A SOCIAL ROBOTICS EXPERIMENTAL PROJECT

Jose M. Giron-Sierra, Sami Halawa, Jose R. Rodriguez-Sanchez, Santiago Alcaide[1]

Abstract *- We have four small mobile hexapods. Each hexapod has almost no brain, but can communicate via radio with a PC, using a limited set of digital messages. The hexapods know how to move, and can detect obstacles and some kind of objects. We have four PCs, one for each hexapod (so each hexapod has a helping brain). The PCs are inter-connected using the parallel port. We can assign a task for the team, for instance to explore a field. The PCs must work coordinated, exchanging messages. The development of this experimental scenario has been the subject of several projects, done by students involved in robotics and computer science. One of the aspects covered is the use of real-time operating systems, for the PCs to work together. Other aspects are related with mobile robotics and behaviors of insectoids. The general set-up has been completed recently, and a new project will start, to accomplish a task and study the results. An object-oriented simulation is also another new project, which will be validated against the experimental results. Every project must generate documentation, for others to use it. In general, the idea is to establish an interesting challenge, with obvious results. The paper presents the main educational objectives, and describes the chief parts of the experimental set-up: robots and PCs, inter-connection characteristics. Then, the paper focuses on the projects done and under way, with emphasis on the pedagogical impact.*

INTRODUCTION

Non-conventional robotics attracts the interest of students. Besides, it is an important field of research, involving many facets where creativity can be useful. Our idea is to develop a group of insectoids (hexapods) with the help of students. The work is partitioned into relatively short, feasible projects. In accomplishing the projects, students face realistic contemporary problems, and learn in a highly motivated way. The result of their work is valuable for next projects.

There is a lot of activity around biologically inspired robots. The book [1] offers a good overview of representative topics and people, with many references. Also the series of Proceedings of the International Conferences `From Animals to Animats' shows a relevant view of the field. The seminal paper [2] is a clear landmark, frequently cited. Other references of interest for our work are [3-8]. In [9] the study focuses on social structures and behaviors that emerge with several interacting robots.

The paper starts with the main concepts and objectives of our work. Then it follows a description of the laboratory system to be built. Next, the aspects of educational interest: the student projects. Finally, the conclusions, with experiences and future applications.

A GROUP OF INSECTOIDS

Our design is based on the idea of remote-brain mobile robot [10]. Even considering mobile robots with very limited functional capabilities, it usually happens that the on-board processing unit falls short. On the other hand, a small hexapod can only carry light weights (including batteries), so we cannot put much electronics. After all, it seems that a way for increasing possibilities is to use a remote-brain for each hexapod. In our case, we employ a radio link between a hexapod and a PC (figure 1). In consequence, the active subjects in our system are insectoid-PC pairs. To begin our research, we deploy four hexapods and four PCs.

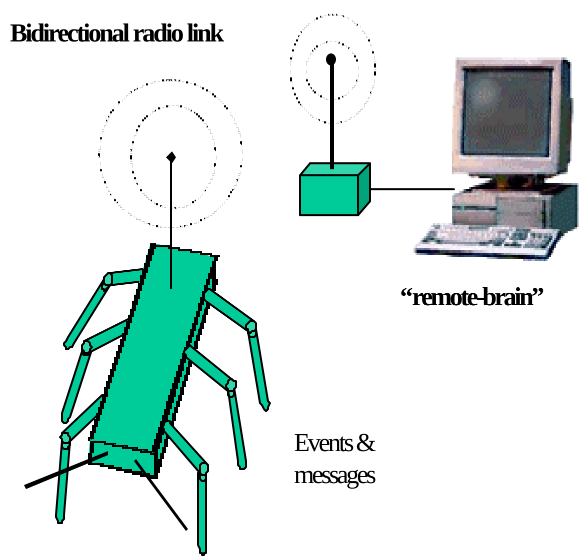

Figure 1. Radio-link between insectoid and PC.

