Concentric and incremental multi-robot mapping to observe complex scenes

Jonathan Cohen[1], Laëtitia Matignon[1], Olivier Simonin[2]

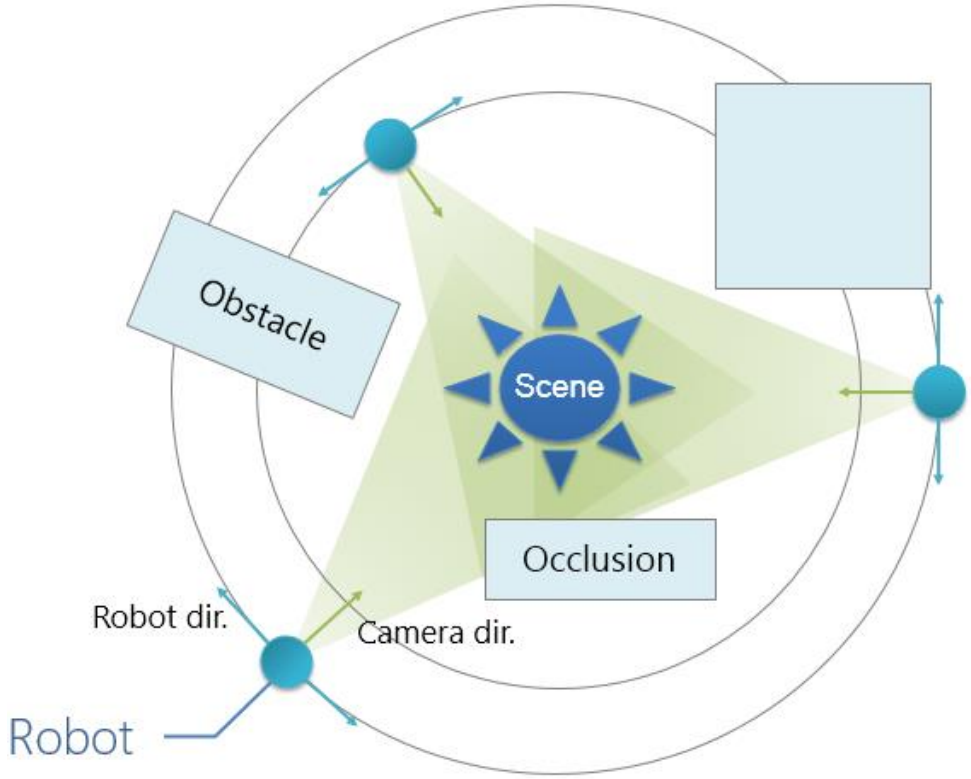
[1] University Lyon 1
[2] INSA Lyon, INRIA

IROS – DEMUR Workshop – Hamburg – October 2, 2015

unsplash.com

The Problem

- Team of mobile robots
  - Observe a scene
  - Can communicate
- Unknown environment
  - Obstacles
  - Occlusions
- Dynamic scene
  - *Someone* doing *something*
- Coordinate the robots online to find the joint best point of view on the scene



