LEARNING MOBILE ROBOTS

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Abstract: *In this paper, an up-to-date review is presented of different approaches to the vast field of robot learning. The objective of this paper is to make a robust systematization of knowledge in this area, while focusing on a simple proposed model. Various kinds of learning methods are listed, such as neural networks, empiric learning, genetic algorithms or statistical learning, together with their strong and weak points. Furthermore, aspects are analyzed that make learning subject for mobile robots, while focusing on the most suitable methods for the Powerbot Mobile Robot platform. A model based on the way in which an autonomous mobile robot can use the World Wide Web to determine environment parameters is detailed. Research issues are listed in the last section.*

Key words: *machine learning, cognition, neural networks, AI.*

1. Introduction

Machine learning has become one of the major fields in computer science. Machine learning can be found in both desktop and heavy industry applications, but in the later it usually appears under the aspect of robot learning.

Learning covers such a broad range of processes that it is difficult to define it precisely. Machine learning usually refers to the changes in systems that perform tasks associated with artificial intelligence (AI) [9]. Such tasks involve recognition, diagnosis, planning, prediction, robot control and others. By observing the interaction between a robot with innate behavior and a robot with learning capabilities, the scientist community reasoned that the second type of robot is able to learn how to modify its actions in a way that improves its performance. The resulted changes might be either enhancements to already performing systems or synthesis of new types of behavior [8].

But things are not always quantifiable. As many parameters as one can implement in an algorithm, there will always remain a part outside the robot's world as the biological learning differs from the logical learning.

An algorithm with more parameters will probably be ranked higher than an equally good algorithm with fewer parameters, but when adding more variables, it is difficult to say which pieces of information contribute to the success and in what degree.

Parameters are one of the first things that robots can ameliorate. Parameter tuning can help the robot to be more efficient (i.e. walk faster, better language understanding, better vision). For example, there are a lot of walking parameters that can be modified for achieving better results (for a legged robot): front locus, rear locus, locus length, locus skew multiplier, height of front of body, height of rear of body, foot travel time, fraction of time foot is on ground and much more [10].

Another thing that robots can asses is the geometry of environment. The Simultaneous

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Localization and Mapping (SLAM) algorithm is one of the most featured learning techniques. SLAM may analyze many aspects based on probabilistic approaches that usually give the best path between starting point and finish. Various sensors are used for mapping the environment, from sonar to laser rangefinder or visual landmarks.

Maybe the most interesting approach, the behavior learning is also the one with the most applicability.

2. Why Learning?

One can ask why we can't just program the robot to do specific tasks and to perform as desired. The first reason we would prefer a robot with learning capabilities is the large number of situations an autonomous entity must deal with. Certain characteristics of the working environment might not be completely known at the time of design. Robot learning methods can be used for improvement of existing behaviors and environment data assessment after the robot is manufactured. Environments can change too. In order to minimize the need of redesign, it is feasible to build robots that can learn.

Large amounts of data can blur the relationships between important items. Using a good reasoning system that improves itself with the gained experience, the robot can better distinguish between targets. The amount of knowledge available for certain tasks might be too large for explicit encoding by humans. By using machine learning, robots can gain knowledge gradually, achieving better and lager sets of correlations that humans could write down. Learning is essential for a flexible structure because it is minimizing the redesign costs.

If we are planning to gather information from an overloaded semantic field like the Internet, it matters to have a flexible structure, a program that can "learn".

3. Web Data for Mobile Robots

The Internet has known a rapid growth and seems to be one of the greatest achievements of humanity. The most important characteristic of the World Wide Web is the fast access to almost unlimited bits of information. This resource can represent in future the basis of any artificial intelligence system. The main contributors in this field are search engines. Assuring fast response and relevant results has been the main area of interest for companies like Google or Yahoo. These were made possible using advanced technologies and intense semantic studies, given the fact that at the base of the Internet lays the written word. In the struggle for providing a list of resources for any possible query, search engines have developed powerful sorting algorithms [14]. Just to give a brief overview, over 100 changes are made every day by Google's engineers to its sorting algorithms. Google uses statistical learning for many of its services (i.e. Google Translate).

When engaging into a web mining process (without using search engines), it is very important to have advanced tools for information retrieval. There are two different approaches to the problem: the agent-based approach and the database approach. While the first relies on pre-defined domain information, some sort of filters or on hard coded models, the later focuses on organizing semi-structured data from web into more structured collections, using database querying mechanisms [1]. Although with a fair medium number of results the database approach is more attractive, when computing with large amounts of data, the only feasible approach is agent-based.

