Simulating Multi-Robot Exploration Using ROS and MORSE

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Plan

Multi-robot exploration

Research background

- Exploring an unknown environment in cooperation
- Building a map of this environment

Application areas

- Search and rescue in earthquake
- Fire searching inside building
- Mineral exploration
- Mine clearance

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Question

Which coordination strategy?

Multi-robot exploration

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Question

Which coordination strategy?

Answer?

Need to compare!

How to compare?

Problem

- Development and validation of coordination strategies with actual robots: **long time!**
- Debugging and testing: **quite complex!**

How to compare?

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Solution

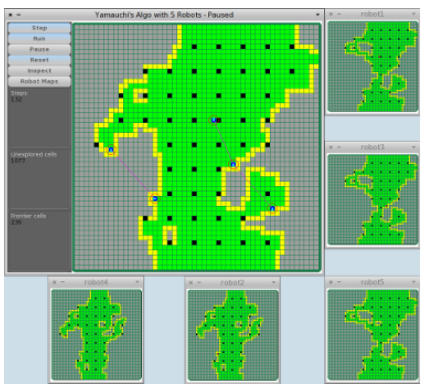
- **Simulation** before deploying to actual robots!
- Which simulator?
  - BOSS: a **discrete** multi-roBOt Simulator in Smalltalk
  - Stage: a **2D** multi-robot simulator

◂ BOSS DEMO WITH 5 ROBOTS ◂ STAGE DEMO WITH 4 ROBOTS

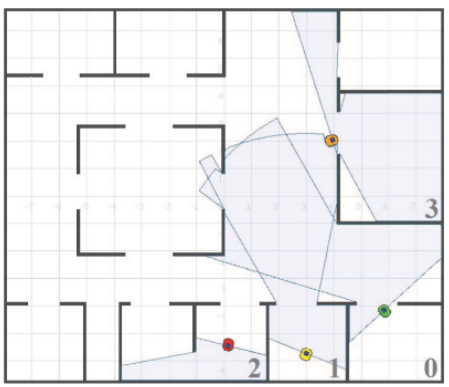
Robotics simulation

Challenges

- Simulations need to be as **realistic** as possible
- **Difference** between simulated and real robots should be **minimized**



OR



Robotics simulation

Our goals

- Build a **realistic test bed** for evaluating different coordination algorithms in different conditions
- Develop **performance benchmarks** for quantitative analysing and comparing different algorithms

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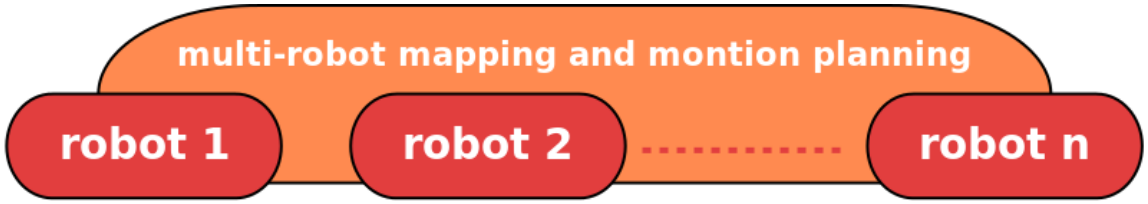
Our propose

