CHILI Robots

Tangible Swarm Interaction with the Cellulo Robots

Before the first session



Part I

Theoretical background

Swarm robotics is a subfield of Robotics that make use distributed system to control several robots. Swarm robots are usually simple and relatively cheap, with limited functionalities, but which together (with capacity of aggregation or formation) can form a complex and robust system.

Swarm robots aims to study the design and behavior of these small robots. Simple rules can make emerge a bunch of complex behaviour at the swarm level. A key element of the swarm is the communication between its members, aiming at cooperation among them. Such systems are expected t hold at least the following 3 properties:

- Robustness: ability for the swarm to function even with some failures of some individuals or changes in the
 environment.
- Flexibility: ability to propose adapted solution to the given tasks
- Availability: ability of the swam to perform whatever its size (number of individuals)

In a swarm every robot is autonomous. Robots are usually able to localize themselves relatively to their closest neighbors and sometimes globally even-though most system try to not rely on this last. Swarm robots can interact, with each other and their environment. Their detection and communication abilities are usually locales and limited. The robots are usually not connected with a central unit; and they don't have a global knowledge of the system in which the stand.

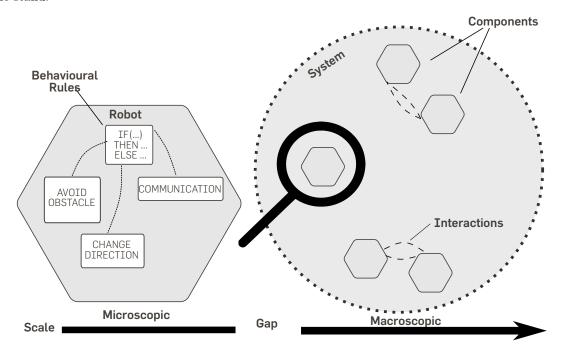


Figure 1: The gap between two levels of description of the same self-organizing system. On the left, the microscopic view: the focus is set on a single component of the system and its behavioral rules. On the right, the macroscopic view represents the full system made of numerous interacting components. The environment in which the system is embodied is not represented for the sake of clarity. Campo 2011

Inspiration from Biological system

Swarm robotics gets inspired from social insects such as ants or bees, as well as from group behaviors and cooperation of other organisms like bacteria, fishes, birds. These living organism show that simple agents can be able to produce collectively smart behaviors that would be impossible individually. Swarm robotics gets inspiration from these biological models extracted from ethology.

Applications

At the moment, swarm robots are mainly studied in laboratories But, several application are foreseen for swarm robots: in surveillance, cleaning of areas hard to access, weather and pollution monitoring; and in different sectors: telecommunication, military or agricultural.

Part II

Organization of the project

In this practical, you will learn and implement basic swarm behaviours using the Cellulo robots. A computer with Linux (Ubuntu 18.04) will be put at your disposition with everything already installed (ROS, Cellulo API ...). You will be using small tabletop robots developed and produced at the CHILI Lab of EPFL, the Cellulo robots Özgür et al. 2017a.

Cellulo Robots

Cellulo is a handheld, small-sized, mobile, haptic robot that operates on printed paper sheets Özgür et al. 2017b. These graspable robots can be used as an interface for interacting with many virtual objects that reside on a plane.

The robots are designed to be simple to operate; all robots are connected wirelessly to a PC device that runs the activity and game logic. The current robots includes: self-localization on the activity sheet covered with a dot pattern; holonomic motion robust against human manipulation; six capacitive touch buttons (independently backilluminated in full RGB) and wireless Bluetooth communication. The platform provides fast (>90Hz) and accurate localization (sub-mm) Hostettler et al. 2016 of many robots which can be logged to record all the interactions during the game, such as user motion.

For the practical, you will be given 5 robots. Please make sure you charge them and turn them off after each session.

Schedule of the practical

In this practical, you will get familiar and will implement some classically known swarm robotic tasks. The additional document will guide you through the process. Your overall work on the two sessions will consist in 4 parts:

Part 1 Familiarisation with Cellulo and ROS environment

Part 2 Leader-Follower

Part 3 Aggregation

Part 4 Coverage

Some parts of the practical can be prepared in advance.

Report

The report of this practical will consist mainly two things: 1) answering and discussing some question that are included in the material we will give you and 2) evaluating your implementation by running the various swarm behavior and tuning the parameters. For this second part, you will have to include we will ask you to explain the results you observe in terms of: completion of the task or not and time for the swarm to complete the task. You will have one week after the practical work to submit your report with the following suggested structure:

- Introduction of the report (objectives and overview)
- Theory (describe method used)
- Experimental results (explain and illustrate with graphs the performance of your implementation tests)

- Discussion and conclusion (discuss the overall tasks, explain limitations and propose other methods)
- Appendix (code for Part 2-3-4, and analysis of logs).