The literature on robot groups usually considers tasks to be accomplished by the mobile robots. For instance

[1] Department of Computer Architecture and Automatic Control, Fac. Fisicas, Universidad Complutense de Madrid, Ciudad Universitaria. 28040 Madrid.Spain., Tf. 34 91 394 4387, Fax. 34 91 394 4687, e-mail: gironsi2dia.ucm.es

exploration, harvesting, garbage collection, etc. Each robot must have sensors to detect obstacles, locate landmarks, etc. In many cases, the robots are able to exchange messages with other robots.

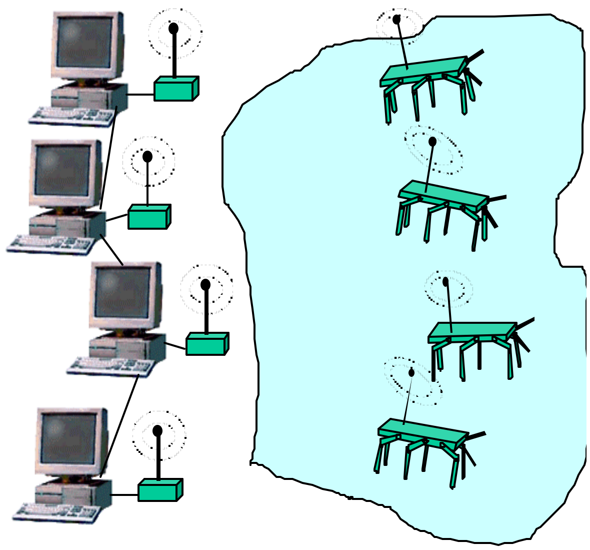

Figure 2. Laboratory scenario with 4 hexapods.

In order to allow for the exchange of messages, the PCs of our system are inter-connected. Figure 2 shows the general arrangement of the system in the laboratory.

To begin with a simple alternative, one of the PCs assumes the role of coordinator. Its chief mission is to signal the moment for each PC to talk with its insectoid. Once a PC finishes its conversation, it sends information to the coordinator. On the basis of this information, the coordinator returns instructions to rest of PCs.

Starting with these ideas, we undertake a concrete implementation. Let us describe the main parts.

IMPLEMENTATION OF THE LABORATORY SYSTEM

The important criterion for the development of the system is to keep things simple. There are many different pieces to combine, in a truly effort of system integration. So it is convenient that these pieces be simple (and non-expensive). This also refers to software. We prefer to work in C and MS-DOS, to use small size code and also for reasons of real-time operation. There will be times, after a first working prototype, for embellishments and complicated GUI environments.

For the radio links we use the radio circuits employed to open garage doors. They transmit a 12 bit code: 8 for I.D. (fixed with DIP switches), and 4 that we can use to transmit messages. Since all these circuits share the same frequencies, they can interfere. Only one conversation insectoid-PC can be permitted at any time. This is an interesting circumstance that makes recall the Ethernet related problems (and the ALOHA origins).

Instead of using invasive means, which force to open the computers to introduce new, perhaps conflictive hardware, we prefer to use the PC parallel port. It is easy to employ it for data I/O, with compact C routines. The emitter/receiver for the conversation with the hexapod is connected to this port.

The inter-connection between the four PCs is based on a shared bus of three wires. We also employ the parallel port here (there are enough pins not used by the emitter/receiver). This is a solution that implies simple programming and fast communication.

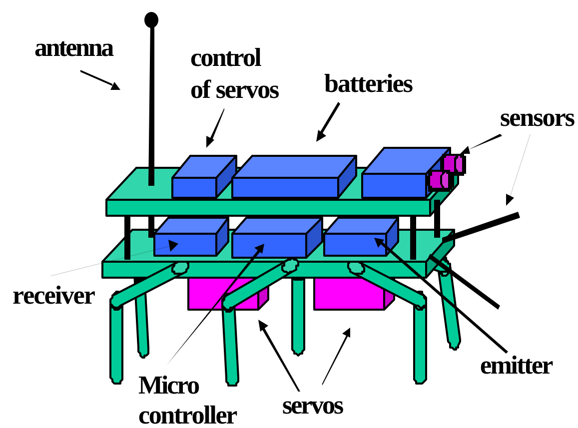

Figure 3. Main components of the hexapod.