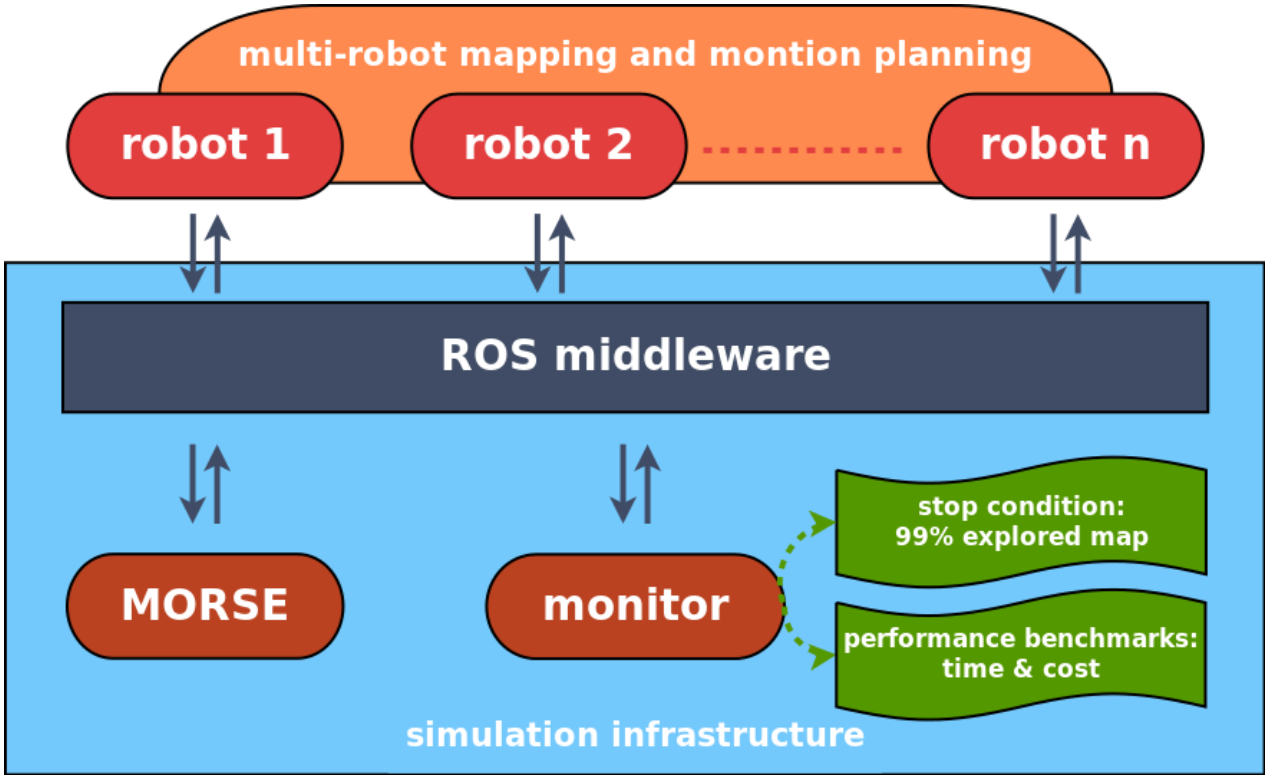
- **MORSE**: a 3D simulator with realistic physics engine
- **ROS**: a *de facto* standard middleware
- **Cluster**: a high performance distributed computing

System overview



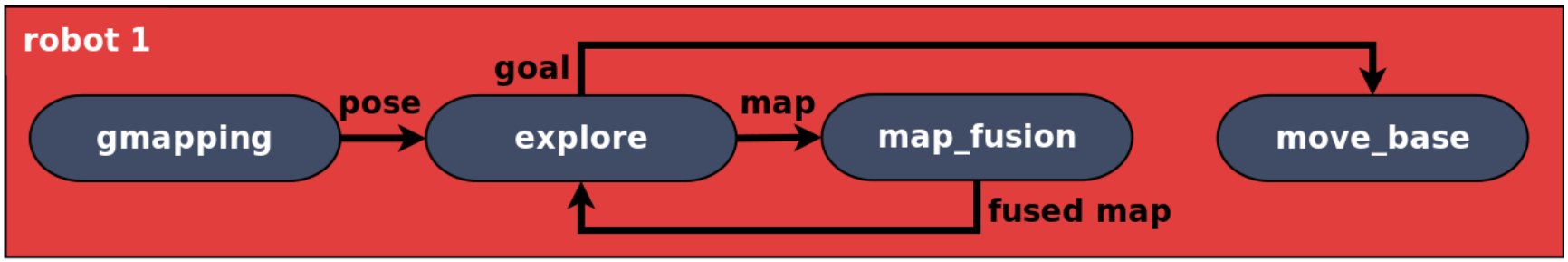
- **Multi-robot mapping**: robot exchanges the explored map with its teammates
- **Multi-robot motion planning**: robot moves towards the nearest frontier

