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Toward Automatic Design of Controllers: Identification and Implementation of Basic Behaviors for Khepera IV Robots

Jeremy Wanner

Professor : Alcherio Martinoli
Assistant(s) : Cyrill Baumann

In today's mobile robotics, the programming of a controller for the robot to fulfill a task is often still done manually and can be extremely time consuming. Unsurprisingly, a lot of research is done to automatically generate controllers. One method is to combine available behaviors and conditions, creating a probabilistic finite state machine (PFSM), with the use of optimization algorithm, as it has been done for the AutoMoDe approach [1].

This project aimed to be the first steps towards the automatic design of controllers for Khepera IV robots at DISAL. First, a set of available behaviors and conditions needed to be implemented, in order to be used later by the arbitrator. Therefore, three behaviors have been implemented: Braitenberg, Light-following and Stop. The Braitenberg behavior makes the robot explore the arena, while avoiding obstacles. For the Light-following one, the robot orients itself and goes toward the greatest source of light. Finally, the Stop behavior makes the robot stop and stay still. Five conditions have been created to trigger transitions between behaviors: Black floor detection, White floor detection, Gray floor detection, Obstacle detected, and No obstacle detected. Those behaviors and conditions use the ring of IR proximity and ambient light sensors of the robot, as well as 4 ground IR proximity sensors.

All behaviors and conditions have been tested on both Webots, a high-fidelity simulator, and on real robot experiments. Keeping in mind the goal to minimize the reality-gap, improvements have been made to those behaviors and conditions as much as the time of this project permitted.

Then, to test the results of combinations of those behaviors and conditions, a more challenging task has been implemented: Foraging task. It consists in picking an object and deposit it at a specific place. The Khepera 4 does not have any arm and we wished to translate the task into simple behaviors and conditions. Therefore, for our experiments, the act to "pick an object" is translated by passing over one of the black ground areas, and the "deposit of the object" is set to be done when the robot attains the white ground area. To help the robot localize the deposit area after "picking an object", a spot light is situated behind it.

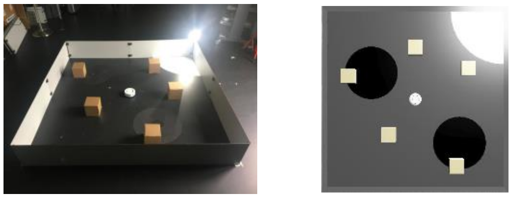

Figure: Real Arena (left) and Arena on Webots (right)

To compare the behaviors and the Foraging task in Webots and in the reality, a fitness function for each behavior and challenge has been determined. For the Braitenberg, it is the average minimum distance to an obstacle during a run of one minute with several starting positions. For the Light-following, it is the time it takes the robot to reach the spot light from different distances and orientations. And for the Foraging task, it is the time it takes the robot to complete the challenge from a given position and orientation.

After a first set of experiments, where large differences between Webots and the real robots have been noted, investigations were done to understand where they came from. The main source of discrepancy was the wheel-speed input difference between the two setups. This problem was solved and the new results were significantly better, but there were still some difference in the performances. It was discovered towards the end of the project that the Khepera 4 model in Webots still needed some improvements and calibration to match the real robot, especially for its IR sensors.

Finally, the last part that has been done in this project is the identification of a suitable metaheuristic optimizer: F-race [2]. In a future work, an arbitrator will be designed leveraging this algorithm, to automatically generate the best controller for a given task.

[1] Francesca G., Brambilla M., Brutschy A., Trianni V., Birattari M., "AutoMoDe: A novel approach to the automatic design of control software for robot swarms." *Swarm Intelligence 8 (2014)*

[2] Birattari, M., Yuan, Z., Balaprakash, P., Stützle, T. "F-race and iterated F-race: an overview." *Empirical Methods for the Analysis of Optimization Algorithms. Springer, Berlin (2010).*