Experiments Design Using a Mobile Robots Simulator*

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Teaching mobile robotics usually implies high costs both in time and in money due to the very nature of the matter. These costs are higher when one tries to introduce robot colonies and to make experiments with different collaborating strategies. RoboCoT (Robot Colonies Tool) is a software tool developed and used by the authors at the University of the Balearic Islands that allows testing the performance of singles or colonies of mobile robots in a very flexible, fast and non-expensive way. Actually, the student can evaluate the behaviour of the robots against different tasks, the configuration of the environment and the number of robots or their particular properties. As for the last point, the user can easily modify the cinematic parameters and the sensory configuration of every robot, as well as its communication capabilities with the rest of the group. Every robot implements a behaviour-based architecture consisting of three functional layers: a mission layer, an adaptation layer and a sensory layer. In the paper a functional description of RoboCoT is shown, some practices of an introductory course of mobile robotics are described and their results discussed. RoboCoT runs under W95/98 on a PC compatible.

Key words: mobile robots, behaviour-based architectures, robotics education and training

1 INTRODUCTION

The huge development in mobile robotics in the last few years has allowed to apply it to several environments, either in the typical industrial scenarios or in less controlled situations. This fact has led to the inclusion of one or several undergraduate and graduate courses about the subject in the curriculum of many universities throughout the world [1]. Practical experimentation is, as in many other cases, essential to reinforce the theoretical concepts underlying mobile robotics. Nevertheless, given the high cost of robotics equipment and the great interest of students in this matter, it is not easy to have at the disposal of the instructor enough material to carry out suitable laboratory assignments. The problem gets worse as one tries to introduce experiments with more than one robot, as it is the case in co-operating robotics.

The use of simulators is an excellent option that allows us to overcome some of the aforementioned difficulties. Although simulators cannot totally substitute experiments with real robots, their flexibility and reconfigurability make them unique: the student can easily test different options interactively and the instructor does not need to make use of as many robots as teams in the laboratory. As an added value, free distribution software

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allows students to work on complementary assignments, at home or anywhere, without any difficulty, such as license restrictions.

RoboCoT was developed to achieve several goals. First, it had to be useful as an educational tool to ease the understanding of simple behaviour-based architectures, specially concerning path planning, obstacle avoiding and goal attainment. Secondly, it had to be user-friendly and possess a great flexibility, which makes it possible to modify the different parameters involved in a typical robot colony mission: robots cinematical parameters, sensor types and distribution throughout the robot, navigation strategies, communication capabilities, number of robots, environment structure and task to execute. A short relation of the main functionality of RoboCoT follows:

- Graphical edition of the environment where the mission will be carried out.
- Definition of the initial and maximum speed and acceleration for every robot.
- Placement of contact and range sensors all around the perimeter of the robot.
- Use and dimension of a environment storage memory.
- Selection of navigation and obstacle-avoidance strategies.
- Scope of the information transmission between robots.
- Definition of the mission to be carried out by the colony including: go through a user-defined set of points of the environment, gather some objects satisfying certain constraints, and transport objects to a specific collection point.
- Size of the colony. RoboCoT can work with colonies from 1 to 20 robots without a significant degradation of the execution time on a regular Pentium based PC.
- Environments, robots and missions library management.
- Simulation results analysis by direct display during the execution of the program or on a log file generated with the most significant events.
- Batch instructions file for large number of simulations.

The rest of the paper is divided in two sections: first, section 2 comments on the main aspects of the architecture of individual RoboCoT robots, then section 3 describes a set of experiments carried out with the simulator to show some properties of the different techniques implemented in the architecture; finally, section 4 presents the conclusions and lines some future work.

2 ARCHITECTURE OF THE ROBOTS

We briefly expose here the structure of the robots implemented in the simulator, a detailed discussion can be found in [2]. RoboCoT implements robots that work according to a control architecture based on behaviours, as they were introduced by Ronald C. Arkin [3]. It has been widely prooved that with these architectures efficient robot navigation capabilities can be obtained at a reasonable low computational cost.

In RoboCoT, the functional structure of the robots consists of three layers that communicate just with their adjacent neighbours (see figure 1).The sensory layer is the only one communicating with robot sensors and actuators. It implements the following tasks: Query and basic interpretation of sensor data and robot motion. No decision is made about the path to follow. When the robot has memory, this layer is the one that fills it up with the information detected by the sensors.