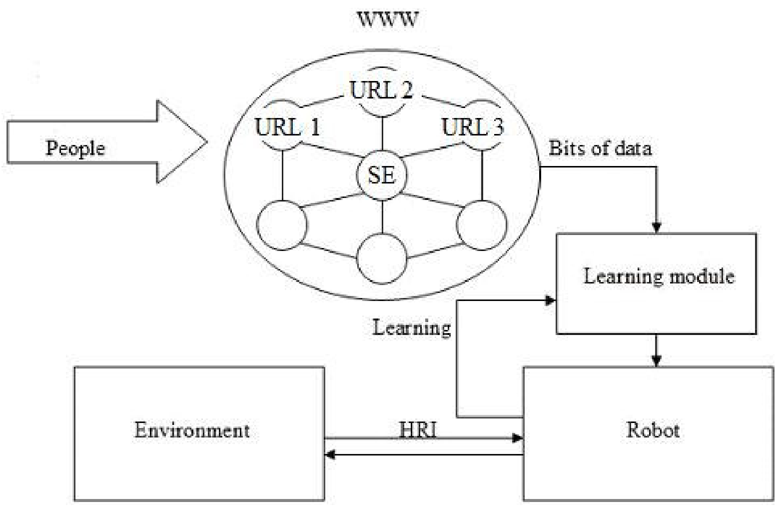

Fig. 1. *Web-based learning paradigm for robots*

Using mostly image search and vision algorithms together with a neural network learning system, a robot can scan the environment and extract concepts which correspond to acquired images from the Internet. This approach has been presented in Figure 1. Notice that the search engine (SE) is viewed as a core node and the Universal Resource Locators (URL 1, URL 2 and so on) are viewed as leaf nodes.

A contest based on this is held every year. Participants combine state-of-the-art vision with image understanding and automatic acquisition of knowledge from large unstructured databases of images algorithms in order to win the first prize [15].

The last year's winner used, besides image search, images taken directly from vendor websites such as Walmart. The main advantage is that images from these sites have higher quality and are more accurately labeled than those obtained from generic image search. Vendor sites also contain additional data such as size, weight and semantic hierarchical descriptions. Moreover, the images provide a mixture of clean product shots and examples of the product in use, unlike in casual search engine results [13].

4. Machine Learning Methods

An interesting yet demanding issue that should be carefully analyzed when building learning attributes for machines is the correlation between the intelligence attribute and learning process in general. Some studies argue that these two concepts are disjunctive while others affirm that learning presumes intelligence and, therefore, the class of intelligent entities is included in the class of the entities with general learning capabilities [6]. Choosing sides could have a large impact on the final design of the robot. While in the first case there is a need of building specialized learning algorithms, in the second case, researchers are focusing their attention on modeling intelligence in a neat manner, indirectly affecting the learning approach [7], [16].

When evaluating a learning method, a few key issues are considered. One of them is accuracy. Accuracy is usually represented by the proportion of correct classifications, although some errors are more serious than others. Speed is another one. In some circumstances, the speed of the method is a major issue (i.e. in a Human Robot Interaction - HRI).

Classifier importance is also essential in the evaluating process. A classifier that is less accurate may be preferred over one that is more accurate but much slower in testing. In the case of HRI, it is very important that the robot's behavior to be as comprehensible as possible, so comprehensibility plays a role too.

Speed may sometimes be mistaken with the time necessary to learn a new rule, although the later refers to software internal changes while the first refers to the actual reaction time of the robot.

Having the above scales in mind, it can now be shown some of the most used approaches. There are three main historical directions of research in machine learning field: statistical learning, empiric learning and neural networks. All of them attempt to derive procedures that would be able to equal, if not exceed, human decision-maker's behavior, to handle a wide variety of problems and, given enough data, to be extremely general and to be used with proven success [8].

While recent research in neural networks and statistical learning has focused mostly on learning from finite data sets without stringent constraints on computational efficiency, learning for autonomous robots requires a different setting, characterized by the need for real-time learning performance from an essentially infinite stream of incrementally arriving data [11]. In most cases, an immediate response is required as speed is the main point of interest. Thus it is recommended to implement highly optimized algorithms.