System overview



- **Multi-robot mapping**: robot exchanges the explored map with its teammates
- **Multi-robot motion planning**: robot moves towards the nearest frontier
- **Time metric**: total time required to complete an exploration mission
- **Cost metric**: sum of energy consumed by all robots in the team

Robot setup



- **gmapping**: laser-based SLAM (Grisetti *et al.*, 2007)
- **explore**: frontier-based exploration (Yamauchi, 1997)
- **map_fusion**: multiple maps merging (developed by our team)
- **move_base**: mobile robot navigation (using Dijkstra pathfinding algorithm)

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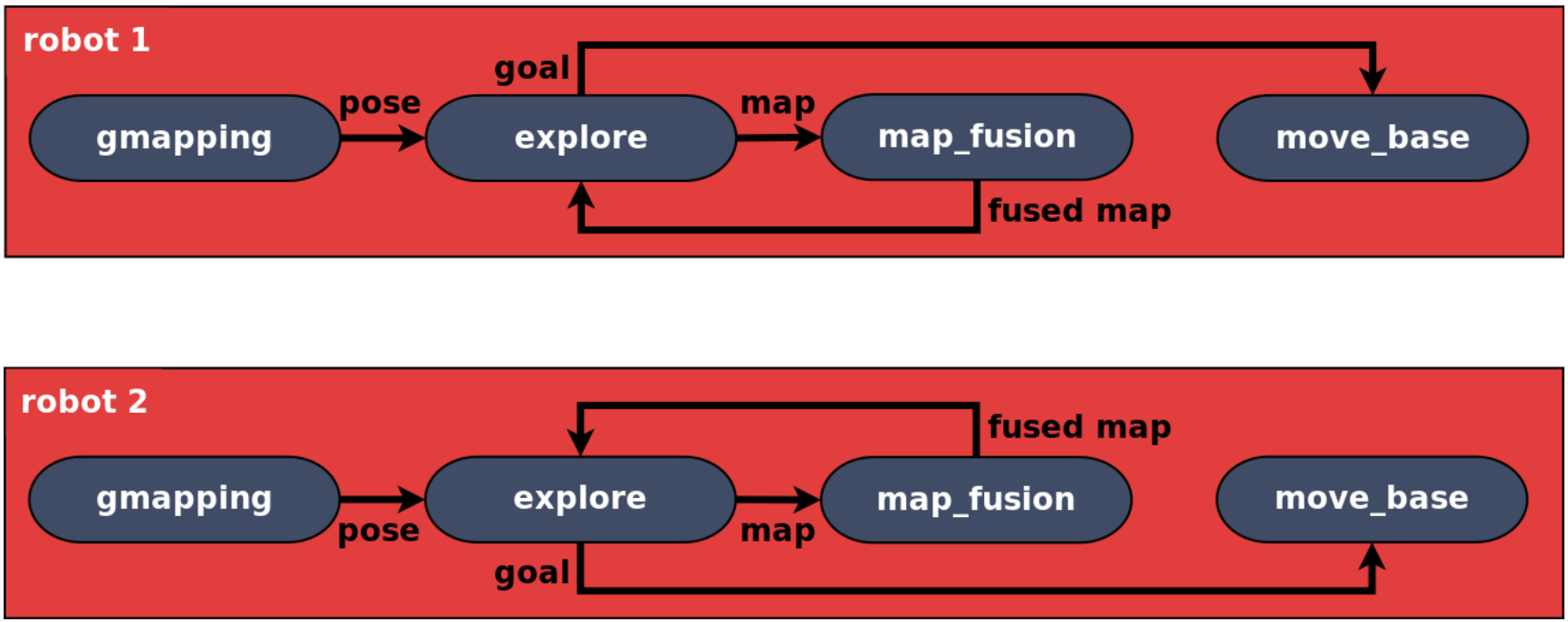