The adaptation layer receives displacement commands from the mission layer in the form of final destination points to move to. This layer makes changes in the trajectory to avoid collisions with obstacles. Such changes in the trajectory generate partial destination points that give rise to subcommands of movement for the sensory layer. RoboCoT incorporates several behaviours to avoid collisions, which can be used if needed. If a robot incorporates more than one of such behaviours, a sequencer will run during the simulation to determine the active one at a given time.

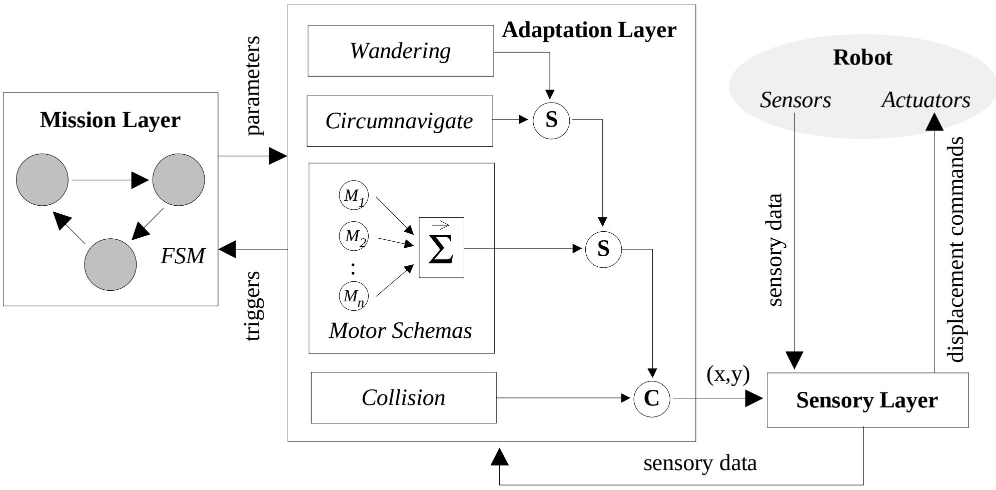


Figure 1. Functional structure of the robots

The highest level implemented by RoboCoT is the mission layer. This layer is in charge of determining the intermediate points to be reached by the robot to get to the goal. Communication between robots is also function executed at this level.

Among all the tasks involved in robot navigation, collision avoidance is certainly the one that more attention has been paid to. Therefore, several techniques have been discussed in the robotics literature, both to avoid collisions and to combine primitive responses through suitable operators [3]. In particular, RoboCoT allow the user to test wandering, circumnavigation [4], and motor schemas [5], as well as behaviour aggregation, selection and cancellation operators. As it is shown in figure 1, a command towards the sensory layer can come from one or any combination of the aforementioned collision avoidance strategies. Motor schemas available are: move towards the goal, avoid obstacles and other robots, inertia and avoid the past [6].

3 EXPERIMENTS IN THE CLASSROOM

Given the configuration flexibility of RoboCoT, the number and type of experiments that can be carried out is really high. Some illustrative cases that have been used in the classroom, including single and multiple robot missions, are discussed in this section. The experiences shown are part of an introductory course in mobile robotics.

3.1 Navigation in a complex environment

The first exercise puts emphasis in the quality of the path followed by the robot when the environment presents a certain complexity. Two examples are shown in figure 2 where the robot is symbolised as a little circle with a mark in the forward direction and the target point appears as a big circle. In RoboCoT, the student can analyse the resultant path by changing the weights of the different forces giving rise to the potential field, enabling different obstacle avoidance strategies and changing the sensorial configuration of the robot.

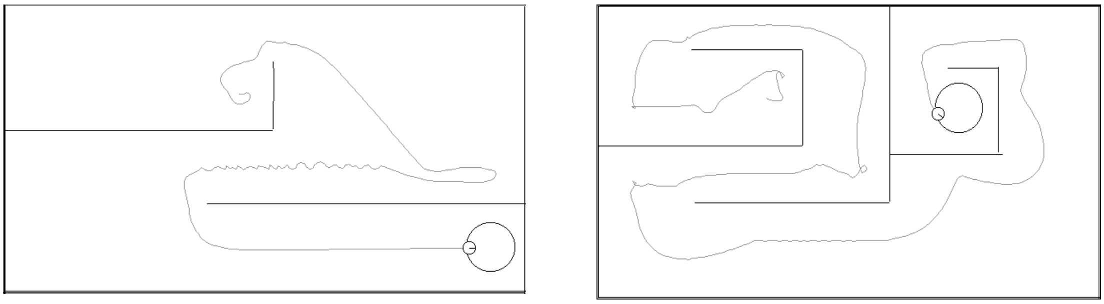
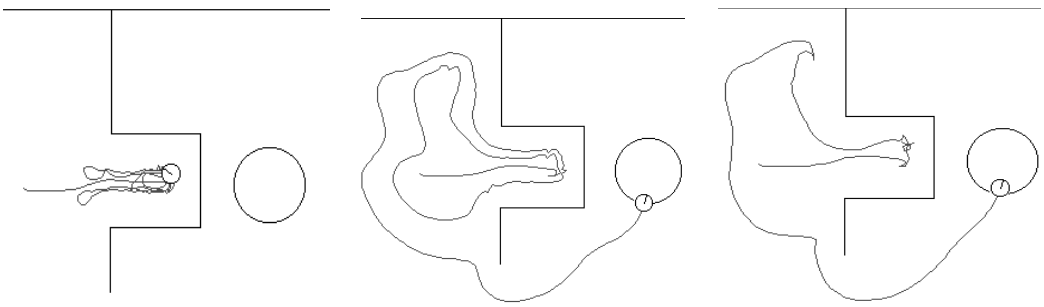


