A PERCEPTION-BASED APPROACH TOWARD ROBOT CONTROL BY NATURAL LANGUAGE

MASOUD GHAFFARI
Center for Robotics Research
University of Cincinnati
Cincinnati, Ohio

SOUMA M. ALHAJ ALI
Industrial Engineering Department
Hashemite University
Zerka, Jordan

ERNEST L. HALL
Center for Robotics Research
University of Cincinnati
Cincinnati, Ohio

ABSTRACT

Mobile robot navigation is an active area of research with many potential military and civilian applications. Yet, there are many unsolved problems which probably either need a breakthrough in the current theories or a completely new approach for the solution. Extraordinary abilities of humans in doing these tasks without any measurement have inspired many researchers. One of these abilities is the ability of processing words instead of numbers. The purpose of this paper is to survey different applications of natural language for robot control and to propose a perception-based model.

INTRODUCTION

The problem of autonomous navigation in unknown environments is very difficult, and calls for sophisticated sensing strategies and control architectures (Oriolo, Ulivi, & Vendittelli, 1996). Most of methods have been basically realized by combining algorithms acquired by human. How can we realize the capability of acquiring algorithms automatically like the human brain? This problem is very difficult to solve (Kubota, Morioka, Kojima, & Fukuda, 2001).

Artificial intelligence, psychology, biology, neuroscience, linguistics, and many other fields try to get insights into what is called human intelligence. This includes being able to model the world, plan and predict events, learn, make decisions, as well as many other abilities.

In many real world applications it is not possible to have previous data about the course and predict the dynamic environment. One example is driving a car in a city. That is a place that human perception shows its extra ordinary capability.

The classical AI methodology has two important assumptions: the ability to represent hierarchical structure by abstraction, and the use of “strong” knowledge that utilizes explicit representational assertions about the world (Boden, 1995). The assumption was that knowledge and knowledge representation are central to intelligence, and that robotics was no exception.

Perhaps these were the result of studying human-level intelligence and not lower live forms of creatures.

LITERATURE REVIEW

ROBOT (Harris, 1977) and SHRDLU (Winograd, 1972) were among the first attempts for natural language communication with robots (Harris, 1977; Romano, Camacho, Ortega, & Bonilla, 2000; Winograd, 1972). However, both of them used simulated robots and not real ones. SHRDLU allows the user to command a robot that moves in a world made of blocks. Selfridge and Vannoy (1986) present a natural language interface to an assembly robot which allows the user to talk with the system in order to recognize the shapes of objects and put them together to make a more complex component. The knowledge base consists of a set of if-then rules (Selfridge & Vannoy, 1986).

Some natural language interfaces include both written and spoken forms of natural language. The users of SAM (Brwon et al., 1992) can use a telephone or a keyboard to command the robot. The robot was a manipulator arm with six axes and a gripper. The user can introduce a description of the objects. This description will later be used to command the robot to perform actions with them (Brown, Buntschuh, & Wilpon, 1992; Romano et al., 2000).

Most of these robots can run a very specific and limited plan. This is a common feature in the majority of systems designed for natural language communication with robots (Romano et al., 2000).

Uncertainty representation is an important point to consider. Initial works mainly focused on probabilistic methods where Bayesian probabilities were used to represent partial beliefs (Elfes, 1987; Gasos & Rosetti, 1999). These approaches cannot distinguish between lack of information and uncertain information, and a probability assignment to a proposition automatically implies an assignment also to its negation (Tirumalai, Schunck, & Jain, 1995). Dempster-Shafer used the theory of evidential reasoning (Kim & Swain, 1995) and fuzzy logic have been used as alternatives (Gasos & Rosetti, 1999; Saffiotti & Wesley, 1996).

Fuzzy logic based approaches uses different types of behavior using fuzzy reasoning rather than simply inhibiting some types of behavior according to an assigned priority. As a result, unstable oscillations between different types of behavior can be avoided (Li, Ma, & Wahl, 1997).

HUMAN PERCEPTION

Perception is the name given for the process of the organization, interpretation and the explanation of the data reaches to the brain from the sense organs. The data reaching at the sense organs have no importance without perception. The senses have to be perceived, in other words explained. We can only decide what kind of a reaction we are going to give to the senses only after perception.

Perception is a vital part of human reasoning. Human do a variety of physical and mental tasks without any measurements and computations. Some examples of these activities are driving in traffic, parking a car, cooking a meal, playing an instrument and summarizing a story. In fact, the capability to perform these tasks is based on the brain's ability to manipulate perceptions, perceptions of time, distance, force, direction, speed, shape, color, likelihood, intent, truth and other attributes of physical and mental objects (Zadeh, 1999).

The literature on perception is huge, including thousands of papers and books in the areas of psychology, linguistics, philosophy, brain science, and many others (Carruthers & Chamberlain, 2000). And yet, what is not in existence is a theory in which perceptions are treated as objects of computation. Such a theory is needed to make it possible to conceive, design, and construct systems which have a much higher machine intelligence than those we have today (Zadeh, 1999).