Outline

1. Observation problem
2. Incremental mapping
3. Navigation with heursitic approaches
4. Experiments

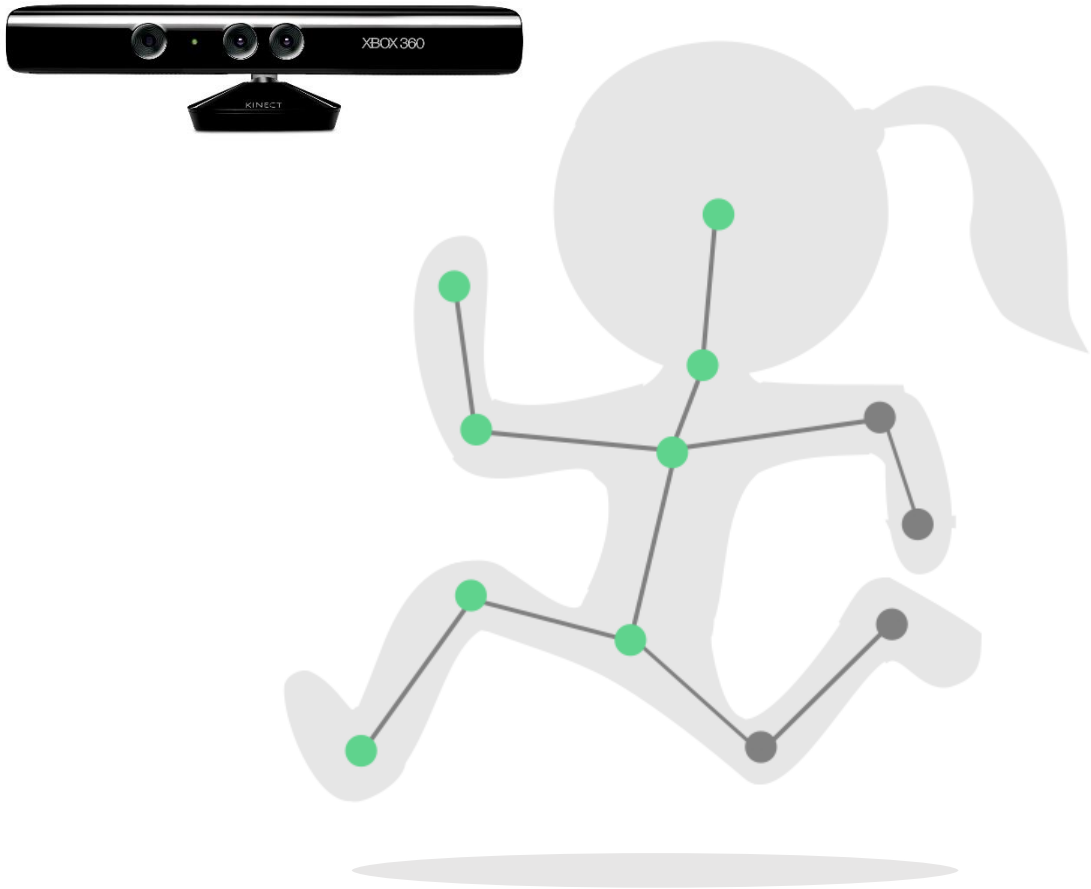
Observation problem

- Local observation
  - Body joints seen by *1 robot*
  - Binary vector

    $o_i = [1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 0\ 0\ 0\ 0]$

- Observation quality
  - Number of bits at 1

    $q(o_i) = 8$



Observation problem

- Joint observation
  - Body joints seen by *the team*
  - Logical OR between local observations

$o_1 = [1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 0\ 0\ 0\ 0]$
$o_2 = [0\ 0\ 0\ 0\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1]$
$[1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1]$
$q(o_1 \cup o_2) = 12$