The insectoids have six legs. They are 25 cm. long. They carry on-board a Stamp II (Parallax) microcontroller. This component has 16 pins for I/O. Each of these pins can be used for input or output. The Stamp II directly handles a special version of BASIC, with instructions for voltage measurement, PWM generation, etc. Everything is ready to serve for a quick and easy software development, especially for measurement and control applications. The programs are developed on a PC. Once the program is written, the source code can be downloaded to the Stamp II, using the PC serial port. As soon as the program is downloaded, it begins to run. In this way, the programs are tested immediately. The Stamp II keeps the program in a non-volatile rewritable memory. The program can be improved/modified at any time.

The hexapod has sensors to detect collisions against obstacles. With a pair of photo-resistors, it can direct its walking to a light. It has an emitter/receiver to communicate with its remote-brain. With rechargeable batteries, the autonomy of the insect is about two hours.

The on-board program includes a repertory of basic behaviors. Move forward or backward. Rotate left or right.

Detect obstacles. Measure light with the two "eyes". The insect walks slowly: it takes around ten seconds per step. Figure 3 shows the general distribution of the main components of the insectoid.

STUDENT PROJECTS

The development of the laboratory system is an interesting challenge for the students. The general undertaking has been organized on a divide-and- conquer way. A logical order has been established, beginning with the basic pieces. A set of projects has been proposed to the students.

All the participants get together in an initial session. The objective is to present a global view of the system to be developed, and comment some of the system possibilities. General instructions and advice are given: to document ideas and developments, to keep things simple and easy to understand. A timing schedule, with sessions for information exchanging, is established.

One of the projects has been to set up the radio communications. Software routines must be developed to handle the parallel port of the PC and some of the 16 pins of the Stamp II. A first step is to create a radio link between two PCs, through the parallel ports and emitter/receiver units. This radio link allows for the measurement of throughput and reach. A "ping-pong" program is implemented, visualizing errors in the transmission of messages. The result is that we have a 30 m. range, and the pace of 4 bit messages must not exceed two per second. Taking advantage of the experience acquired with the emitter/receiver units, a simple portable device has been built to detect the radio waves (for measurement of reach).

Another project is the communication between the four PCs. A protocol must be created for exchanging messages. Data must be sent in series of bits. A channel must be provided to manage circumstances when all PCs must stop activities and pay attention to special communications. That means to employ interruptions, using a real-time operating system. To such purpose we selected the TICS operating system. It comes with C source code. Good documentation and tutorials makes easy to learn its use. The programs employing TICS are simple and compact.

The building and programming of the hexapods is another project. The mobile platform is a commercial kit that we modified to make it stronger. We added two plastic boards to be able to include all the electronics and the batteries. The different parts are inter-connected. Small programs are developed to test walking, sensors and communications. The routines to create the repertory of insectoid behaviors are developed. Some scenarios are designed to test the correct work of the hexapod.

With the three projects just described, a first phase is completed. Now it comes a second phase, devoted to compose the system. A new project starts, focusing on the design and implementation of functions and protocols. First at all, the attention is addressed to the insectoid-PC functions. The initial scheme we consider is as follows. The hexapod walks till an event occurs: the collision with an obstacle, the finding of something of interest, the completion of n walking steps, etc. When its remote-brain, the PC, ask for news, the insectoid sends its status (walking, or stopped because an event occurs). In the case of an event, the PC answer with new instructions for the hexapod (the hexapod has a repertory of behaviors, the PC chooses one). For instance, once finished n walking steps, the PC can tell to the insectoid to advance m steps more.

A second constituent to develop concerns the conversation between PCs and the coordination of activities. Since only one radio link can be established at any time, a protocol of turns is established. Each PC waits for its turn, to connect with its insectoid. For the moment a simple protocol is considered: the coordinator assigns turns in a round-table fashion, one PC after one. This protocol also includes the coding of messages and orders. The PCs exchange information about the status of the insectoids, using messages. The orders are used for coordination. If an important event occurs, the coordinator can urgently order every PC to stop its insectoid. For this purpose, the protocol insectoid-PC must include the possibility of halting the insectoid at any time (without waiting for an event to occur).

