in Robotic Swarms

Gonçalo Martins
Matthew J. Rutherford
Kimon P. Valavanis

(Department of ECE)

June 2011

UNIVERSITY OF DENVER

Outline

- Motivation
- Scenario Description
- Search Methodologies
- Experimental Analysis
- Conclusions

UNIVERSITY OF DENVER

Motivation

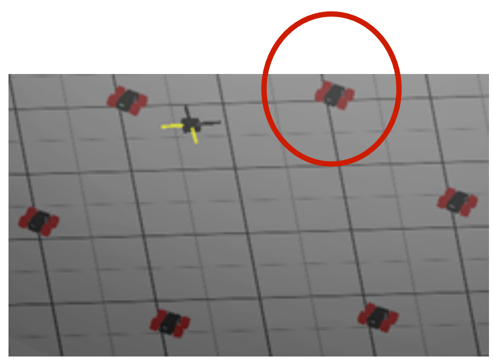
- In a swarm of robots (ad-hoc network) there are continually communication failures
- Swarm of robots constituted by small/medium sized unmanned systems
- Some limitations:
  - Computational power available is limited
  - Energy consumption (battery life)
- How can we minimize these failures?
  - Unmanned systems are moving around
  - Should get a fast and “adequate” solution

Motivation

- Exhaustive methods:
  - Pros: they give the optimal solution
  - Cons: they take time (CPU time)
- Meta heuristics:
  - Pros: normally fast (comparing with exhaustive methods)
  - Cons: they give local solutions
- Concerns:
  - How good are the results with meta heuristics?
  - Which meta heuristic technique is more suitable? (single based or population based)

Scenario Description

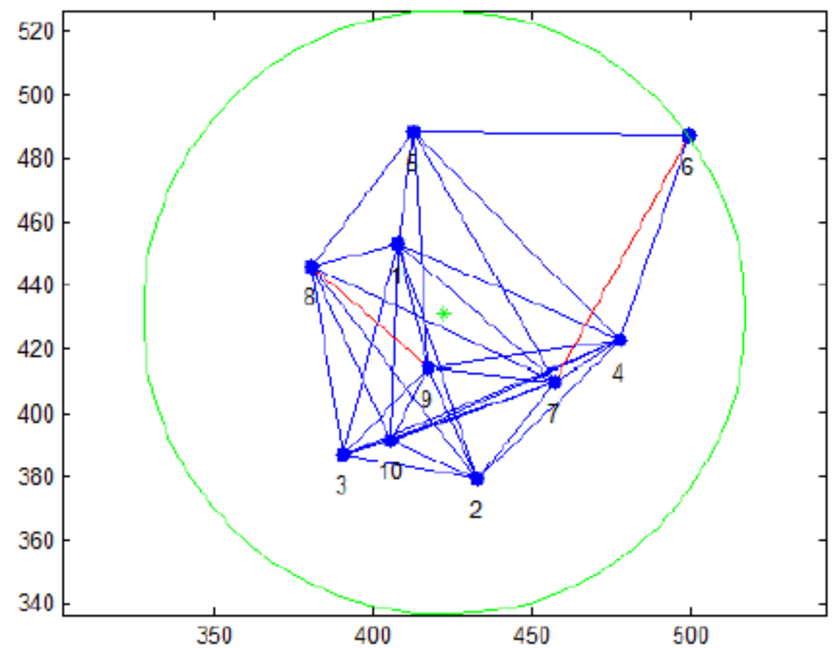
- Consider all unmanned systems as “nodes”
- Assume a heterogeneous network with two groups of nodes:
  - General nodes *(GNp)* – perform mission tasks
  - Support nodes *(SNp)* – focus on serving the communication network



UNIVERSITY OF DENVER

Scenario Description

- The main idea is to dispatch support nodes to the site of a communication failure in order to bridge the gap
    - It is not our intention to study the mechanism by which link failures are detected
    - The focus is to select the best location to place or request a *SNp*



