Distributed Intelligent Systems

Course Project:

Multi-robot navigation in cluttered and dynamic environments

7.11.2018

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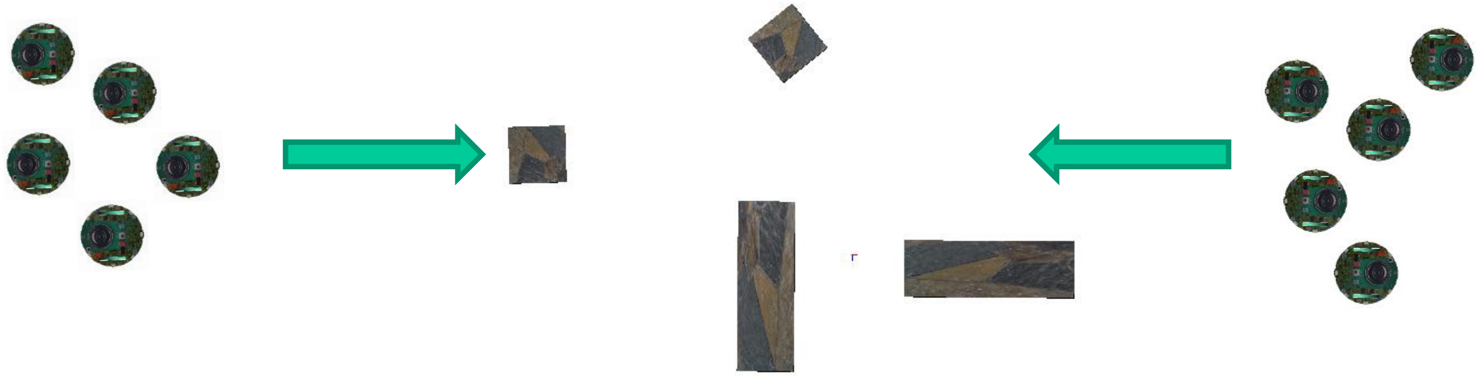
Goal

- Implement a multi-robot navigation strategy in cluttered and dynamic environments:
  - use one of the strategies for collective movement given in this course.

- Multi-Robot system:
  - Group of e-puck robots

Environments

- Cluttered and dynamic:



- Simplify: two individual scenarios:
  - Static obstacles
  - Different groups crossing each other

Scenario 1: Obstacles

- Maze with obstacles
- The group should be able to navigate around them and regroup

Scenario 2: group collision

- Arena
  - 2 groups
  - Each group starts at opposite ends

Project Phases

- Simulation (Webots):
  - Implement chosen navigation strategy.
  - Study influence of parameters on the performance / Scalability of the group.
- Real experiments (real e-pucks):
  - Adapt your best solution to the real e-puck.
  - Demonstrate the behavior of a group robots on the given scenarios.
  - Compare results with simulation.

