ADVANCES IN NATURAL LANGUAGE INTERACTION IN MOBILE ROBOTS USED FOR PRACTICE EDUCATION

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ABSTRACT

This paper presents a proposal for the development of laboratory assignments about the design and implementation of advanced interfaces for mobile robots using speech recognition. In these assignments, the main objective is the analysis of the possibilities for using speech interfaces as a complementary system for other interaction components with a mobile robot, such as artificial vision. The paper also describes how to develop introductory practical works to the analysis and implementation of intelligent dialogue for mobile robots.

KEYWORDS: Engineering Education, Artificial Intelligence, Command and Control Systems, Qualitative Reasoning, Man-Machine Interface / Communications, Man-Machine Interaction.

INTRODUCTION

The development of laboratory assignments about the design and implementation of advanced interfaces for mobile robots can be used for understanding two learning areas: mobile robots programming and natural language processing. Using this type of laboratory activities the students can also join together two technologies that have been investigated independently.

In these practices the students can apply knowledge from different subjects. On one hand, they can use knowledge about the design of interfaces using high-level languages, implementing a system which translates commands from this high-level language to the language directly executable by the mobile robot. And they can also apply knowledge about programming languages and planning for mobile robots.

The paper is organized in the following way: Section 2 describes the programming of mobile robots used in the laboratory; Section 3 describes the general techniques for natural language processing which are explained to the students; Section 4 describes the general structures of the lab assignments; and, finally, section 5 summarizes the main conclusions.

The lab assignments described in this paper are designed for post-graduate students of a Master in Advanced Robotics Engineering or Computer Science. These students should have basic knowledge and background about Robotics and programming languages for mobile robots. The course could also be very useful for PhD students who are interested in the design of advanced and intelligent interfaces for human-robot interaction/communication.

MOBILE ROBOTS AND ENVIRONMENT USED IN THE EXPERIMENTS

As the basic robot for the laboratory assignments we used the robot RugWarrior Pro developed at MIT by J. Jones and A. Flyn [1] as a practical exercise of integration of the technologies associated to the design of robots. It is a very simple educational kit based on the 8-bits microcontroller Motorota 68HC11 having a development environment that allows the concurrent programming [1], [2].

The robots are formed by the following elements (Figure 1):

- **The mechanical structure**: a diferencial mechanical scheme activated by two CC motors and sensors.

- **Controller**: The 8-bits Motorola 68HC11 microcontroller with a memory of 32K (static RAM). The robot has a microphone, an LCD screen and encoders. It has also analog and digital inputs in order to add additional sensors.

- **Programming environment (IC 3.2, Interactive C)**: IC is a programming environment of C code for the microcontroller MC68HC11. IC permits the development of the application in language derived from the C programming language.

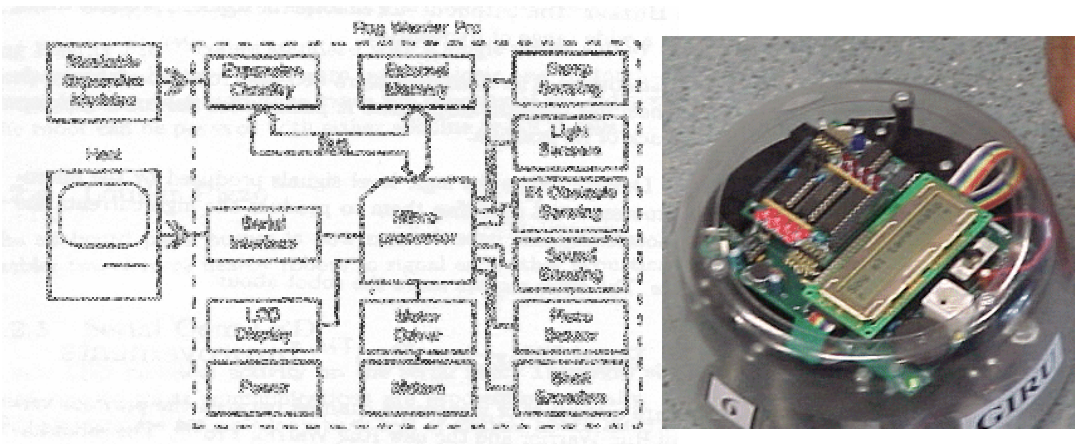

Figure 1. Block diagram of the robot Rug Warrior Pro.