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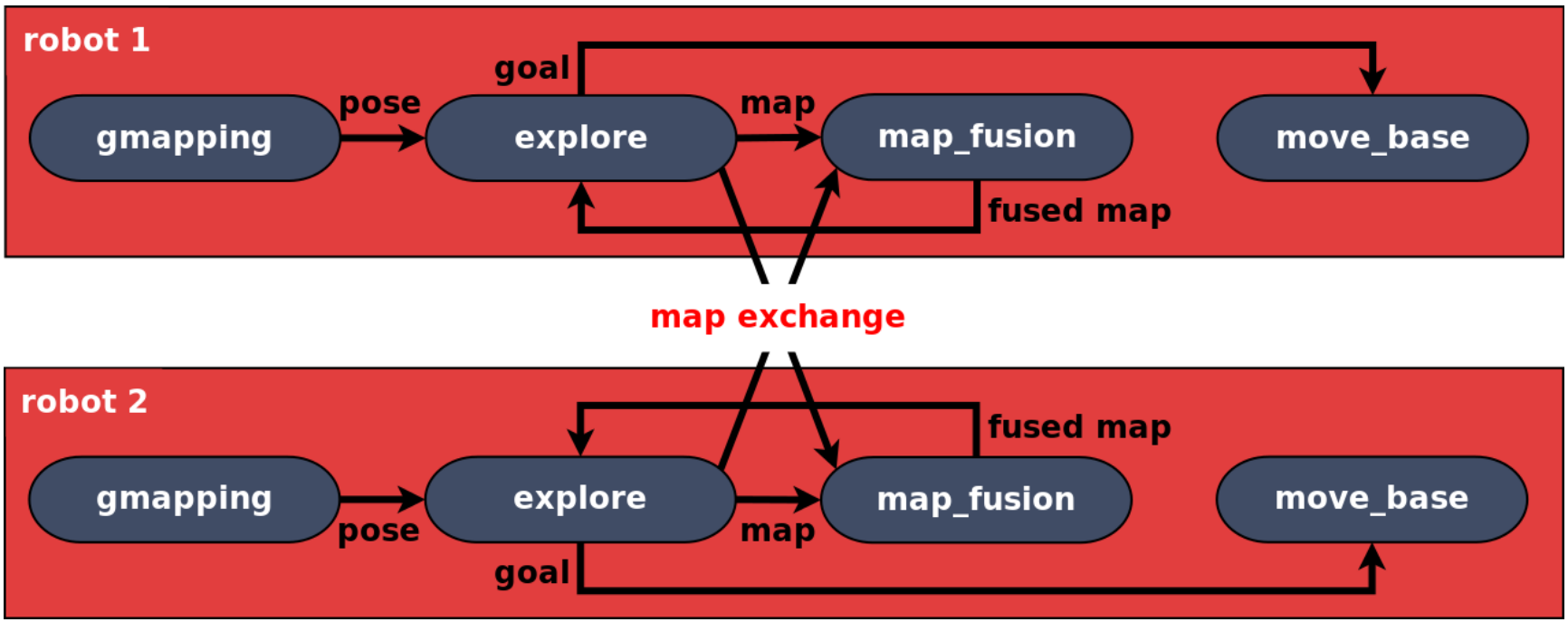

