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Hierarchical behaviour for object shape recognition using a swarm of robots

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Abstract. A hierarchical cognitive architecture for robot exploration and recognition of object shape is presented. This cognitive architecture proposes the combination of multiple robot behaviours based on (1) Evolutionary, (2) Fuzzy Logic and (c) Bayesian approaches. First, the Evolutionary approach allows a swarm of robots to locate and reach an object for exploration. Second, Fuzzy Logic is used to control the exploration of the object shape. Third, the Bayesian approach allows the robot to detect the orientation of the walls of the object being explored. Once the exploration process finishes, the swarm of robots determine whether the object has a rectangular or circular shape. This work is validated in a simulated environment and MATLAB using a swarm of E-puck robots. Overall, the experiments demonstrate that simple robots are capable of performing complex tasks through the combination of simple collective behaviours while learning from the interaction with the environment.

Keywords: Swarm robotics · Hierarchical control · Bayesian perception

1 Introduction

It has been demonstrated that in social organisms, collective decisions arise from a democratic consensus by pooling individual interactions and estimates about the environment [1]. Particularly in ant foraging, information retrieval about food sources is a collective process that involves individual activities as well as behaviourally integrated groups [2]. Based on the principles of self-organisation, ant foraging is a societal activity that has inspired a number of researchers in the area of robotics to create algorithms for different purposes. Examples of applications include search and rescue in hostile environments, demining and removal of toxic material. Some of the benefits from the foraging approach in swarm robotics are the robustness, collective intelligence and emerging behaviours to unexpected events. In this paper, a hierarchical cognitive architecture, composed of evolutionary aggregation, fuzzy logic, and Bayesian perception, is proposed for the control of the collective behaviour of a group of robots with basic computation capabilities [3], for exploration and identification of geometric shapes.

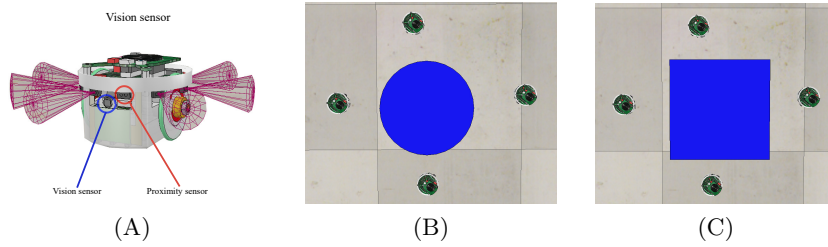


Fig. 1. (A) E-puck robot and (B,C) Examples of objects for shape recognition.

2 Methods

2.1 Robot platform and sensory system

This work employs the E-puck robot platform, which is a differential wheel miniature robot [4]. The E-puck is equipped with eight infrared sensors to evaluate either the proximity of obstacles or the intensity of the surrounding environment and a colour CMOS camera with a resolution of 640×480 pixels. The E-puck robot and its sensors are shown in Figure 1. The implementation of the hierarchical cognitive architecture in the E-puck, is performed using two development tools for robotics; V-REP and ENKI simulators.

2.2 Hierarchical architecture for control of robot behaviour

The proposed hierarchical cognitive architecture implements three robot behaviours a) evolutionary aggregation, b) fuzzy logic theory and c) Bayesian perception for exploration and recognition of object shapes using a swarm of robots. Examples of the object shapes used for exploration and the hierarchical cognitive architecture are shown in Figures 1B,C. The initial task for all robots in the arena is to aggregate around the object and find the closest clear edge. For this process of aggregation, each robot employs a recurrent neural controller (Figure 3A) that evolves a stochastic and derandomised self-adaptation evolutionary strategy CMA-ES. The sensor data used for the aggregation process is collected from the camera as a binary input. Once the robots are aggregated around the object, the E-puck robots determine the orientation of the object shape. For this process, the robots employ proximity sensor data with a Bayesian formulation (Figure 3B). This approach allows the robots to naturally accumulate evidence

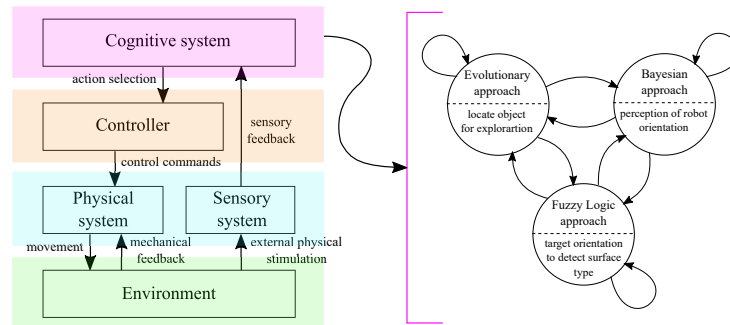


Fig. 2. Hierarchical architecture for robot control for the exploration of object shape.

for accurate and robust decision-making processes [5]. Thus, using the data from the 8 proximity sensors, the robot is capable to estimate its orientation or angle with respect to the object edge being explored. This information is used by the robot for object exploration. This process is controlled with a Fuzzy Logic method which is implemented using an Interval Type-2 Fuzzy Logic Controller (IT2 FLC) [6], which receives as input the orientation estimation (Figure 4). Thus, the robot makes decisions to move forward, backward, to the left or right according to the orientation estimated. These processes are repeated to perform the exploration of the whole object, and determine if it has a polygonal or circular shape. Finally, the E-puck robots emit a red or blue colour light to indicate that the object explored has circular or polygonal shape, respectively.