- Find the joint position that maximize the quality of the *joint observation*

Our approch

Environment representation

Concentric modeling

Incremental mapping

Space exploration

Anytime algorithm

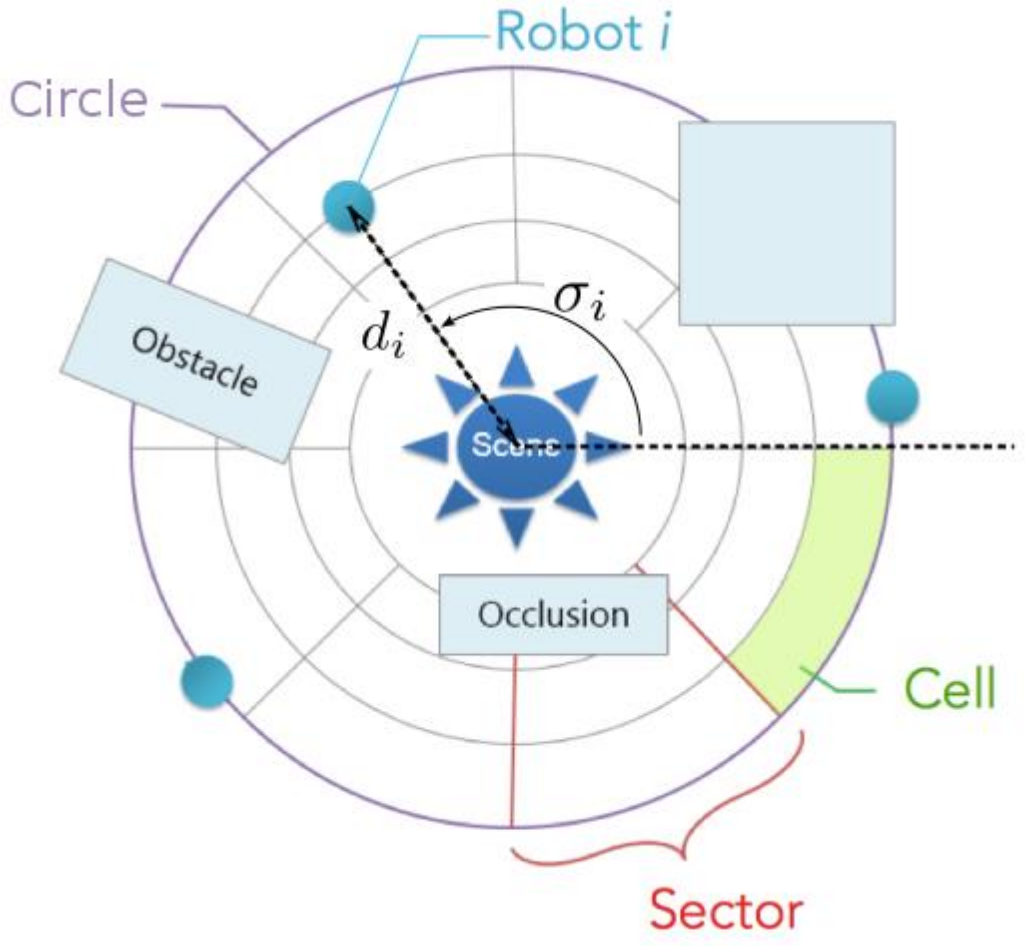
Heuristic search

Outline

1. Observation problem
2. Incremental mapping
3. Navigation with heuristic approaches
4. Experiments

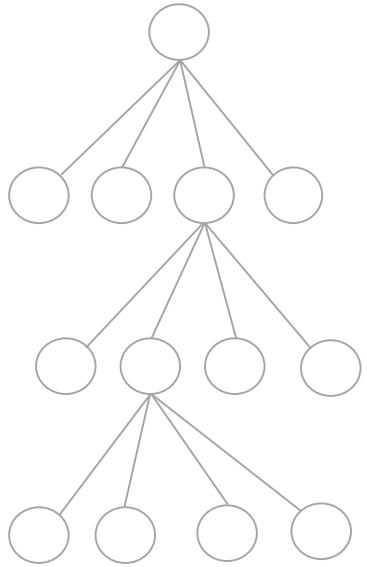
A Map of the World

- Concentric model
  - Circles
  - Sectors
  - Cells
- Polar coordinates
- Robots can move to adjacent cells
  - 1 cell = 1 position



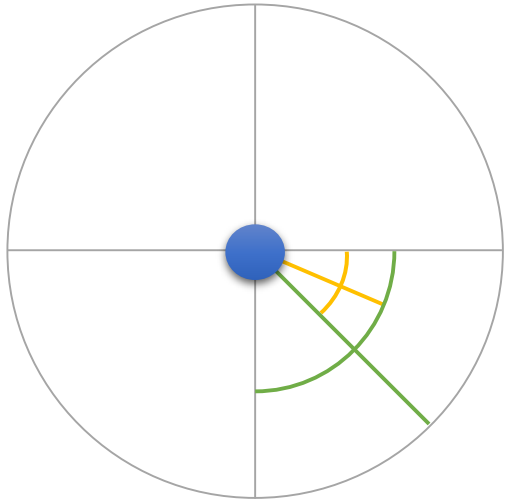
The Map

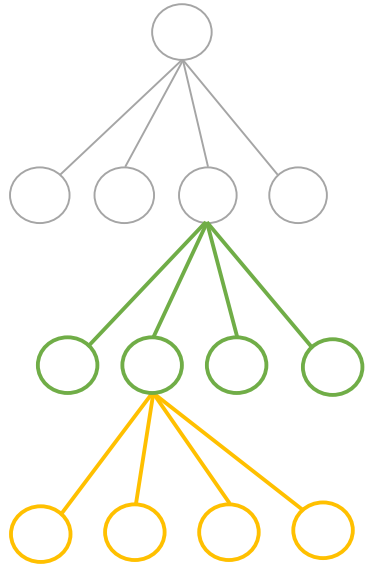
- Quadtree
  - Tree structure
  - 0 or 4 children per node
  - 1 node = 1 cell = 1 position
    - Stores mean local quality
- Occupancy grid
  - 1 occupancy value per node
  - Probability that a cell is occupied
    (Kraetzschmar & al, 2004)
- But how can this quadtree be a map?