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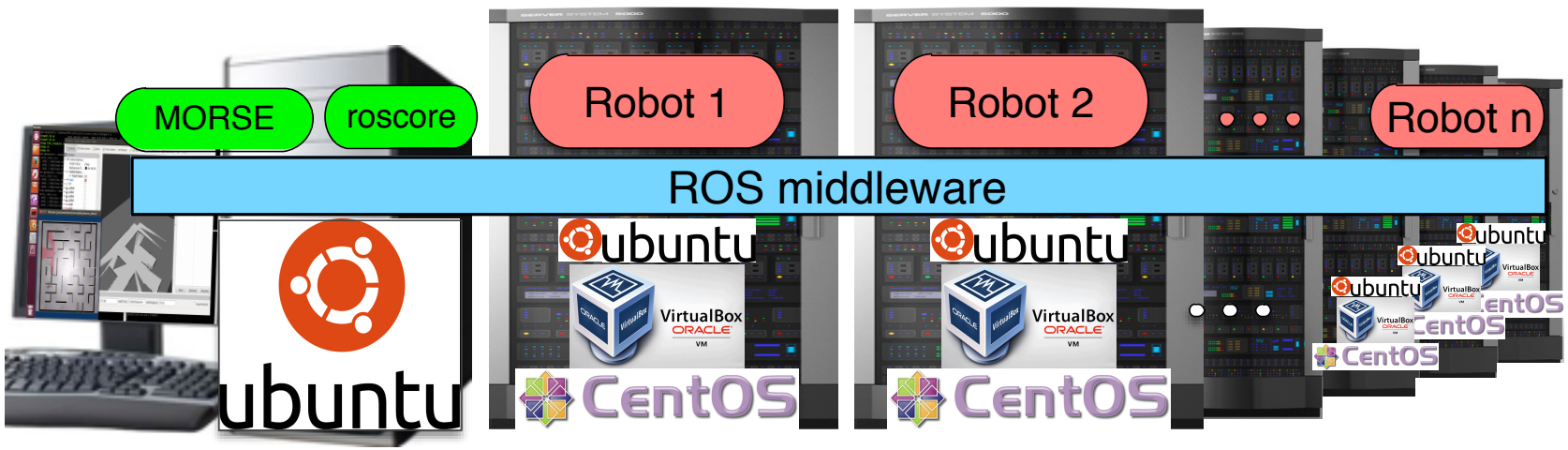
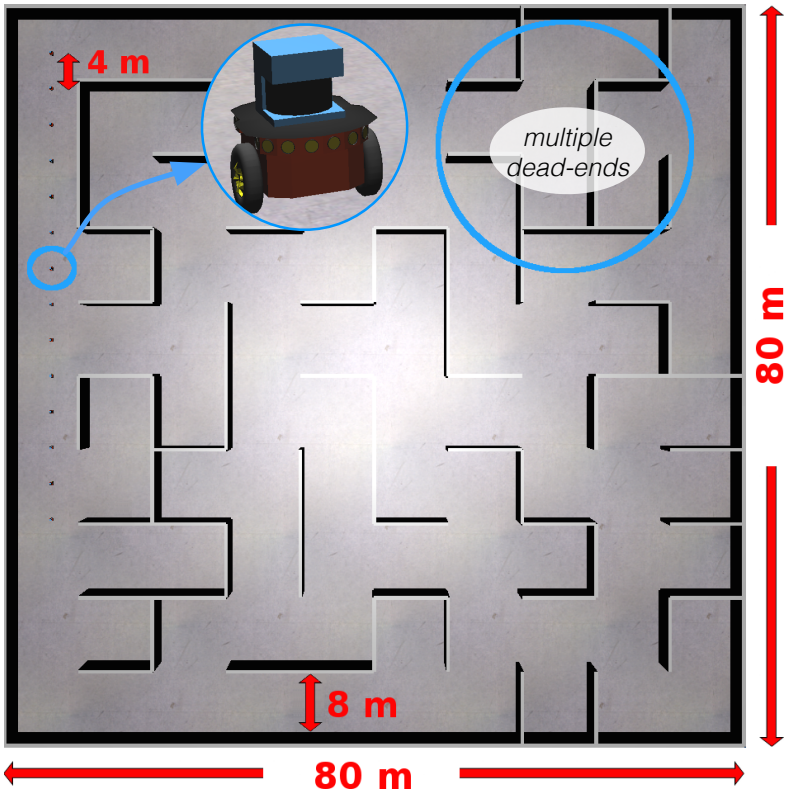
Test bed setup