UNIVERSITY OF DENVER

Scenario Description

- Two Objective Function (OF):

$$Static\ \ OF : Max\left(\sum\left(V_{FL} \in P\right)\right)$$

$$Dynamic\ \ OF : Max\left(\frac{\sum\left(V_{FL} \in P\right)}{d}\right)$$

- V_{FL} – Vector of failed links
- P is the set of positions that are inside of the SNp coverage area
- d – Euclidean distance between nodes

UNIVERSITY OF DENVER

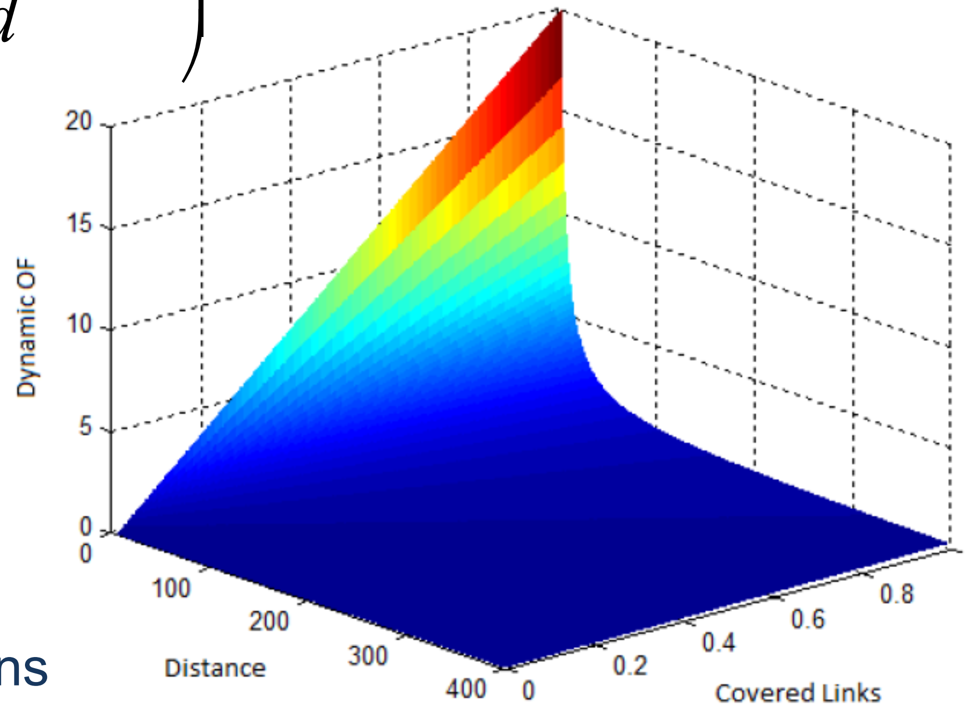
Scenario Description

$$Dynamic\ \ OF : Max\left(\frac{\sum\left(V_{FL} \in P\right)}{d}\right)$$

- Issue:
  - If d = 0 → OF = ∞

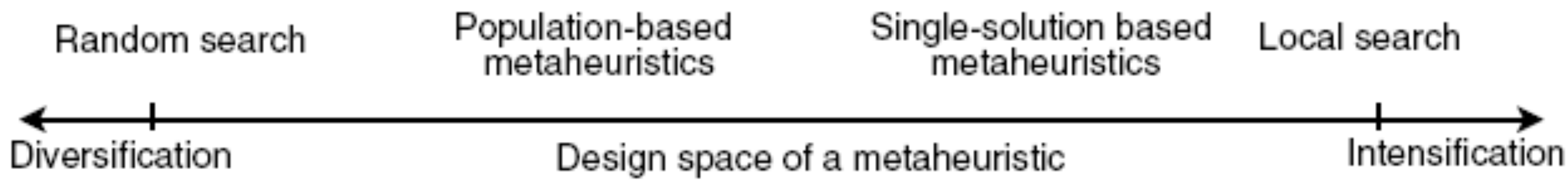
- If d = 0 then the result is discarded

- If result discarded is actually a good position, neighboring positions are likely to be almost as good (d ≠ 0)