In particular the question you will have to answer in your report are marked in boxes:

Deliverable 1

Yellow boxes indicate that the question can be prepared before coming to the lab session.

Deliverable 2

Part III

Software framework

As you can see from Figure 2, the Cellulo robots are actually all centrally connected. Each of the robots actually features a precise localization system. However, for the sake of this practical, we emulate a basic swarm robot that features a proximity sensor.

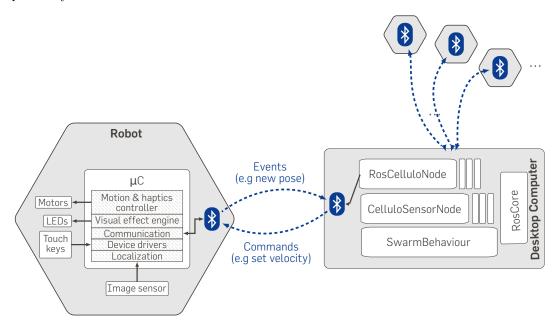


Figure 2: Cellulo ROS Software Architecture

ROS Cellulo Node

The ROS Cellulo node implements the ROS API for the Cellulo Robot. The different topics, publishers and subscribers are detailed in the README.md file.

Useful Subscribers:

- cellulo_node_(mac_adr)/setGoalVelocity $\mbox{sets the }(x,y, heta) \mbox{ velocity of the robot}$
- cellulo_node_(mac_adr)/clearTracking clears the velocity buffer of the robot
- cellulo_node_(mac_adr)/setVisualEffect sets the LEDs color
- cellulo_node_(mac_adr)/shutdown turns off the robot
- cellulo_node_(mac_adr)/reset clears all buffers and settings of the robot

Useful Publishers:

- cellulo_node_(mac_adr)/velocity
- cellulo_node_(mac_adr)/touchKey
- cellulo_node_(mac_adr)/longTouchKey
- cellulo_node_(mac_adr)/kidnapped

ROS Cellulo Sensor Node

The sensor node has the role to emulate the presence of proximity sensors on the robot. This node has two main publishes and one subscriber:

The sensor message has 4 arguments:

- timestamp: indicating the time of the detection in ns.
- detected: indicating the number of detected objects.
- Distance: an array of 3D vectors where x is the difference in x direction, y is the difference in y direction, z is the Euclidean distance. Fig. ?? describes how the distances are calculated.

Publishers:

- sensor_node_(mac_adr)/detectedRobots publishes the distances to detected robots within a predefined detection threshold.
- sensor_node_(mac_adr)/detectedObstacles publishes the distances to detected obstables (including walls) within the predefined detection threshold.

Subscriber:

/setThreshold modifies the detection threshold.

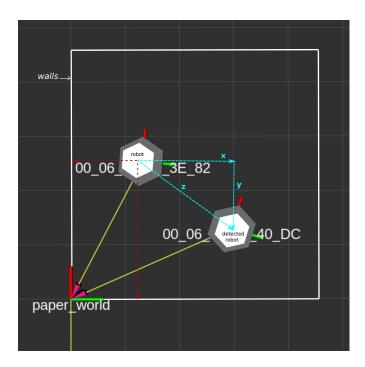


Figure 3: Sensor Description: The walls are considered as obstacles. Dotted red arrows indicated the distance from the walls (obstacles) and the dotted aqua lines indicates the distance from another detected robot.

References

Campo, Alexandre (2011). "On the Design of Self-Organized Decision Making in Robot Swarms". PhD thesis. Université Libre de Bruxelles.

Hostettler, Lukas et al. (2016). "Real-time high-accuracy 2D localization with structured patterns". In: Robotics and Automation (ICRA), 2016 IEEE International Conference on. IEEE, pp. 4536–4543.

- Özgür, Ayberk et al. (2017a). "Cellulo: Versatile handheld robots for education". In: *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*. ACM, pp. 119–127.
- Özgür, Ayberk et al. (2017b). "Haptic-enabled handheld mobile robots: Design and analysis". In: *Proceedings of the* 2017 CHI Conference on Human Factors in Computing Systems. ACM, pp. 2449–2461.
- Shlyakhov, NE, IV Vatamaniuk, and AL Ronzhin (2017). "Survey of methods and algorithms of robot swarm aggregation". In: *Journal of Physics: Conference Series*. Vol. 803. 1. IOP Publishing, p. 012146.