Toward a Person-Follower Robot

Onofrio Gigliotta[12], Massimiliano Caretti[1], Solaiman Shokur[1], Stefano Nolfi[1]

[1]Institute of Cognitive Sciences and Technologies, CNR
Viale Marx, 15, 00137, Roma, Italy
[2]Dipartimento di Psicologia, Università di Palermo
Viale delle Scienze Ed. 15, 90100 Palermo, Italy
Onofrio.Gigliotta@istc.cnr.it, Massimiliano.Caretti@istc.cnr.it, Stefano.Nolfi@istc.cnr.it

Abstract

In this article we described the attempt to build a robot able to locate and follow an human target moving in a domestic environment. After a brief review of the state of the art in relative location technologies, we described our approach that aims to develop robots provided with simple and robust relative location technologies that do not require to structure the environment and on simple semi-reactive strategies that does not require the use of internal maps and the ability to self-localize. More specifically, the approach is based on a control system able to display and integrate an exploration, obstacle avoidance, and target following behavior and a relative location device based on an signal emitter (placed on the target person) and a directional sensor (placed on the mobile robot).

1 Introduction

In this article we describe the research conducted in the attempt to develop a person-follower mobile robot. Rather than structuring the environment by introducing external cameras that can allow the identification of the current position of the robot and of the target person, we decided to provide the target person with a transmitter (that broadcast infrared and/or radio signals in the environment) and the robot with a sensor able to detect the current relative direction of the target person. From the control point of view this implies that the robot should be able to display an exploratory behavior, allowing the robot to identify the source signal (when the signal cannot be detected), and an person following behavior (when the source signal is available). The robot should also be able to exhibit an effective obstacle avoidance behavior and to integrate obstacle avoidance with target following and exploration behaviors.

In section 2 we discuss current research in relative location technologies and we present the sensor-emitter device that we developed. In section 3 we describe the work carried out in the attempt to develop the control system for the robot, Finally, in section 4, we describe our plan for the future.

2 Relative Location Technologies

Existing systems that provide positioning information are often not a practical solution for mobile robotics since they typically rely upon pre-installed and calibrates environmental infrastructures. Surprisingly, indeed, research on the development of relative location systems based on infrared and/or radio sensors/emitters is a rather unexplored area. The few existing products and technologies address rather small distance range (few cm, based on short-range electromagnetic signals (Pattern et al, 2001) or rather high distance ranges (e.g. in the case of the radio products developed for tracking wildlife animals, see for example http://www.telonics.com).

The need for simple and reliable relative location devices triggered by the recent spreading of wireless technologies and ubiquitous computing, very likely will change this situation soon. Indeed, relative position information of users' portable device (e.g. laptop, mobile phones, and PDA's) can be used to enhance network connectivity and to allow automatic configuration of the association between devices (Krohn et al., 2005). For example laptops and projectors might change their interaction modes on the basis of their relative location in space thus allowing the users to manipulate the functionality of the devices by simply manipulating their physical displacement.

Moreover, relative location devices might constitutes an important prerequisite for the development of new mobile technologies for edutainment. A simple relative location device based on infrared sensors/emitters has been incorporated in the *jojo pot de colle*, a mobile toy developed by OUAPS (http://www.ouaps.com) recently commercialized in France, that aims to entertain and monitor 12 months child by following them (see Figure 1).

Finally, a new IST R&D project called RELATE, that aims to develop new relative location technologies based on infrared and ultrasound sensors-emitters, has recently being funded by the European Commission.

Figure 1. The “Yojo pot de colle”. Left: the carrot to be weared by the child. Right: the mobile toy.

After reviewing the existing technologies and related research we decided to develop an infrared sensor-emitter device based on the IR Beacon (see Figure 2) commercialized by Pololu (www.pololu.com). The emitter device, to be placed on the target person, include 4 infrared emitters (Figure 3). The receiver device, that includes four infrared receivers oriented in the four cardinal directions, computes the intensity of the received signal, and return the relative direction of the emitter (up to a distance of about 6m).

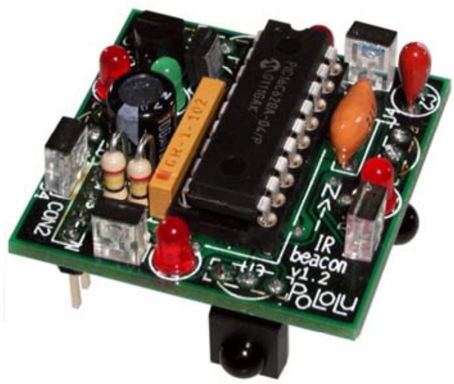

Figure 2. The Pololu IR Beacon.

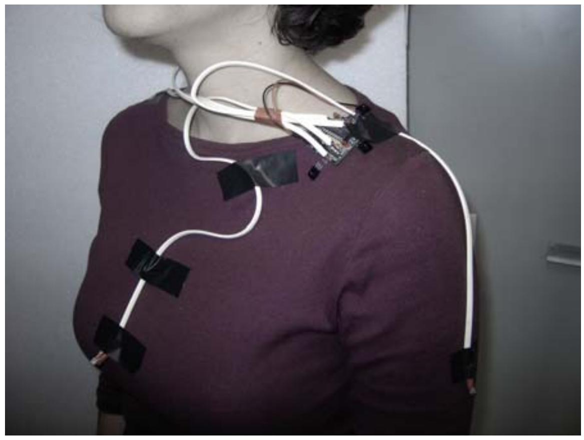

Figure 3. The transmitter device.