Statistical learning is useful because there are many uncertainties in robot's environment, its behavior when facing with new situations, its reaction time and many others, thus solutions have to be data-driven. Statistical approaches are generally characterized by having an explicit underlying probability model, which provides a good accuracy.

The empiric learning generally treats automatic computing procedures based on logical or binary operations, learning a task from a series of examples. This presumes mainly decision-tree approaches, in which classification results from a sequence of logical steps. Empiric learning aims to generate classifying expressions that can be easily understood by the human.

Neural networks appeared as reproductions of human brain and they are one of the most powerful techniques used to emulate the learning function. To win the challenge of reproducing intelligence itself, neural networks were based on layers of interconnected nodes, each node producing a non-linear function of its input. A neural network represents a very complex set of interdependencies which may incorporate any degree of nonlinearity, allowing very general functions to be modeled. It has been argued that neural networks mirror to a certain extent the behavior of the networks of neurons in the brain [5]. Given enough training data, neural networks make a good compromise between speed and accuracy, also scoring for comprehensibility and time to learn parameters.

Considering the input data type as a classification parameter, different classifications to robot learning can be made. The learning process can be categorized into supervised learning and unsupervised learning. In supervised learning, for example, the values of a function F for a large training set with m samples are known, and the assumption made is that if a hypothesis h that is closely to F can be found, h would be a good guess for F on all the training set. As a geometrical example a simple curve-fitting case is shown in Figure 2 (m = 4, after we choose h, we concur that $h = F$).

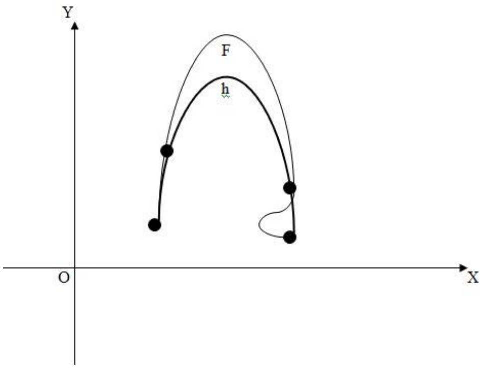

Fig. 2. *Curve-fitting through 4 points*

In unsupervised learning, a training set of vectors is given from the start. The problem in this case lays into grouping the subsets in groups with similarities. Unsupervised learning has applications in taxonomic problems in which it is desired to invent ways to classify data into meaningful classes.

Other learning techniques rely on evolutionary models. As in nature, besides individuals that learn to perform better, species evolve too. The distinction between evolving and learning can be blurred in computer learning field. Certain aspects of biological evolution have been proposed as learning methods to improve performance of autonomous robots.

Genetic algorithms (GA) try to find solutions to problems by generating candidate solutions from the space of all solutions and testing the performance of the candidates. Depending on the difficulty of the problem, GA chooses a certain population size. If the number is too small, the solutions will be inaccurate. If the number is too large, unnecessary resources will be spent and the reaction time will be much higher. Instead of choosing some random number, some techniques have been developed to adjust the size of the population of candidates during this phase [3-5], [8].

5. Suitable Learning Methods for Mobile Robotics

Not all learning algorithms are suitable for mobile robots. Most of the times, mobile robots have to process information in real time in order to interact with their work environment. In the following lines, we focus our attention on a mobile robot called Powerbot. Powerbot is designed by Active Media as a research platform. It has a robust shell, a maneuverable wheel structure and a great sensorial system. It has 28 sonar sensors displayed in front and in the rear, a laser rangefinder and a good pan tilt camera. Powerbot has also mounted a mechanical arm with 6 joints for interaction with the environment, contains an embedded computer and also a wireless receiver (see Figure 3).

Fig. 3. *Powerbot with arm* [12]

Using sonar and laser sensors, SLAM algorithms have been implemented for mapping the environment. Using the camera and the internal computer for processing images, vision capabilities can be added. This kind of approach is called Sensor Fusion. Sensor Fusion solves the problem of integrating perceptual information from all sensorial systems into a coherent description of the world [2].

6. Conclusions

There are still many issues opened to research in the field of robotic learning. When building learning capabilities for robots, researchers should have in mind the tasks that need to be satisfied upon completion. For a robot that interacts within a fast changing environment, it is mandatory to use learning behaviors in order to adapt itself and reach its objectives. The approaches should take into consideration parameters like accuracy, speed, time of learning or comprehension.

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