APPLICATIONS OF NATURAL LANGUAGE CONTROL

In practical products, applications of natural language perception-based control might be implemented differently. One application might be object identification. Range sensors such as laser, ultrasonic, and stereovision, the most commonly used sensors in robot navigation, only provide information about the existence of objects in some given positions of space. Many applications require identifying the type of objects that have been detected to make the appropriate decision by the robot, considering the fact that the object identification problem has not been solved for many real world situations (Gasos, 2001).

For example an unmanned combat vehicle may face a variety of environments. If the object recognition algorithm tries to match the description of the detected object with all possible objects, the search would be huge and probably unpractical. But, if a user describes the more probable objects that might be found in a certain mission, object identification would be much easier.

Natural language also can be used for industrial robot programming especially when users are inexperienced and don't know about computer programming. It can replace the current teach pending modules which still use a keyboard interface. Another potential application of natural language perception-based control is in Ergonomics.

Ergonomics studies the human-machine interaction and tries to find a more user friendly interface for man machine communication. Human made systems are getting more complex and sophisticated everyday. At the same time human operators have to interact to and control these systems. They get information from the system status and they perform proper actions. It is possible to reduce complexity of interaction by designing automated systems and by designing an adequate interface between the operator and the system. Design of a friendly interface which decreases complexity of interaction and allows the operators to act in a simple and quick way in every kind of situation is important (Romano et al., 2000).

Probably it is not unrealistic to predict a time that design software packages like AutoCAD™ are able to design modules by recognizing the verbal description of system from the designer. Combination of such a system with the traditional interfaces could change the human design's ability tremendously. The software industry already is moving in that direction. Now, there are voice recognition word processors and in many packages menu commands can be run by voice.

PROPOSED FRAMEWORK

Most of research on verbal communication with robots has mainly focused on issuing commands, like activating pre-programmed procedures using a limited vocabulary (Lauria, Bugmanna, Kyriacou, & Klein, 2002). They directly convert the voice commands to measurement without computing on perceptions. The focus of this approach is on mimicking human perception and some degree of computation on perception.

Information which is conveyed by propositions drawn from a natural language will be said to be perception-based (Zadeh, 2002). Natural language perception-based control (NLPC) can be defined as "*perceiving information about the dynamic environment by interpreting the natural language and reacting accordingly*".

In the NLPC, perceptions are not dealt with directly. Instead, NLPC deals with the descriptions of perceptions expressed in the natural language. Therefore, propositions in a natural language play the role of surrogates of perceptions. In this way, manipulation of perceptions is reduced to a familiar process, manipulation of propositions expressed in a natural language (Zadeh, 1999). Table 1 compares measurement-based and perception-based information.

Table 1. Comparison of measurement and perception-based information

Information	**Data**	**Example**
Measurement-based	Numerical	There is a obstacle 20.2 feet away
Perception-based	Linguistic	There is a ramp in front

The problem is how to compute on perceptions and use it for robot control. To be realistic, the proposed framework applies some assumptions to restrict the scope of model.

- Application of computing theory of perceptions in is limited to the robot control.
- Natural language processing is limited to simple propositions related to the robot navigation.
- The robot will work on the semi-supervised mode by receiving the feedback from the environment. Full autonomous mode of work, which includes replacing of the operator by sensory systems, is not in the domain of this research.
- Less precision, which is an intrinsic part of perception, in exchange to the lower cost and complexity of sensory system, is accepted.

An experiment of proposed framework was implemented and tested by the authors (Ghaffari et al., 2004). The robot control was implemented in two phases. The first phase is the instructional mode. The commands was given to the robot and robot followed the instructions based what operator perceives. Table 2 shows some examples of these commands.

The second mode is the declarative mode. In this mode the environment was described to the robot with simple propositions. The robot should make its movement decisions based on what is described to it. Propositions are limited to what is expected in the Intelligent Ground Vehicle Competition (IGVC) course. Table 3 gives an idea about some of these propositions.

Table 2. Example of instructional control commands

What	Where	How much
MOVE	LEFT	A LITTLE
MOVE	FORWARD	UNTIL SEE OBSTACLE/LINE DISAPEAR
GO TO	OBSTACLE	UNTIL VERY CLOSE/CLOSE
FOLLOW	KNOWN ROUTE	UNTIL it is DEFFERNT
LOOK	from RIGHT CAMERA	UNTIL SEE A LINE/OBSTACLE
CONTINUE	in AUTOMODE	
STOP		

What makes these two modes of control different is different between traditional language based robot control and the perception based control. The first mode is based on issuing commands. In this case it is not difficult to covert voice commands to computer instructions. In contrast, the second mode of control calls for more sophisticated algorithms. This mode is closer to human communication and it is a place that perception-based control shows its advantages.