UNIVERSITY OF DENVER

Search Methodologies



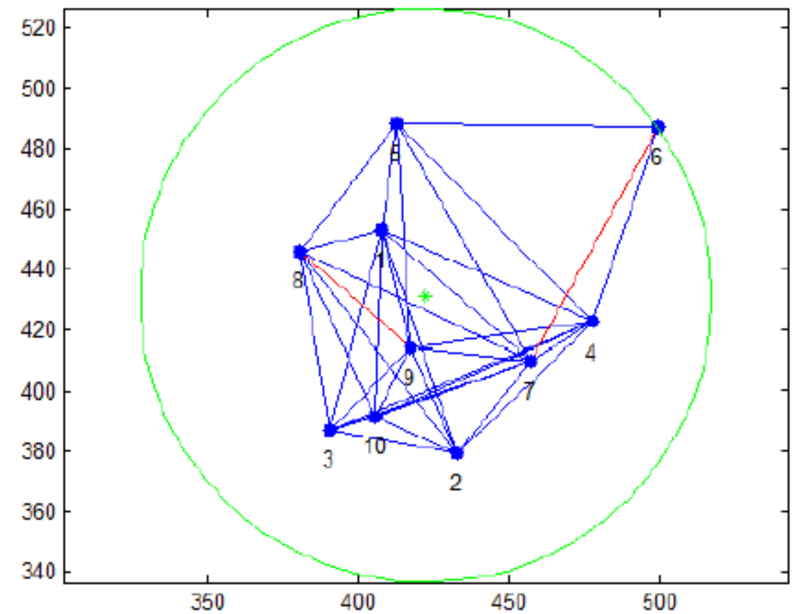
- Single based:
  - Tabu Search (TS)
  - Hill Climbing (HC)
- Population base:
  - Particle Swarm Optimization (PSO)

Experimental Analysis

- Design Setup:
  - Simulations done in C++
  - Nodes are placed in a square with dimension of 500 meters
  - For each simulation run, general nodes are placed randomly

Particle Swarm	# Particles	20
	Iterations	200
	Velocity Inertia Coefficient	0.5
Hill Climbing	# Neighbors	10
	Iterations	200
Tabu Search	# Neighbors	10
	Iterations	200
	Short Memory Size	10

Table I: Heuristic Search Parameters



UNIVERSITY OF DENVER

Experimental Analysis

- Monte Carlo Method:
  - Due to their non-determinism, the heuristic algorithms provide solutions that vary for each execution

Table II: Description of trials

Trial Identifier	1	2	3	4	5
Number of general nodes	10	25	50	75	100
Number of failures	2	5	10	15	20

  - Changing the number of GNp – shows that works for different sizes of unmanned systems
  - Changing the number of falied links – shows the necessity of re-running the optimization when all failed links cannot be covered by just one SNp