The receiver device was mounted on a Koala robot, a commercially available robot developed by K-Team (http://www.k-team.com/, see Figure 4). The Koala robot has three soft rubber wheels on each side. The robot moves by means of the two middle wheels that are connected to two corresponding motors and are slightly lower, while the other four wheels only provide physical support. The robot also has 16 infrared obstacles up to a distance of about 20 cm. Initial test performed on the basis of a simple evolved reactive controllers showed that the robot was indeed able to approach and follow a human target wearing the emitting device located in the range of sight.

Figure 4. The Koala robot with location device mounted on the top part.

3 Evolving a Person-Following Neural Controller

The problem of developing a control system for a person following robot can be divided into three sub-problems: (1) the problem of developing a target following behavior based on the directional information provided by the location sensor, (2) the problem of effectively integrating an approaching/following behavior with an obstacle avoidance behavior, and (3) the problem of exhibiting an effective exploration behavior when the signal from the target is not available (because the target is too far from the robot or the signal is shadowed by some obstacle). In this section we focus on the third problem. The first and the second problem have been already discussed in Bianco, Caretti & Nolfi (2002).

To achieve this goal we evolved a neural controller with a fixed architecture on the basis of standard evolutionary robotics technique (Nolfi & Floreano, 2000). The neural controllers consist of feed-forward neural network with 21 sensory neurons, 4 internal neurons, and 2 motor neurons. The first 16 sensory neurons encode the activation state of the 16 corresponding infrared sensors. The next 4 neurons binarily encode the orientation of the signal detected along the 4 cardinal directions. The last sensory neuron indicated whether the signal could or could not be detected. Finally the two motor neurons encode the desired speed of the two motors controlling the corresponding wheels. Neural controllers were evolved for the ability to explore the three indoor environments shown in Figure 5 by entering as many room as room as possible (at least once) during a fixed 'lifetime' consisting of 5000 cycles of 100ms each. Robots were tested for 5 times in different environments randomly selected from the three type shown in Figure 5. The initial position and orientation of the robot was randomly selected in each trial. The population was composed by 100 individuals, the best 20 were selected, and each selected individual was allowed to produce 5 offspring asexually (mutation rate was 4%).

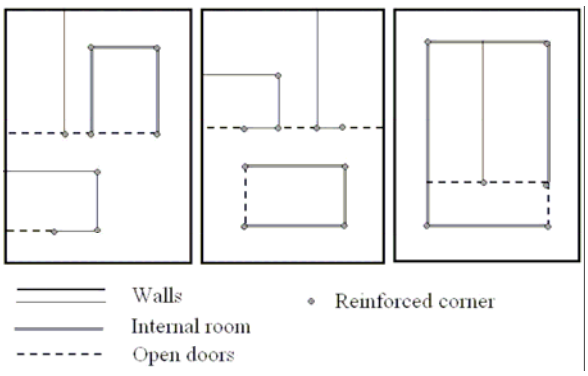

Figure 5. The three environment used to evolve the exploratory behavior.

Thee experimental setting were compared in simulation. For each experiment, we performed 10 replications (each lasting 300 generations). In the first experiment, robots were provided with simple reactive controllers (i.e. neural controllers in which the motor action produced by the robot is only based on the current sensory state and in which the robot always reacts in the same way to the same sensory state). In the second experiment, robots were provided with an additional stochastic sensory neuron (i.e. a sensory neuron with a activation value randomly selected each time step with an uniform distribution between the interval [0.0, 1.0]. In the third and last experiment, robots were provided with a modular architecture including two modules and an arbitration mechanism for switching between the two modules (for more details see Shocur [2004]).

Obtained results indicate that: (1) simple reactive controllers reach rather limited performance, (2) reactive controllers provided with the additional stochastic neuron produce poor by slightly better performance than reactive controllers, (3) robots provided with the modular architecture and able to exhibit two different forms of behavior and to switch between the two display rather good performance. In particular, systematic analysis of the obtained results and of hand-crafted variations of the evolved strategies indicate that rather effective performance can be achieved when: (a) the two modules display a right and left wall-following behaviors, and (b) the arbitration mechanisms switch between the two modules randomly with a given probability. In particular the results of the tests performed indicate that, although the time necessary to explore all rooms in all cases is very variable, robots are able to explore all rooms in 5000 time steps, on the average, in 50% of the cases.

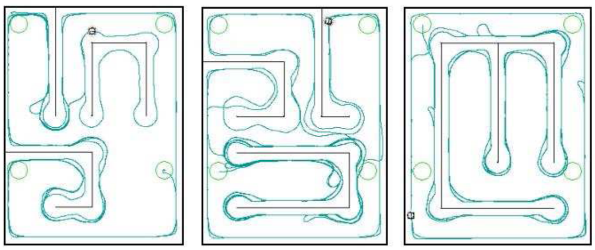

Figure 6. Typical behaviour exhibited by the robots displaying the left & right wall-following behaviours in the three test environments.

4 Discussion and Future Work

In this article we described the work done in the attempt to build a robot able to locate and follow an human target moving in a domestic environment. After a brief review of the state of the art in relative location technologies, we described our approach that aims to develop robots provided with simple and robust relative location technologies that do not require to structure the environment and on simple semi-reactive strategies that does not require the use of internal maps and the ability to self-localize. More specifically, our approach is based on a control system able to display and integrate an exploration, obstacle avoidance, and target following behaviour and a relative location device based on an signal emitter (placed on the target person) and a directional sensor system (placed on the mobile robot).

In future work we plan to:

(1) perform experiments in simulation by developing a control system able to combine the three requested behavioural capabilities: (a) target approaching and following, (b) obstacle avoidance, and (c) exploration;

(2) test the controllers evolved in simulation in the real robot;

(3) investigate the possibility to also use relative location devices based on radio or ultrasounds signals.

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