NATURAL LANGUAGE PROCESSING TECHNIQUES

In this section we describe the general scheme of the natural language processing system used in our experiments. Once we have the voice transcription in an ASCII text obtained by the speech recognition module, the next phase is the interpretation of the command and its translation into an understandable language for the robot.

If the students want to make experiments using voice commands, then they need to translate the voice signal into a text. For this translation we use commercial software packages (for example, IBM Run Time Voice Engines). For a revision of speech recognition techniques see, for example, [3].

In general, there exists two approaches to perform the natural language processing: (1) *design* and (2) *learning* or *adaptation*. Using the *learning* or *adaptation* method, the system adapts itself to the syntactic and semantic restrictions of the application by examples [4]. It can be used, for example, recurrent neural networks such as RAM networks, that basically consist of an encoder that transforms the utterance into an internal analog representation, and a decoder that transforms this internal representation into a command or a program for the robot. Using this approach, the operation of the encoder and decoder is what should be learned.

In the assignments proposed in this paper we used the *design* method. This method consists on the design and implementation of a specific grammar for the application and follows three typical analysis steps: (1) *lexical* analysis; (2) *syntactic* analysis; and (3) *semantic* analysis [6], [7].

The lexical and syntactic analysis are the more algorithmic phases in the process. There are several algorithms that we can use, independently of the application. The main objective in these two phases is to obtain a tree structure that represents the syntax of the input command. Depending on the subject, the students could program directly the lexical and syntactic analyzer (parser), or they could also use an automatic tool to implement them (as, for example, yacc and lex) [5].

The next phase, *semantic analysis*, is application-dependent. In this phase we want to obtain a representation of the sentence *meaning* in order to translate it into the object language. Therefore, it is the more critical and less algorithmic phase of the design. In this case the students should also use an automatic software-generation tool in order to implement the program which translates the original command into the directly-executable program for the robot.

In Figure 2 the outline of a typical natural language processing system is shown.

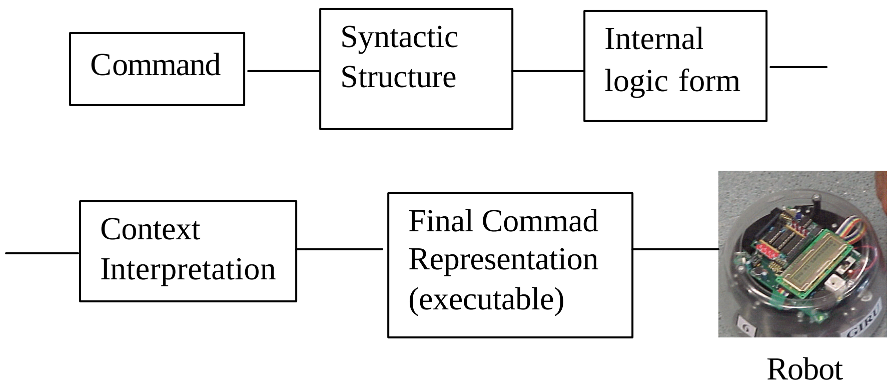

Figure 2. Natural language processing system scheme.

In the syntactic and semantic phases it is tried to obtain a meaning structure from the word sequence received from the speech module. In the case of a natural language interface to a mobile robot, this structure can be represented directly by the sequence of primitives for the robot expressed in the object language.

In most of the natural language processing systems, and in particular in a robot interface, it is necessary to carry out two additional phases to the semantic analysis: *integration* and *pragmatic analysis*. In the *integration* phase, the object coordinates and locations indicated by the operator are obtained. This task is done accessing the object database of the system. In the *pragmatic analysis* phase, the intermediate commands obtained are translated into instructions directly executables by the robot (or the instructions defined in the communication protocol with the robot).

LABORATORY ASSIGNMENTS

The main objective of the laboratory assignments proposed in this paper is the application of natural language processing for the teleoperation of mobile robots. The practices will be developed in several phases:

1. In a first phase, the teacher will establish the environment in which the mobile robots will work (typically a room with some obstacles, from which a structured map can be built, Figure 3).

Figure 3. Example of a practical environment.

2. Then, the students will study the physical specifications and characteristics of the robots that will be used in the practices ("mini" mobile robots). These characteristics include the sensors used in the robots (see section 2).