Figure 2. Navigation in a complex environment

3.2 Getting out of a potential well

For obstacle avoidance strategies based on potential fields, it is well known that there exist some situations where the balance between attraction and rejection forces give rise to local potential minimum where the robot can get trapped during its path to the target point. With RoboCoT, some of the solutions to this problem proposed in the literature can be tested. Here we present three results obtained combining the behaviour "avoid the past" with potential fields based techniques in a typical "reach a destination point" mission. The robot paths are shown as a result of assigning different values to the behaviour parameters (Past-Mark and Past-Horizon in figure 3).

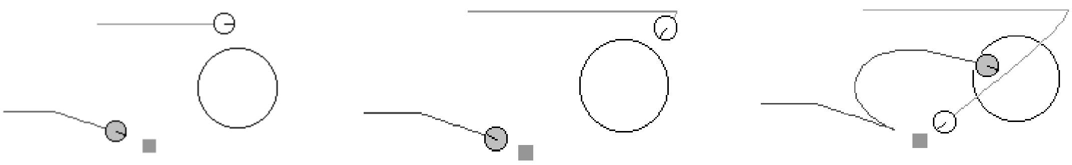


(a) (b) (c)

Figure 3. (a) PM=PH=5, (b) PM=PH=20, (c) PM=PH=30

3.3 Testing the communication effect

The third experience focuses on the influence of the communication in a simple situation with robots (see figure 4). In this mission some objects placed at the collecting point (square mark) have to be moved to the delivery point (big circle). In 4.a the grey robot detects the collecting point, while it remains unknown for the white one. In 4.b the grey robot gets a piece from the collecting point and starts to move to the delivery point.



(a) (b) (c)

Figure 4. Communication process and its effect in a two-robot cooperative task

At the same time, it sends its local map to the white robot, which changes its path and faces the collecting point. In 4.c the white robot is reaching the collecting point and the grey one is at the delivery zone.

3.4 Some cooperation experiences

The following is a detailed study of a “find and transport” mission. The experience is described as follows: *From a random initial position for robots and objects, robots must locate those objects, and carry them to a common delivery point. The mission finishes when all the objects have been collected.* In this case the student attention is focused on the execution time in accordance with the environment in which the mission is carried out, the number of robots involved and their communication capabilities. Thus, the mission is first executed with one object and one robot; then the number of objects and robots is gradually increased. The same experience can be repeated in different environments and allowing the communication between robots or not. Figure 5 shows an initial situation in an environment free of obstacles.