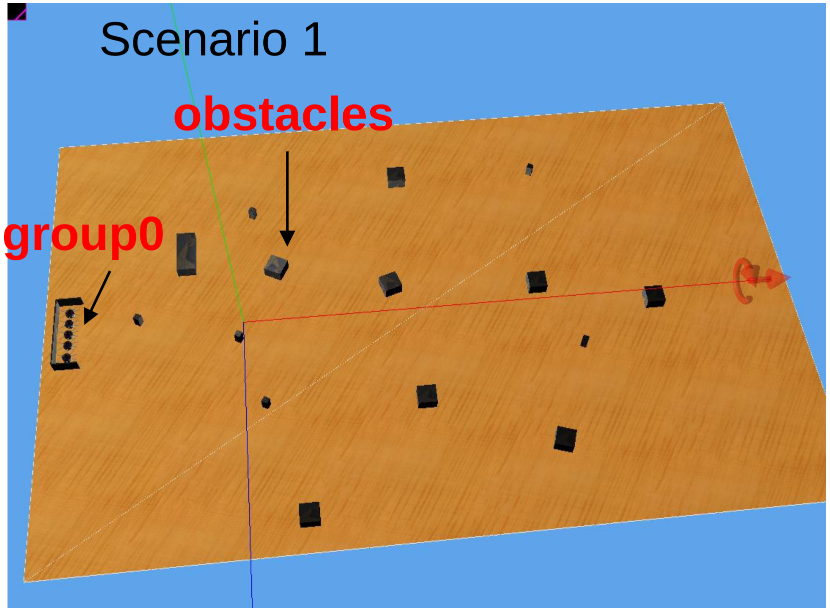
Ground rules

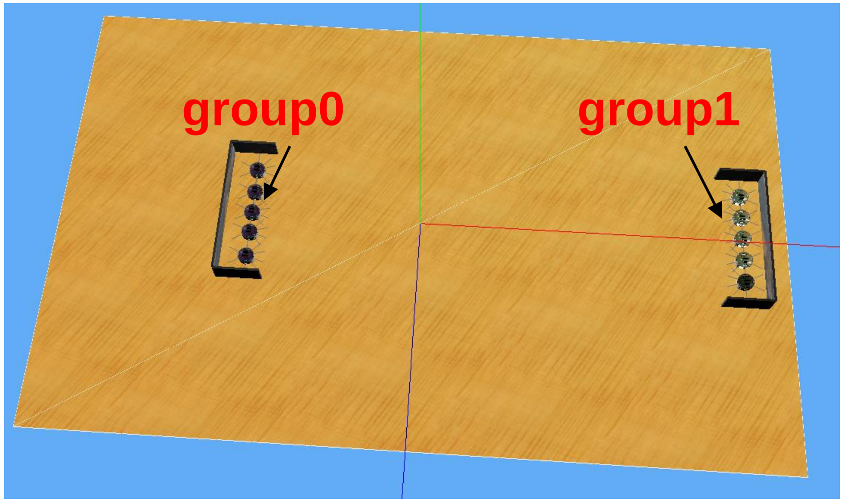
- No global positioning
  - Relative positions OK
  - Use range and bearing (R&B) module as in the lab

- Migratory urge
  - Simulation: you may add a compass node
  - Real experiments: make the robots go forward and point them to the desired direction.
    - Use odometry to keep track of that direction

Simulation

- Initial environment for each scenario provided in Moodle:





Real Experiments

- Proximity sensors will be used for R&B
  - Bad sensor
    - Noisy and discretized
    - Slow communication
  - Move the e-pucks slowly
  - Use the code provided in Moodle as a start
- R&B sensor range is ~25cm (between center of two robots)
  - Adapt the algorithm to cope with the limitation

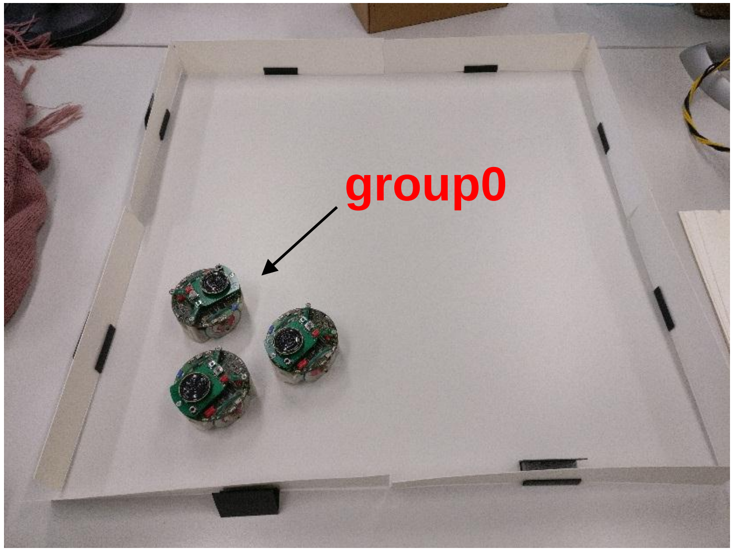
libIrcom(1)

- Starting
  - ircomStart();
  - ircomEnableContinuousListening();
  - ircomListen();
- Sending
  - ircomSend (long int value); // to send
  - ircomSendDone() // to verify it is sent

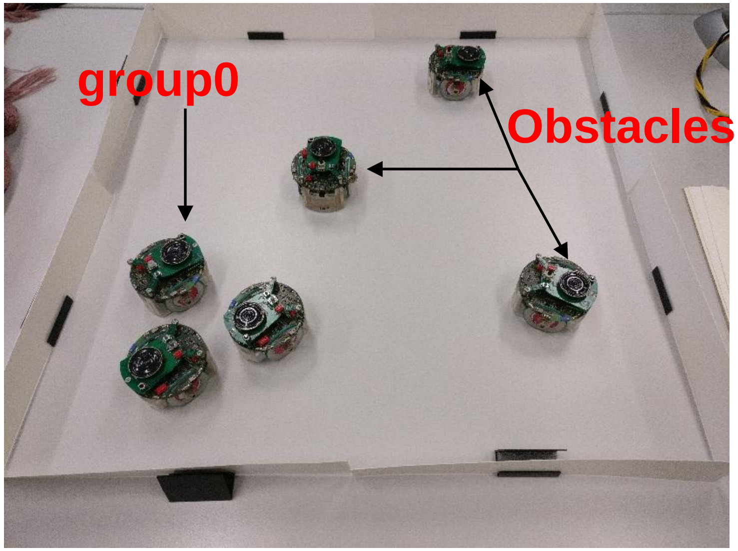
libIrcom(2)

- Receiving
  - ircomPopMessage(&imsg); // get new message
- IrcomMessage structure
  - long int value; //gives the value sent by the emitter
  - float distance; //emitter range
  - float direction; //emitter bearing (discretized)
  - int receivingSensor;
  - int error;
- Library provided on Moodle (check README)