UNIVERSITY OF DENVER

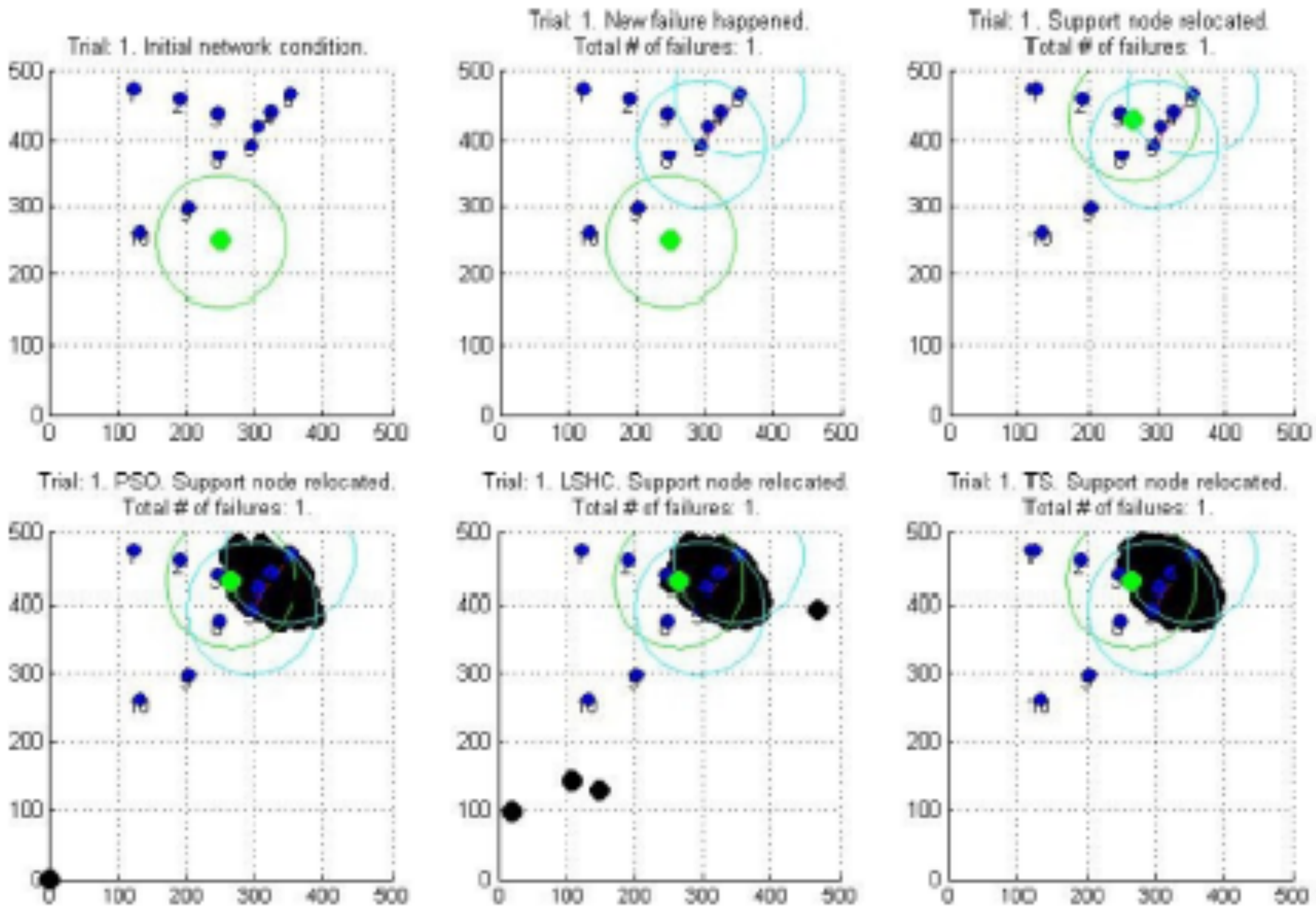
Experimental Analysis

- Monte Carlo Method:
  - 5 trials
  - For each trial – generate 10 000 random maps
  - For each map:
    - Apply the global optimum search algorithm once
    - Independently apply the 3 heuristics algorithms with 200 iterations each time
  - The universe of study is 50 000 maps
  - For each run we collect:
    - Maximum of broken links
    - Distance to the SNp
    - Total execution time