Concentric incremental mapping

- Incremental space division
  - Split cells recursively
  - Avoid bad positions, refine interesting areas only
  - Deal with space complexity





Outline

1. Observation problem
2. Incremental mapping
3. Navigation with heuristic approaches
4. Experiments

Which robot will go?

- Marginal contribution $\boldsymbol{w_i}$ of a robot $\boldsymbol{i}$ (Shapley, 1953)
  - What it sees that *no other robot* sees

$$w_i = q(o_i) - q(o_i \cap \bigcup_{j \neq i} o_j)$$

- Example
  - $o_1 = [1\ 1\ 0\ 1\ 1\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ ] \implies w_1 = 4$
  - $o_2 = [0\ 0\ 1\ 1\ 0\ 0\ 1\ 0\ 1\ 0\ 1\ 1\ ] \implies w_2 = 3$
- Move the robot with the *lowest marginal contribution*
  - Prevent quality drop
  - Detect changes in scene activity

What to do? Where to go?

- A robot can…
  - … split a cell
  - … move to an adjacent cell
- Metaheuristics for exploration-exploitation trade-off
  1. Simulated annealing
     - Decreasing temperature parameter
  2. Tabu search
     - Queue containing k forbidden cells
- Anytime algorithm
  - Always get the best joint position found so far

Scheme of the algorithm

1. Select a robot
   - The one with the lowest marginal contribution
2. Choose and execute an action
   - According to a metaheuristic
3. Compute the new joint quality
4. Go to 1

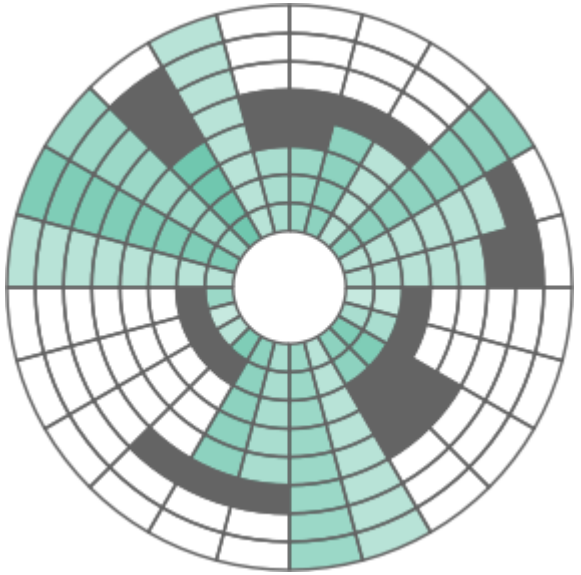
- Anytime algorithm
  - Always get the best position found so far