Computer cluster

- **70 computing nodes**: 8 to 12 processors and 16Go to 48Go RAM
- **1 master node**: scheduler

Experimental setup



◂ MORSE DEMO WITH 8 ROBOTS

Fixed parameters

- **Robot characteristics**: a homogeneous team of Pioneer 3-DX robots equipped with a SICK LMS500 laser scanner
- **Terrain properties**: a maze-like space with 80 meters long and 80 meters wide
- **Communication range**: 200 meters
- **Coordination strategy**: collaborative mapping, robots exchange their map once every 5 seconds

Experimental setup

Experiments A
Blind positionning

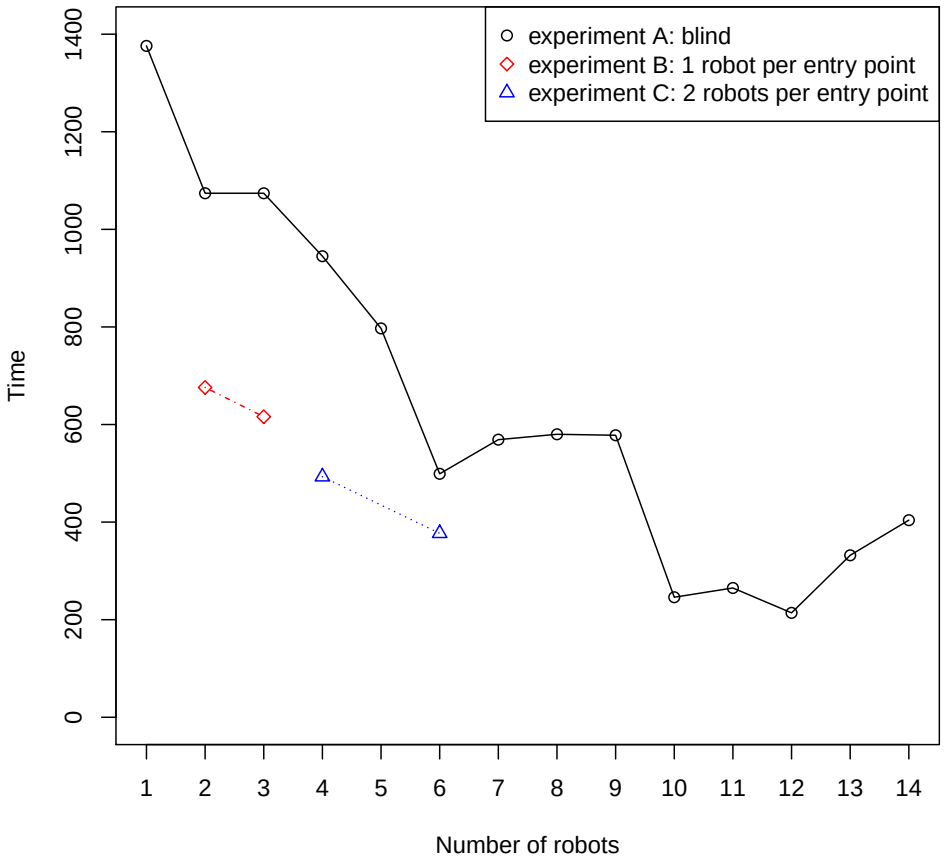
Experiments B
1 robot per entry point

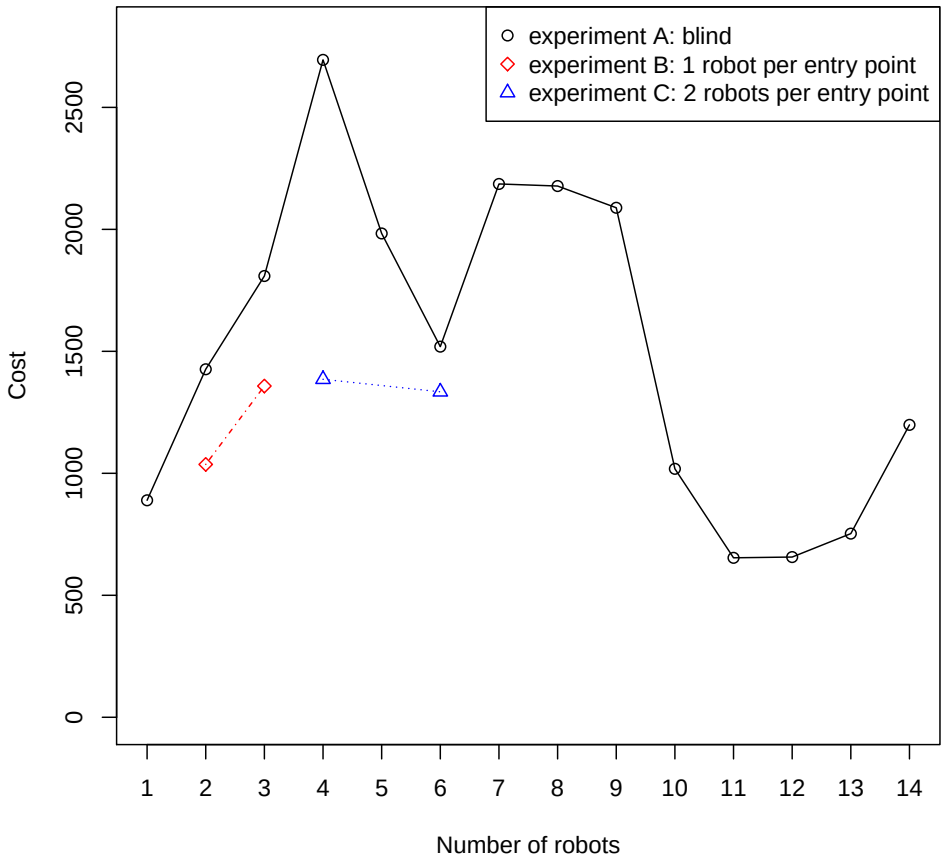
Experiments C
2 robots per entry points

Varied parameters

- **Exploration team size**: from 1 to 14 robots
- **Initial positions of robots**: experiment A, B and C

Results


experiment A: blind
experiment B: 1 robot per entry point
experiment C: 2 robots per entry point
Time
0
200
400
600
800
1000
1200
1400
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Number of robots


experiment A: blind
experiment B: 1 robot per entry point
experiment C: 2 robots per entry point
Cost
0
500
1000
1500
2000
2500
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Number of robots

Conclusion and future work

Contribution

- A **realistic test bed** for evaluating different coordination strategies for multi-robot exploration
- Preliminary experiments with **time and cost** evaluation metrics

Future work

- Different representative environments
- More robots $\rightarrow$ homogeneous and heterogeneous teams
- Odometry noise $\rightarrow$ more efficient map fusion algorithms
- Communication range $\rightarrow$ more efficient coordination strategies

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Multi-robot communication

Algorithm 1 Communication Connection for $robot_i$

1: Querying all published ROS topics
2: Subscribing to odometry topics
3: **if** $\exists robot_j \in$ exploration team : $distBetween(robot_j - robot_i) <$ $max\_comm\_distance$ **then**
4: Establishing connection with $robot_j$
5: **end if**

Multi-robot mapping

Algorithm 2 Map Fusion for $robot_i$

1: $\delta \leftarrow (robot_i.init\_pose - robot_j.init\_pose) \times map\_scale$
2: $robot_i.fused\_map \leftarrow robot_i.map$
3: **for all** *grid* in $robot_i.fused\_map$ **do**
4: **if** $grid = NO\_INFORMATION$ **then**
5: $grid \leftarrow robot_j.map_{grid.pose+\delta}$
6: **end if**
7: **end for**