Once the second phase is accomplished, the students have an experimental system where several alternatives can be studied. We started to exploit the system, proposing two new projects. One is devoted to a typical social robotics scenario: the robots must perform an exploration task. The coordinator gets a map of the field explored, gathering information from the insectoids through the interconnection with the other PCs. There are several objects of interest, lights (landmarks) and obstacles. In parallel with this project, the second project is an object-oriented simulation of the system. The object-oriented paradigm, from the point of view of agents with behaviors, suits naturally to the modeling of insectoids. The simulation environment must offer facilities for the study of any configuration of the field to be explored (location of landmarks, obstacles, etc.). The results of the simulation will be validated with the real performances of the experimental system.

EDUCATIONAL PERSPECTIVE

The educational context of this work pertains to our Department of Computer Architecture and Automatic Control. The students enrolled in the projects are from last courses on Digital Control and Robotics, with required experience in Electronics, Computer Networks, Programming and Operating Systems. Each team of students must work in a cooperative way.

The objective of our projects is to promote a deep study of key problems and methods. In this case, those related with distribution and cooperation (distributed computer systems, teams of robots, etc.).

All things considered, the development of the system compels to learn and exercise several important conceptual and technological aspects. The diagram of figure 4 depicts a synthesis of the main elements considered by the projects. Clearly, they fit well to the contents of the students' background and present interests (as students of Robotics and Digital Control).

Now, with the new experimental system, it is possible to study such contemporary topics as reactive behaviors, social organizations for tasks, and telerobotics.

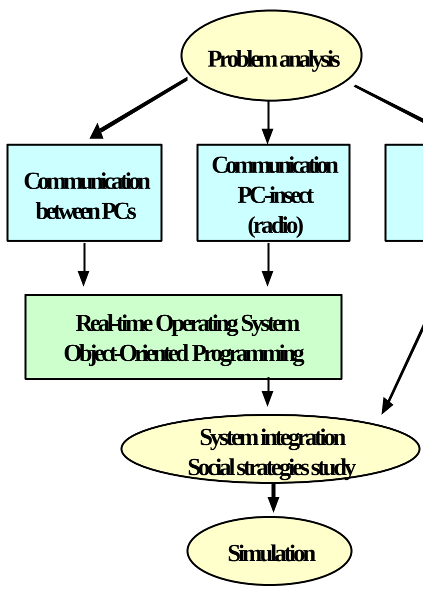

Figure 4. Educational aspects of the projects

Some time is required to achieve the projects. In general, it takes two months (6 laboratory hours per week) to finish each one. Since students tend to discuss the interesting problems during free time, and prefer to work some things at home, it is difficult to have a real measure of the complete time. For an easy management, the teams are of 2 or 3 students per project. There are final sessions where the students present, in a formal way, the results and the documentation. This material is conveniently filed for its use in subsequent projects. The results and the work done are evaluated as part of the course mark.

Conclusions

We have described the development of an experimental multiple-robot system. We adhered to a remote-brain paradigm, so the robots are insectoids connected via radio to a PC. There are four insectoids and four PCs. The insectoids are hexapods with limited intelligence. The four PCs are interconnected, so they can exchange messages and orders. The complete system is an experimental platform for education and research on social robotics.

The development itself has been the root of some student projects. These projects have attracted a lot of interest. Their educational impact has been positive in several ways. In general, projects have good pedagogical effects, as frequently commented in the literature. In our case, they add motivation to deepen on important problems and methods related to distribution, coordination and cooperation. They also fit well to the educational objectives of our Department. In addition, the nature of the development plan (combining pieces) promotes good work habits, such the collaboration between teams.

Taking advantage of the experimental system created with the projects, there are interesting problems to study in the future. For instance, other ways to coordinate messages between PCs, so the complete system will be event-driven. Also, exploit the remote-brain approach to add functional richness to the insectoid-PC pairs. This may imply other distribution of responsibilities between insectoid and PC. Of course, there are topics of social robotics that can be tackled, such hierarchies, aggressive behaviors, several insectoid states (more or less active, open for collaboration or not, etc.).

A recent new project we started is the integration of the system with Internet, for distance studies. In consequence, there will be an URL in the next future to get more information and see experiments.

The authors are open to give the pertinent details to reproduce the experiments, and to collaborate to related research.

ACKNOWLEDGMENTS

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