UNIVERSITY OF DENVER

Experimental Analysis

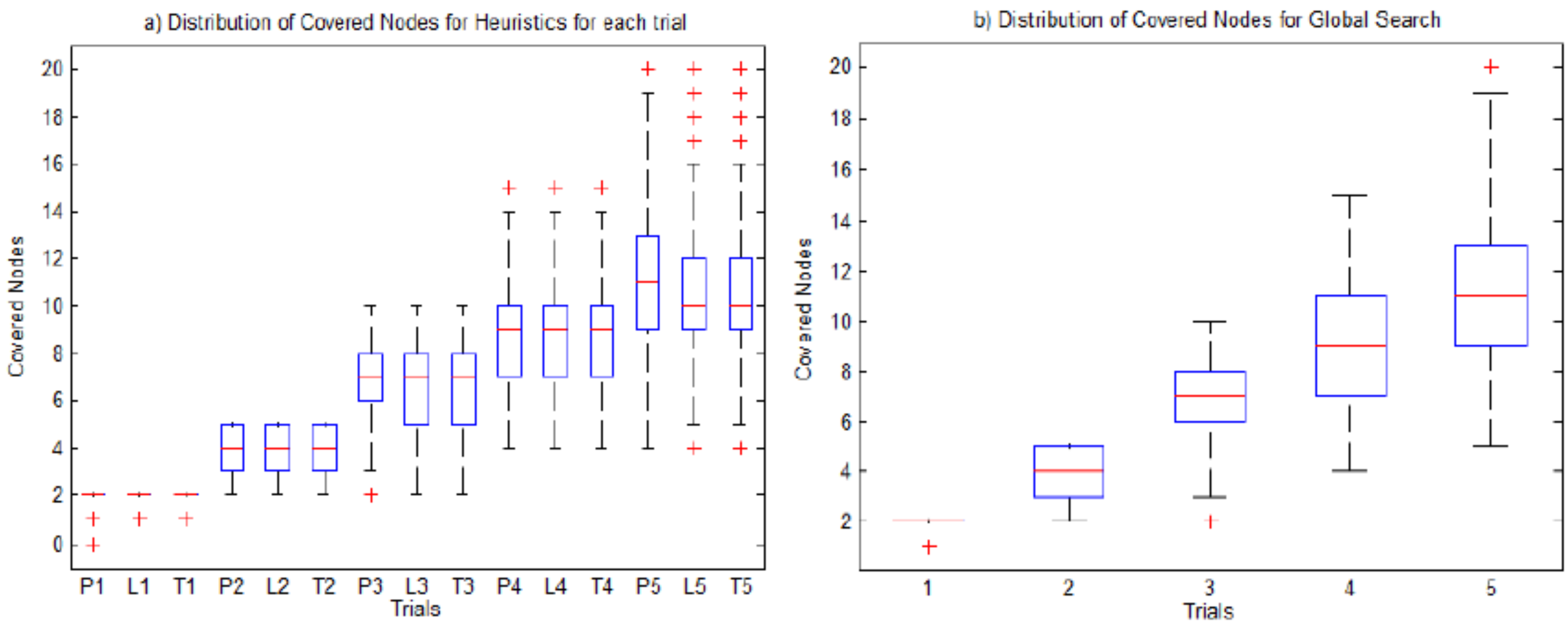
- Results:



Trial #1

Experimental Analysis

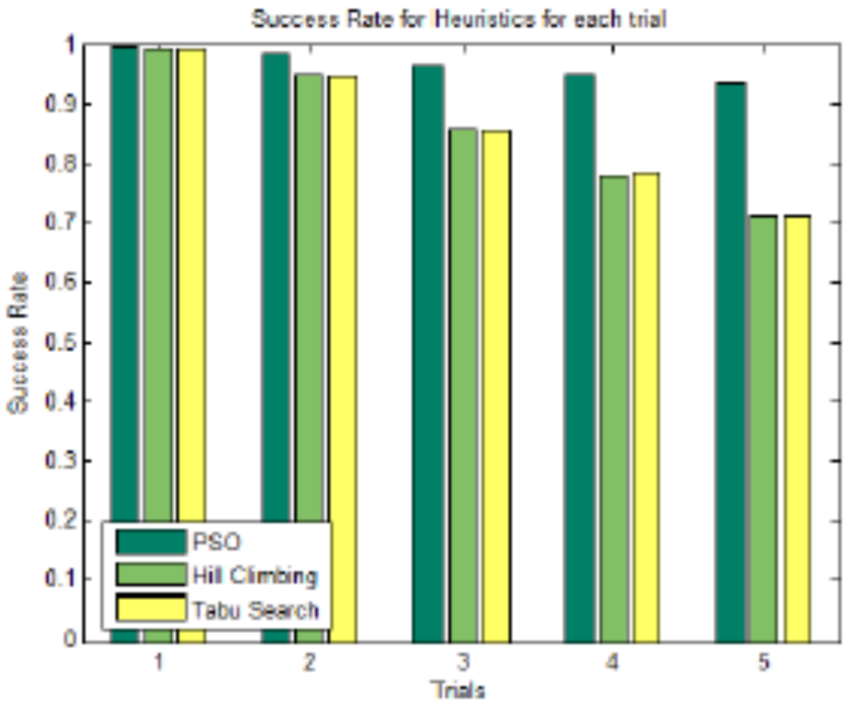
➢ Results – Static OF:

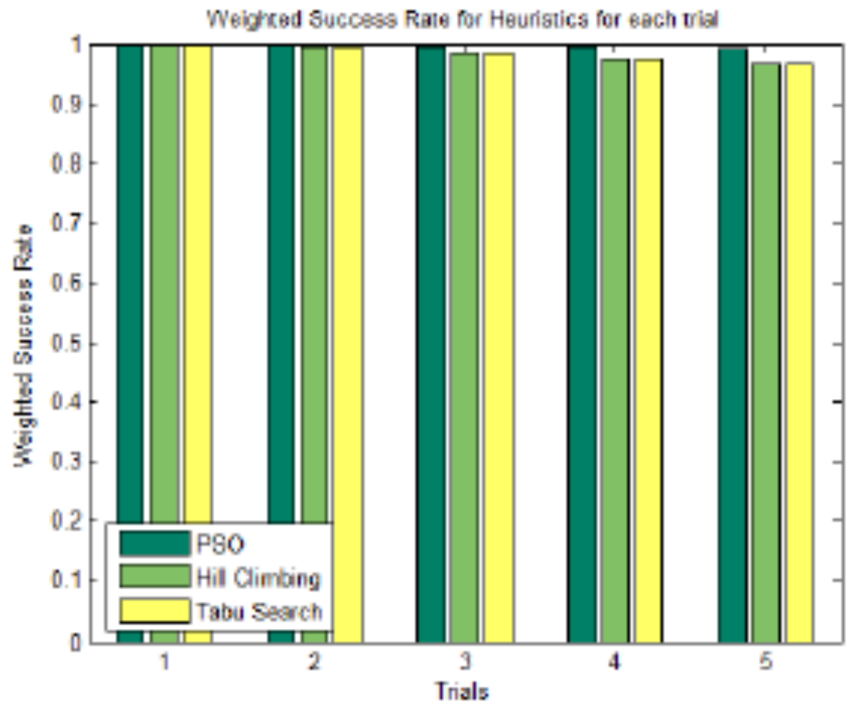


- What is the success rate?

Experimental Analysis

➢ Results – Static OF:





$$SR : \frac{Successful\ runs}{Total\ runs}$$

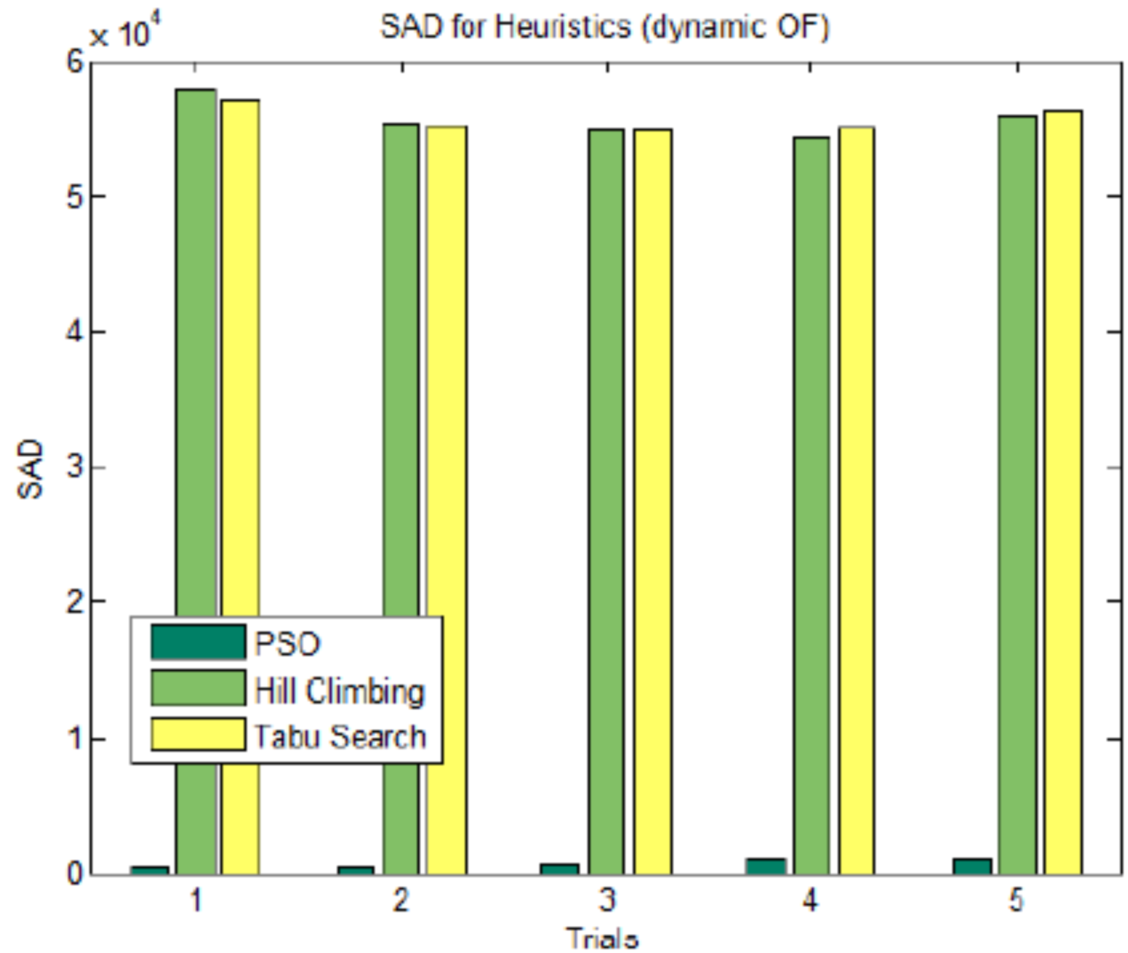
$$WSR : \frac{w * \text{Re}\,latively\ Successful\ runs}{Total\ runs}$$