3. In the third phase the programming language directly executable by the robot will be analyzed ("low level" language).

4. Then the teacher will specify the type of commands that the robot should understand, using voice interfaces.

Before designing the language processor it is necessary to have a model on the actions that the robot is able to perform. These possible actions will depend on the capabilities of the robot's movement and the installed sensors. The robots used in the assignments have a basic programming library which includes functions for the basic actions that it can perform. These functions are implemented in a programming language which is very similar to the C programming language (called IC, Interactive C).

The language directly executable by the robot is not usually the most appropriate to use in the natural language processing algorithms. For this reason, for the assignments proposed in this paper, the students should design an intermediate language between the high level natural language and the language executable by the robot. The teacher can give to the students a simple model of intermediate language that can be used as a starting point for the final design.

For the design of an initial intermediate language we consider that the robots have only one type of sensors: contact sensors (bumpers). In a later phase of the design, the students can extend the model of the robot in order to consider other capabilities (for example, proximity sensors or an artificial vision system). The robot knows a map of the fixed or semi-fixed objects which exist in the environment. This way, the students must design a simple database with two differentiated parts: the static part, constituted by the elements that do not usually move from their location (the map mentioned previously) and another dynamic part, formed by the elements which usually move from its initial location.

The representation of the areas of interest for the navigation of the robot is made using definitions of geometric areas in two dimensions. A geometric area is a polygonal region of the robot's working environment. They will be used to represent two types of information: The objects of the environment and other two-dimensional regions of interest. These areas are also used to represent any bidimensional region which the robot needs to execute commands expressed in natural language. Figure 4 shows some representations of these areas, with some references in natural languages to them.

The geometric areas will also be used to represent any two-dimensional region that is useful or necessary to execute the commands expressed in natural language. In Figure 4 some representations of geometric places can be observed, together with some references in natural language to the same ones.

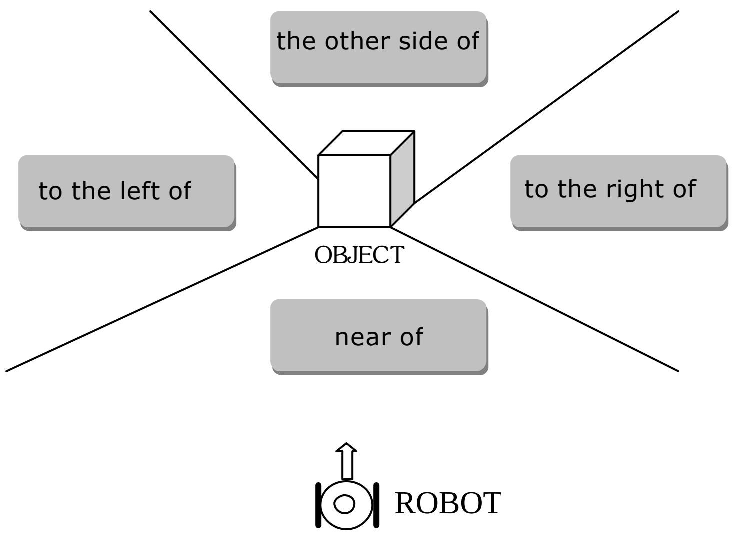

Figure 4. Some geometric areas of interest defined for an object.

Consider, for example, the following simple command: "Go to to the table". the intention of the user that emits this command is evident: the robot should go closer to the table (until a preset distance in the system is reached, associated to the action verb "*to go towards*" or "*to go to*"). According to a simple intermediate language, the translation (`T()`) of this command is very simple:

```
T("Go to the table") =

AproxRegion(GetGeometricArea(table, -, room), v)
```

where the function `GetGeometricArea(table, -, room)` gets the geometric area which enclose the table, and it can be used as a region to represent the table. The first parameter is the static or dynamic object in the environment, the second is the distance that the robot must go near the object (if this parameter is not specified, then a preset and small distance is used), and the parameter `room` is the room where the table is located.

CONCLUSIONS

The use of small mobile robots is a challenge for Engineering students which allows to motivate them in some assignments whose objective is to assimilate the fundamental concepts of programming a robot in a high-level language. These assignments assume an important background for the student which includes programming aspects, Automatic Control, Artificial Intelligence, etc.

To design a translation process from a high-level language (close to spoken language), the students need to know exactly the low-level tasks that the robot must perform to achieve the objective of the command. This gives an opportunity to practice the theoretical konowledge about robot programming and behaviour.

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