Outline

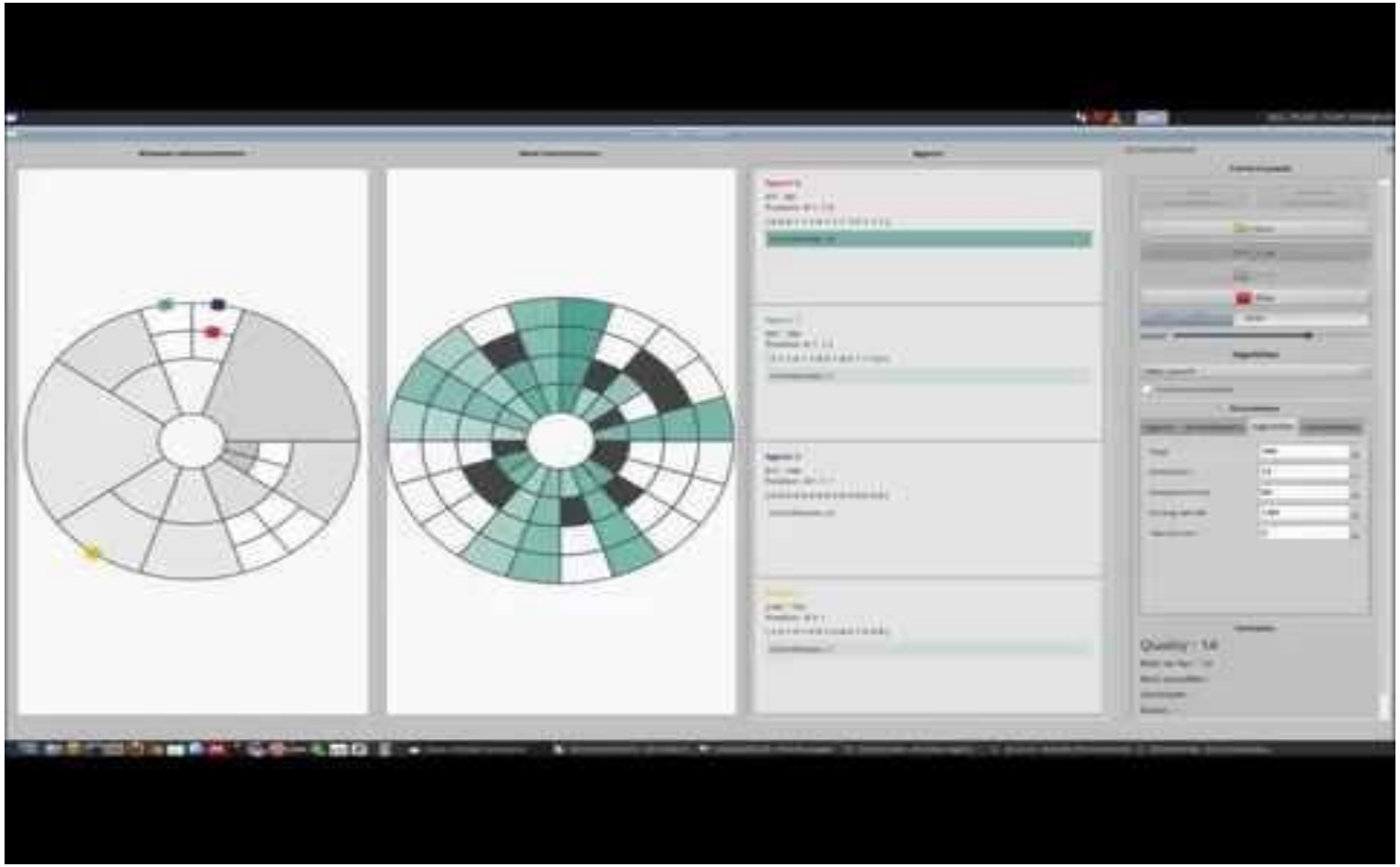
1. Observation problem
2. Incremental mapping
3. Navigation with heuristic approaches
4. Experiments

Experiments

- Simulated environment
- Count how many times each metaheuristic finds the best joint position
- Compared with a random algorithm
  - Random robot selection
  - Random move on the map