$$w = [1, 0.9, 0.7, 0.4, 0.1]$$

UNIVERSITY OF DENVER

Experimental Analysis

- Results – Dynamic OF:
  - Sum of Absolute Differences

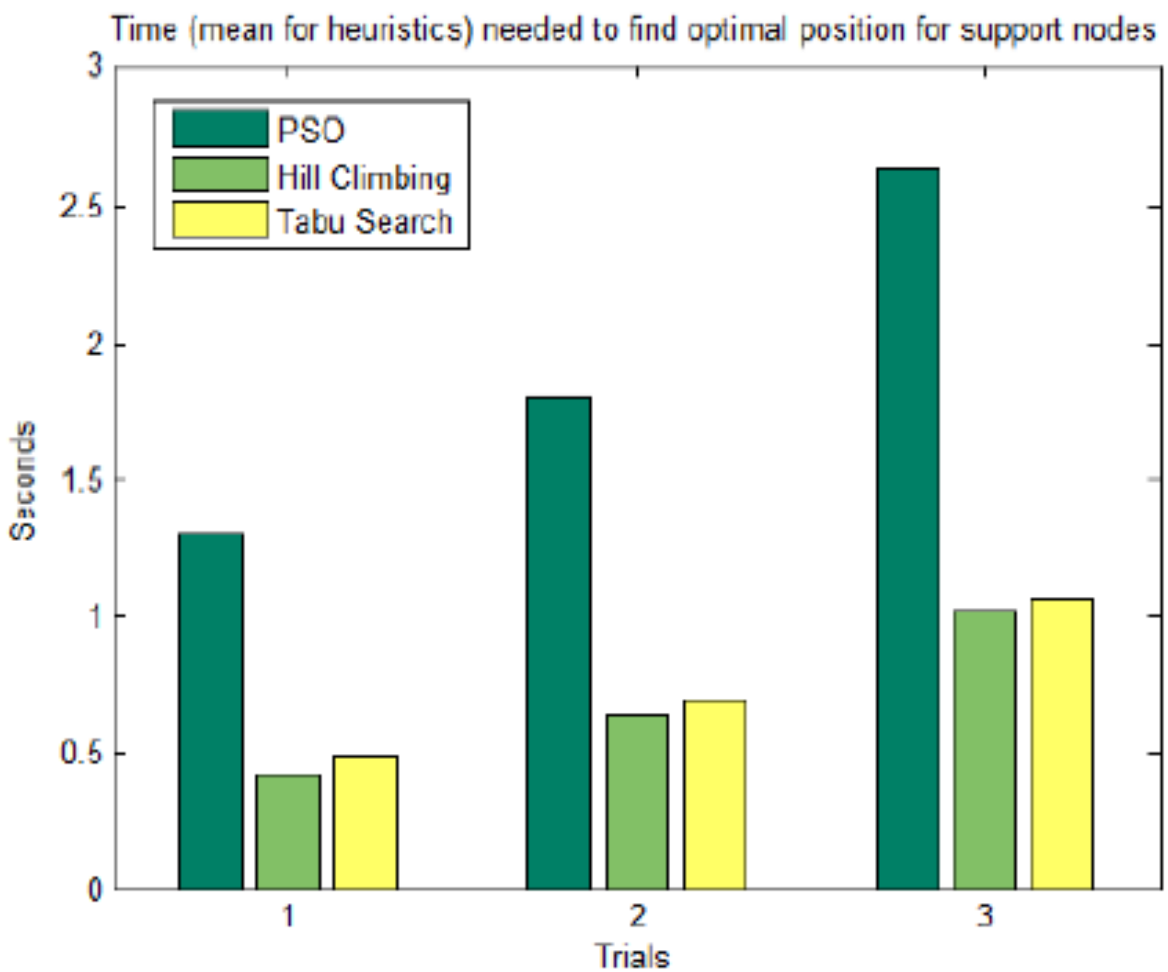


$$SAD = \sum_{i=1}^{numMaps} abs\left(GS_{OF}(i) - Heuristic_{OF}(i)\right)$$

UNIVERSITY OF DENVER

Experimental Analysis

➢ Results – Computational time:



UNIVERSITY OF DENVER

Conclusions

- It was proposed two diferent objective functions that depend on the mission at hand
- The results shows that meta heuristics:
  - give satisfactory results for this type of problem
  - should be used when computational time is something to consider
- Overall the data gathered indicates that PSO provides the best solution
- Future work:
  - See the implications of the results for diferent meta heuristics parameters
  - Implement in a real swarm of robots

UNIVERSITY OF DENVER