3 Results

This preliminary study analysed the hierarchical behaviour of a swarm of E-puck robots for exploration of an object in a simulated environment. This architecture was implemented in MATLAB and the robots and objects were simulated in V-REP. MATLAB received signals from the camera, proximity sensors, and motor values from all robots. These data were processed and the output control signals were sent to V-REP to control the speed and movement of each robot during the exploration of the object shape. Figure 5 shows the processes performed by the robot for exploration of the object shape. First, the robots search for an object using data from the camera, and then, they start moving towards the object. Second, the robots start the angle detection using proximity sensors to place the robot in position for exploration of the object shape. Third, the robots start moving forward and backward to collect data from the object edges using the proximity sensors. Then, each robot estimates if the corresponding edge belongs to a polygonal or circular object. Finally, the robots make a consensus, using majority vote, to determine if the complete shape of the object is polygonal or circular, displaying a blue or red colour light. The hierarchical architecture was tested using objects with different shapes such as triangles, squares, rectangles and circles. These experiments were repeated 10 times for each object, achieving a mean error of 10% for the recognition of object shape with a swarm of robots.

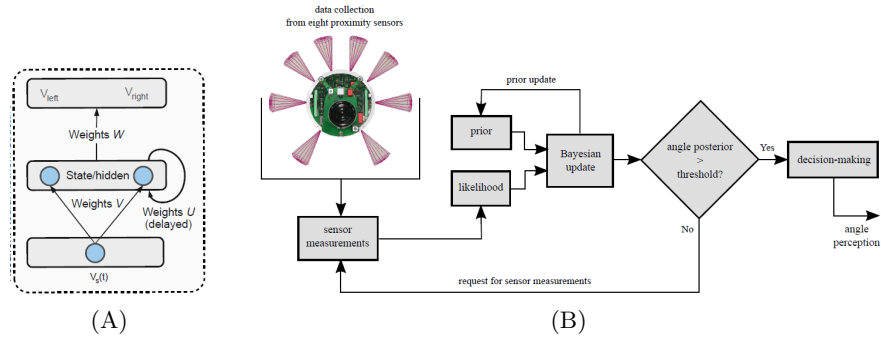


Fig. 3. (A) RNN for robot aggregation behaviour. (B) Bayesian method for estimation of the robot orientation or angle with respect to the object edge begin explored.

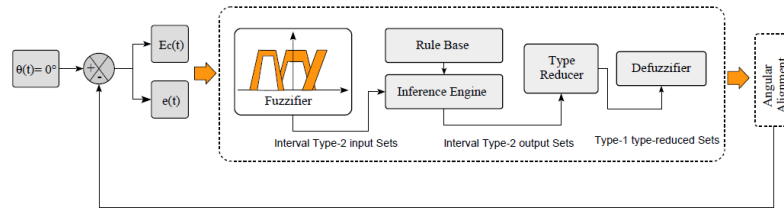


Fig. 4. Fuzzy Logic Controller for object exploration by the E-puck robot.

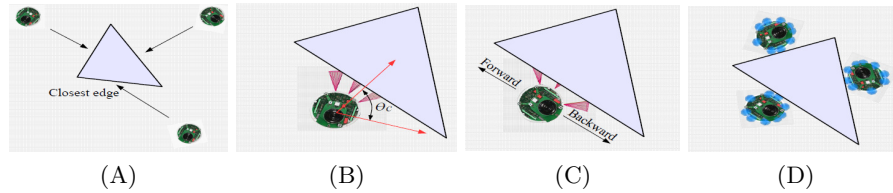


Fig. 5. Robots performing (A) aggregation to reach the object, (B) angle estimation and (C) forward and backward movements for edge angle perception. (D) Robots emit a blue light if the object shape is polygonal and red light otherwise.

4 Conclusions and Future Work

This work presented a hierarchical architecture for object shape recognition with a swarm of robots using an evolutionary approach, a Bayesian method and fuzzy logic. Even though this work presented preliminary results from simulations, they showed that it is possible to bring together different learning and control paradigms for the development of intelligent robots. In the future work, we plan to implement this cognitive architecture using real E-puck robots for autonomous exploration and recognition of shapes from object in the real world.

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