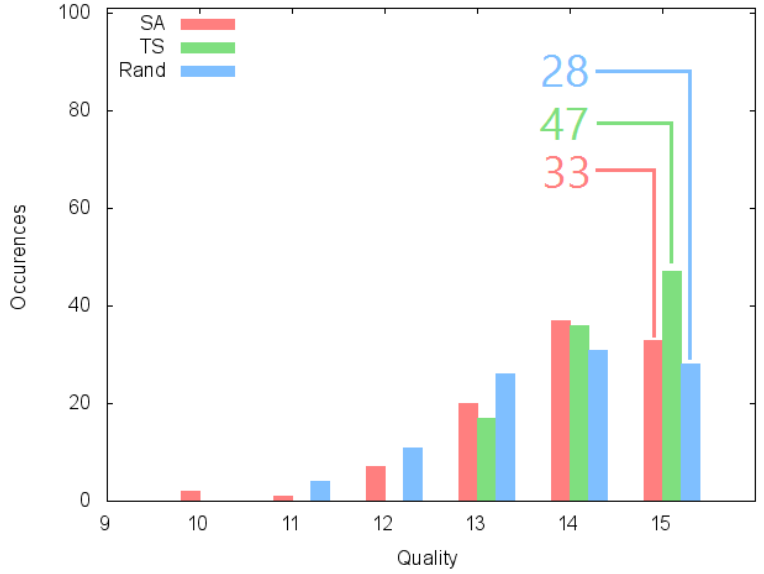


Simulator

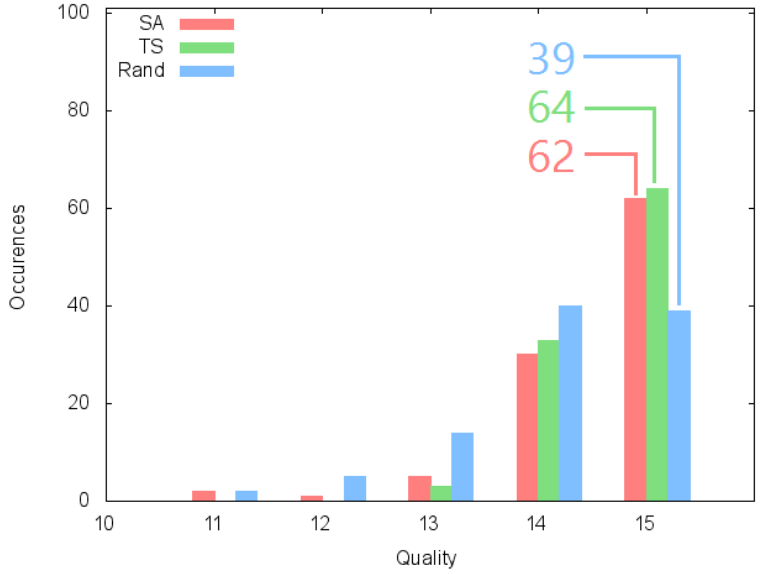


Results

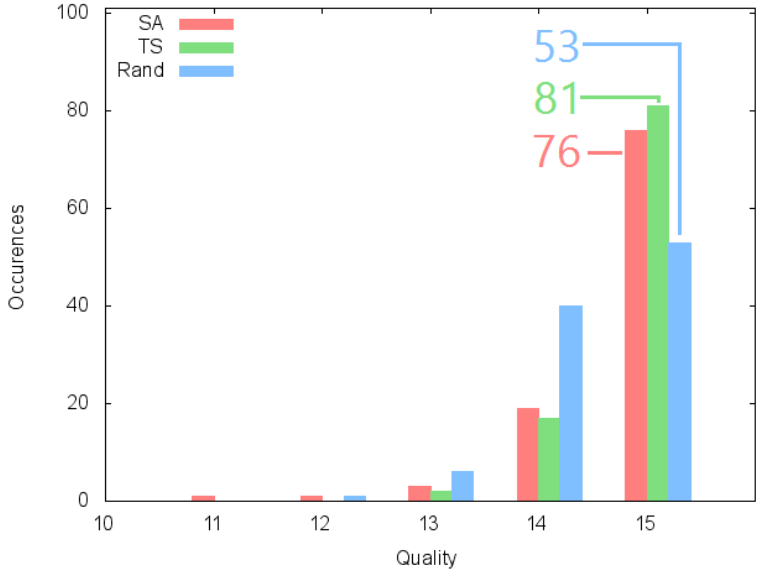
3 robots



100 steps

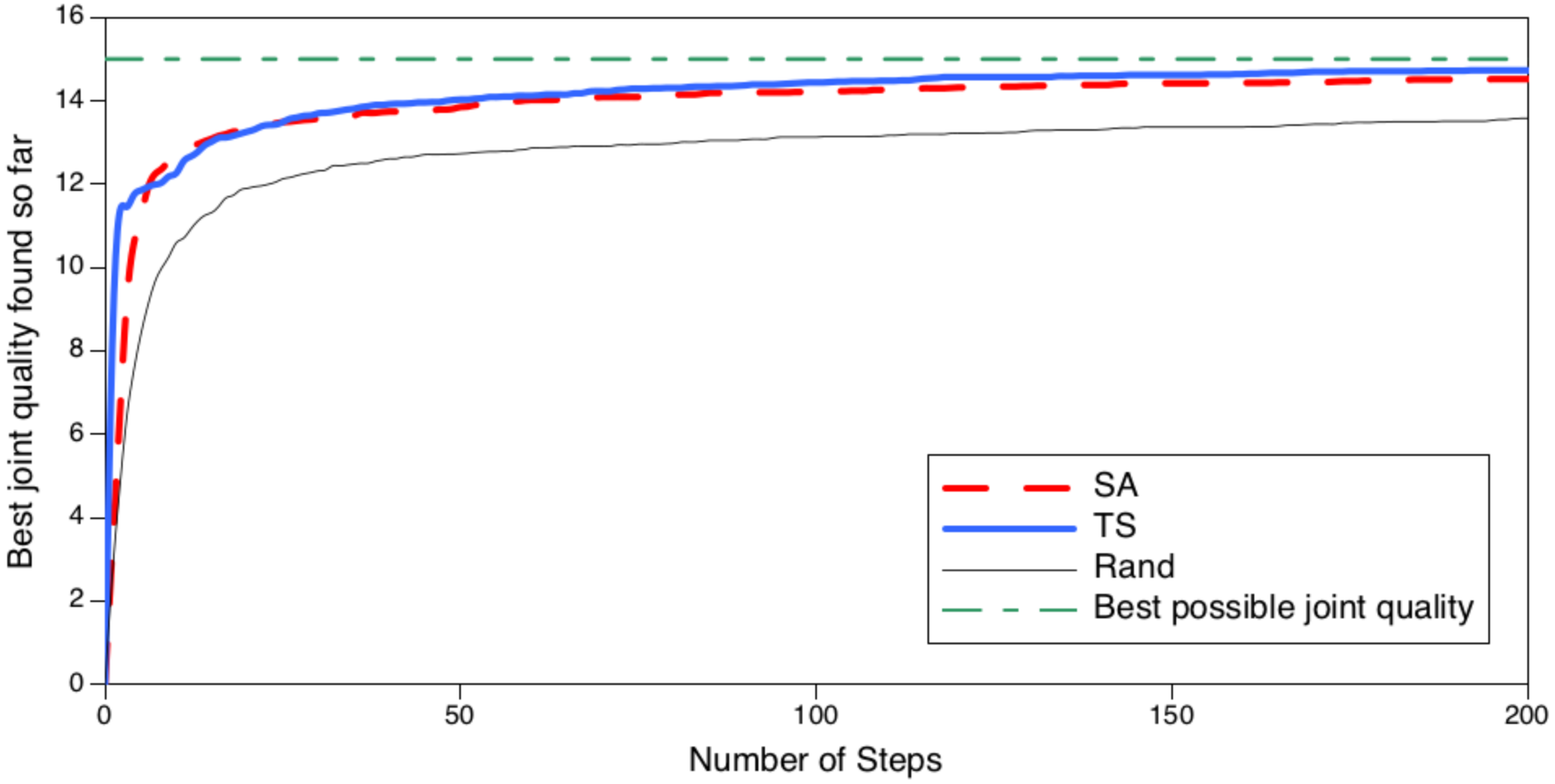


200 steps

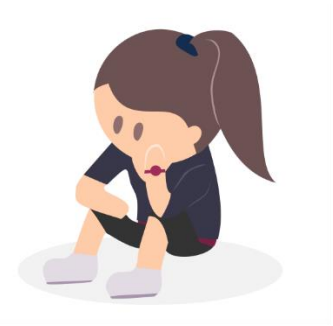


300 steps

Results


Best joint quality found so far
Number of Steps
0
2
4
6
8
10
12
14
16
0
50
100
150
200
SA
TS
Rand
Best possible joint quality

In a nutshell



Problem

Scene to observe

Mobile robots

Unknown environment

Mapping

Incremental map

Occupancy grid

Observation

Contribution

Metaheursitics

Anytime algorithm

Ongoing work

Adaptation to scene changing

(ICRA 2016)

Thank you.

Questions?

References

Cohen J., Matignon L., Simonin O. *Concentric and incremental multi-robot mapping to observe complexe scenes*. 2015.

Kraetzschmar G. K., Gassull G. P., Uhl K. *Probabilistic quadtrees for variable-resolution mapping of large environments*. 2004.

Shapley, L. S. *A value for n-person games*. 1953.