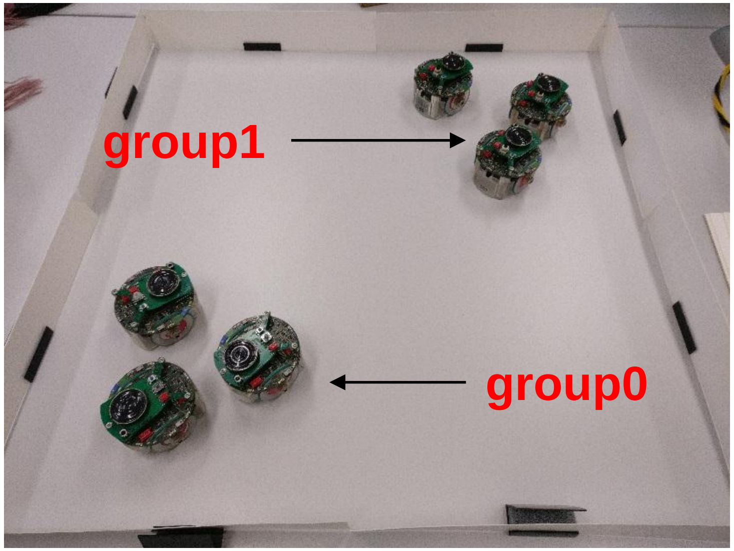
Real Experiments



Scenario0



Scenario1



Scenario2

Communicate IDs between robots to detect members of different groups, and obstacles

Algorithms-literature

- **Primary:**
  - *Reynolds, C. (1987). Flocks, herds and schools: A distributed behavioral model. In Proceedings of the 14th annual conference on computer graphics and interactive techniques (SIGGRAPH '87) (pp. 25–34). New York: ACM Press*
  - *Falconi R., Gowal S., and Martinoli A., Graph Based Distributed Control of Non-Holonomic Vehicles Endowed with Local Positioning Information Engaged in Escorting Missions, Proc. of the IEEE Int. Conf. on Robotics and Automation, 2010, Anchorage, AK, U.S.A., pp. 3207-3214.*
  - *Turgut, Ali E., et al. "Self-organized flocking in mobile robot swarms." Swarm Intelligence 2.2-4 (2008): 97-120.*
- ***Secondary:***
  - *Pugh J., Raemy X., Favre C., Falconi R., and Martinoli A., A Fast On-Board Relative Positioning Module for Multi-Robot Systems. Special issue on Mechatronics in Multi-Robot Systems, IEEE Trans. on Mechatronics, 14(2): 151-162, 2009.*

Calendar

- Initial report by Friday 23th November
  – Description of project and preliminary simulation results; Work plan and tasks (2 pages max.)
- Final report by 16th December
  – Strategy and results (simulation and reality)
  – Template provided in Moodle
  – Submit also the code
  – Reports distributed to another team for review
- Project testing at 17th December
- Final presentation by date 18th or 19th December
  – Strategy and results
  – Questions for other teams

Project testing

- Between report and presentation
- Simulation: competition on performance
  – See performance metrics file on Moodle
    - *Turgut, Ali E., et al. "Self-organized flocking in mobile robot swarms." Swarm Intelligence 2.2-4 (2008): 97-120.*
  – A different test environment will be used
    - *Make sure your solution works for any given environment.*
- Real experiments:
  – Performance visually measured

Performance metrics

- Combination of three metrics
  - Orientation between robots

$$o[t] = \frac{1}{N}\left|\sum_{k=1}^{N} e^{i\psi_k[t]}\right|$$

  - Distance between robots

$$c[t] = \left(1 + \frac{1}{N}\sum_{k=1}^{N} dist(x_k[t], \bar{x}[t])\right)^{-1}$$

  - Velocity of the team towards the goal direction

$$v[t] = \frac{1}{v_{max}} max(proj_{\Phi}(\bar{x}[t] - \bar{x}[t-1]), 0)$$

Evaluation

- Readability of the code
  - We have to understand it
- Results of the performance metrics of your solution during project testing
- Quality of the report
- Quality of the presentation

Some tasks

- Start from the given worlds but generate your own variation
  - A different Webots world will be used to test your solution

- Measure performance metrics from supervisor

- Study and implement your strategy (start in simulation and only then move to real experiments)
  - You are free to reuse the code templates of the labs, but redo your own controllers.

Notes

- You can use additional tools from the course to optimize your solution in simulation.

- In simulation you start with 5 robots (but you can vary the number to assess the scalability of your algorithm).

- Real experiments will use groups of 3 e-pucks and up to 3 obstacles. So up to 6 e-pucks per team (you can come to the lab to get the e-pucks when you need them).

Notes

- Office-hours
  - 4 1h slots each week (starting after this week)
  - Each team will be assigned to a priority office-hour.
  - Teams can go to all the 4 slots on the week but they have to give way to teams with priority on that slot.
  - No assistance on the project will be given outside the office hours.

Group Formation

- Finalize groups until this Friday.

- Groups of four (default) or three (if needed) students belonging as much as possible to different teaching sections or programs (at least two different sections will have to be represented in the team).

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

QUESTIONS?