A Robotic Platform for Studying the Evolution of Communication

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1 Introduction

In order to study animal-like communication in embodied agents, a versatile physical platform is needed for agents to interact with their environment, and communicate with other agents. Toward this aim, we present the e-puck robot epu (2008), a simple, robust and user-friendly open-hardware robotic platform. Compared to similar robots, the e-puck is small in size and is equipped only with basic sensors and actuators, making it relatively affordable, which is an important feature for any studies involving groups of robots. Despite its simplicity, though, a user may customize the robot to specific experiments by building (or purchasing) additional turrets that can be stacked on the robot to extend its capabilities. The development of the e-puck robot is based on an open-hardware concept, where all documents and code are freely available and are continuously being developed by its user community epu (2008), which results in a large degree of flexibility and transparency. In this appendix, we briefly describe this platform, in addition to two extension turrets that were built for visual communication, and show how it can be used to study communication in embodied agents.

2 The E-puck Robot

The e-puck is a simple 2-wheeled cylindrical robot with a diameter of $7cm$ (see Fig. 1). The base model comes equipped with 11 IR sensors (8 proximity and 3 ground sensors), a 3-axis accelerometer, 8 red LEDs with a diffusion ring, a speaker, 3 microphones, a 2D color camera facing forward, an IR remote control, and a 16-position selector switch. The e-puck's core is a dsPIC microcontroller from Microchip, which is a type of enhanced microcontroller with digital signal processing (DSP) capabilities, allowing for some powerful on-board calculations. For more complex processing, the e-puck can connect to a workstation using its built-in Bluetooth module.

One of the e-puck's main advantages is its versatility due to its extension ports. Two connectors on its surface allow the user to stack extension turrets on the main robot, which can be custom-tailored to meet a specific task. We have therefore developed specific extensions to the e-puck robot that can be used for communication. Specifically, two communication turrets were built to enable the use of visual communication: an LED turret that can light up in many colors

and an omni-directional camera that can allow the detection of lights emitted by other robots in all directions (see Fig. 1, left).

Fig. 1. Left: The e-puck robot is equipped with an omni-directional camera turret and an LED light turret used to emit blue light. It can thus be used to carry out experiments similar to that described in Chapter **??**. Right: A replicate of the experiment in Chapter **??**. Robots explore the arena containing food (bottom left) and poison (top right) objects emitting red light. Robots that have detected the food light up in blue to attract others.

3 Communication Turrets

3.1 LED Light Turret

The LED turret features 8 3-color LEDs spread out on the turret's perimeter and covered by a diffusion ring. The original LED ring built on the e-puck base robot could only light up in red. Using this turret, however, the 3 colors of each LED can be mixed together to create thousands of different colors, and are controlled by powerful integrated lighting management chips. These chips allow the e-puck to emit light patterns ranging from a simple one-color pattern to a multi-color blinking or sequential lighting pattern at varying frequencies.

3.2 Omni-directional Camera Turret

To complement the LED turret, a camera turret was developed that provides the robots with omni-directional (360°) vision. This turret features a camera pointing upward toward a custom-designed hyperbolic mirror reflecting the environment around the robot (Fig. 1, left). The mirror was designed to provide a

full 360° view around the robot, and can see up to 5° above the horizon. Using this camera, the robot can detect signals emitted by any robot in its vicinity (up to a distance of $1m$). Several algorithms have been implemented for the turret and are freely available (epu (2008)), including basic drivers for reading an image from the camera, as well as image processing algorithms.

4 Communication Experiments

The e-puck equipped with the two turrets thus represents an ideal platform to conduct communication experiments. To illustrate this point, consider the experiments described in chapter **??**. Briefly, the experimental setup consists of a foraging arena in which a food and poison source, both emitting red light, are placed in the arena and can only be distinguished at a close range through two differently-colored pieces of circular paper placed underneath them. The robots' task is to find the food source and avoid poison. They can use blue light to communicate information relevant to the task. For this experiment, two e-puck robots constantly emitting red light can be used as food and poison sources, while the other e-pucks use the LED turrets for signaling in blue, the omni-directional camera for capturing the blue light signals produced in the robots' vicinity and the red light emitted by food and poison. The distance sensors below the robot allow it to detect the color of the paper placed below the food and poison, thereby distinguishing the two sources (see Fig. 1, right).

The study described in chapter **??** was carried out with simulated s-bot robots Mondada et al. (2004), and was later verified by transferring the controllers to real s-bot robots. Compared to the e-puck, s-bot robots are larger in size, significantly more expensive and require a high level of technical maintenance. Although the s-bot boasts many more features than the e-puck, most were not used in the experiment. The e-puck hardware platform is instead open-source, easy to use and can be similarly combined with a simulation platform (available at Magnenat et al. (2007, 2005)) to replicate the experiments described in chapter **??** or to carry out similar studies. For more information, including manuals and other technical information on the e-puck platform see epu (2008).

Bibliography

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