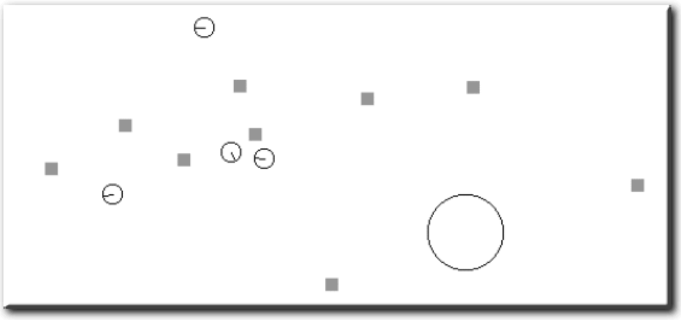


Figure 5. An initial situation with 9 objects and 4 robots randomly placed

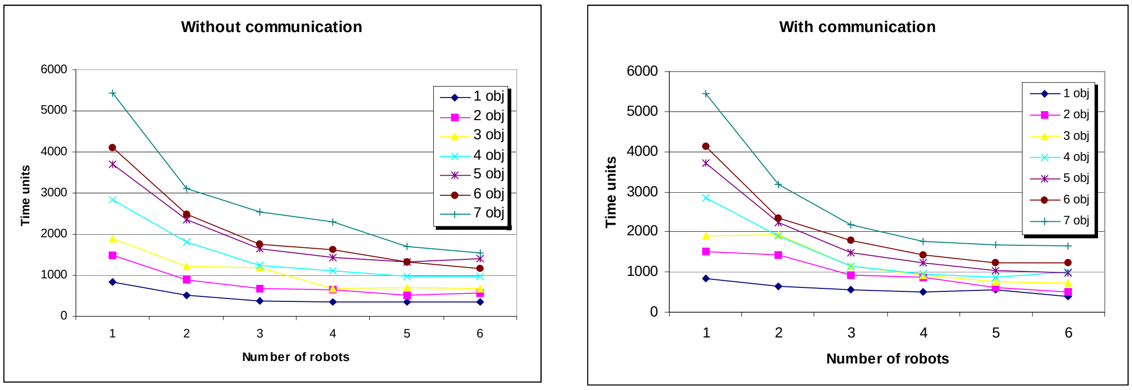


Figure 6. Execution time as a function of the number of robots in the simulation

In this experience, every student generates a set of initial situations and stores the main events in a log file. When all the simulations have finished, the results are collected, conveniently combined and exposed to the classroom for a discussion. Figure 6 makes manifest the reduction of the mission’s time, for a given number of objects to deliver, as a function of the number of robots available, with or without communication between them. However, figure 7 in a more detailed analysis reveals that the communication influence decreases when the robots or the number of objects to collect increases. This result can be interpreted as a consequence of the initial random location of the robots and the objects on a scene free of obstacles.

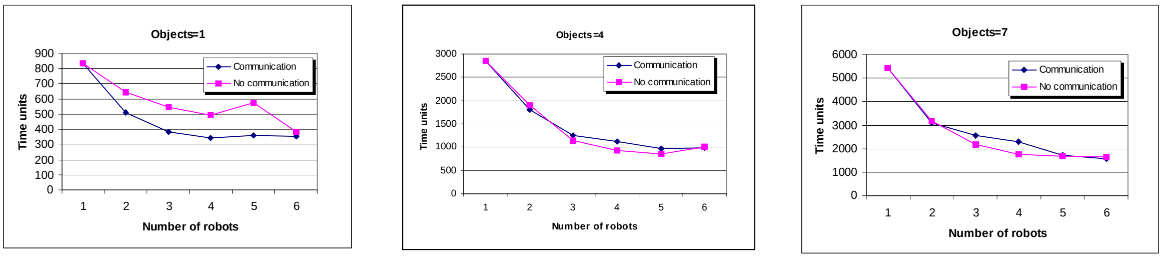


Figure 7. Influence of the number of objects and of robots and their communication capabilities

3.5 Range and volume communication effect

The objective in this experience is to study the influence on the execution time of some parameters of the communication between robots. The results shown have been obtained using four collector robots and six objects randomly placed. The same mission has been repeated increasing the maximum distance allowed for the robots to interchange their known local maps from 0 (no communication) to 280 world units. The size of the window containing the local map transferred in the communications has been increased from 10x10 to 70x70 world units. As it can be seen in figure 8 the execution time raises abruptly with the communication and tends to decrease slowly as the range increases.

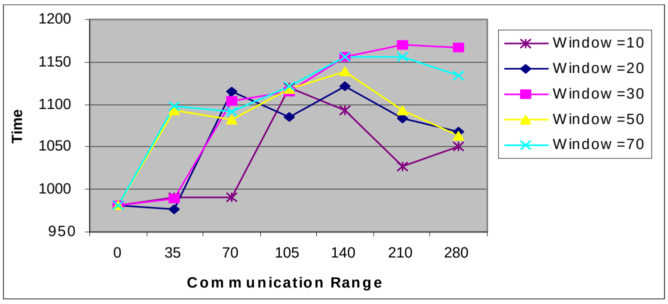


Figure 8. Execution time as a function of communication range and transferred map size

6. CONCLUSIONS

RoboCoT is an educational tool oriented towards mobile robotics courses involving behaviour-based architectural and cooperating issues. Its flexibility allows testing several strategies related with robots navigation control in a non-expensive way, helping, thus, to reinforce concepts as behaviours, potential fields, or environment maps. The paper describes some experiments that can be easily executed in a laboratory using RoboCoT.

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