Table 3. Examples of propositions in the declarative mode

Proposition	Possible action
There is an obstacle in the front left	Move a little bit to right
Left line is disappearing	Switch to the right camera for line following
The obstacle is very close in front	Make a big turn
There is a obstacle in front close to the left line	Turn to right and then left

MODEL VALIDATION

The IGVC course was used as a test bed for model validation. In the navigation challenge of this contest there are white lines to follow, which sometimes disappear, and barrels to avoid. This course declared to the system by an operator and the robot was supposed to navigate through the path.

CONCLUSIONS

New efforts have been made that pay more attention to computation of words, and perceptions carried out by natural language. Among many disciplines who study human brain abilities probably fuzzy logic and its new trend, computational theory of perceptions, have closer ties to engineering and practical applications. This research provided a survey of current technology and a framework for perception-based natural language control of robots. Further description and design details of the test robot is explained in (Ghaffari et al., 2004).

REFERENCES

Boden, M., 1995, "AI's Half-Century," *AI Magazine,* Vol. 16, 2, pp. 69-99.

Brown, M. K., Buntschuh, B. M., & Wilpon, J. G. ,1992, "A perceptive spoken language understanding robot," *IEEE Transactions on Systems, Man and Cybernetics*, Vol. 22, 6, pp. 1390-1402.

Carruthers, P., & Chamberlain, A., 2000, "Evolution and the human mind, modularity, language and meta-cognition," Cambridge: Cambridge University.

Elfes, A., 1987, "Sonar-based real world mapping and navigation," *IEEE Journal of Robotics and Automation*, Vol. 3, pp. 249-265.

Gasos, J., 2001, "Integrating linguistic descriptions and sensor observations for the navigation of autonomous robots," In D. Driankov & A. Saffiotti (Eds.), *Fuzzy logic Techniques for autonomous vehicle navigation,* Vol. 61, pp. 313-339. New York: Physica-Verlag.

Gasos, J., & Rosetti, A., 1999, "Uncertainty representation for mobile robots: Perception, modeling and navigation in unknown environments," *Fuzzy Sets and System,* Vol. 107, pp. 1-24.

Ghaffari, M., Alhaj Ali, S. M., Murthy, V., Liao, X., Gaylor, J., & Hall, E. L., 2004, "Design of an Unmanned Ground Vehicle, Bearcat III, Theory and Practice," *Journal of Robotic Systems,* Vol. 21, 9.

Harris, L. R. ,1977, "ROBOT: a high performance natural language processor for data base query," *ACM SIGART Newsletter,* Vol. 61, pp. 39-40.

Kim, H., & Swain, P., 1995, "Evidential reasoning approach to multi source data classification in remote sensing," *IEEE Transactions on Systems, Man and Cybernetics,* Vol. 25, 8, pp. 1257-1265.

Kubota, N., Morioka, T., Kojima, F., & Fukuda, T., 2001, "Learning of mobile robots using perception-based genetic algorithm," *Measurement*, Vol. 29, pp. 237-248.

Lauria, S., Bugmanna, G., Kyriacou, T., & Klein, E., 2002, "Mobile robot programming using natural language," *Robotics and Autonomous Systems*, Vol. 38, 171-181.

Li, W., Ma, C., Wahl, F. M.,1997, "A neuro-fuzzy system architecture for behavior-based control of a mobile robot in unknown environments," *Fuzzy Sets and System,* Vol. 87, pp. 133-140.

Oriolo, G., Ulivi, G., & Vendittelli, M., 1996, "Fuzzy Maps: A New Tool for Mobile Robot Perception and Planning," *Journal of Robotic Systems,* Vol. 14, 3, pp. 179-197.

Romano, J. M. G., Camacho, E. F., Ortega, J. G., & Bonilla, M. T. , 2000, "A generic natural language interface for task planning application to a mobile robot," *Control Engineering Practice,* Vol. 8, pp. 1119-1133.

Saffiotti, A., Wesley, L., 1996, "Perception-based self localization using fuzzy locations," In L. Dorst (Ed.), *Reasoning with Uncertainty in Robotics, Lecture Notes in Artificial Intelligence,* pp. 368-385, Berlin: Springer.

Selfridge, M., Vannoy, W. , 1986, "A natural language interface to a robot assembly system," *IEEE Journal of Robotics and Automation,* Vol. 2, 3, pp. 167-171.

Tirumalai, A., Schunck, B., Jain, R., 1995, "Evidential reasoning for building environment maps," *IEEE Transactions on Systems, Man and Cybernetics,* Vol. 25,1, pp. 10-20.

Winograd, T., 1972, *Understanding natural language*. New York: Academic Press.

Zadeh, L. A., 1999, *A new direction in fuzzy logic-toward automation of reasoning with perceptions.* presented at the Fuzzy Systems, IEEE International.

Zadeh, L. A., 2002, "Toward a perception-based theory of probabilistic reasoning with imprecise probabilities," *Journal of Statistical Planning and Inference,* Vol. 105, pp. 233-264.