Evaluation of Soft Computing Methods in Robotics

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Abstract

This research Paper focus on different soft computing techniques used in robotics domain. Soft computing is an emerging approach to computing that gives the remarkable ability of the human mind to argue and learn in the atmosphere of uncertainty and distrust. As soft computing deals with development of approximate models in finding solutions to real world problems, it is considered as one of the emerging area of research in all fields of engineering and sciences. Because of rapid development in mechanization, vast research has also been carried out by the researchers in the field of robotics for the development of robots in various applications such as industry, medical, rehabilitation, agriculture, military etc. to assist human being.

Keywords*:* Robotics, Fuzzy Logic, Neural network, soft computing, genetic algorithm.

1. Introduction

The rapid development in intelligent robotics in twenty-first century, made robotics application possible in the areas where it was not possible before. In many robotic applications, such as autonomous navigation in unstructured environments, it is difficult to obtain a precise mathematical model of the robot's interaction with its environment. Even if the dynamics of the robot itself can be described analytically, the environment and its interaction with the robot through sensors and actuators are difficult to capture. The lack of precise and complete knowledge about the environment limits the applicability of conventional control system design to the field of robotics. What is needed are intelligent control and decision making systems with the ability to reason under unpredictability and to learn from experience. It is unrealistic to think that any learning algorithm is able to learn a complex robotic task, in reasonable learning time starting from scratch without prior knowledge about the task. The situation is similar to software design in which the design process is constrained by the three mutually conflicting constraints cost, time and quality. Optimization of one or two of the objectives, often results in a sacrifice on the third objective. In robot learning the three conflicting objectives are complexity of the task, number of training examples and prior knowledge. Learning a complex behavior in an unstructured environment without prior knowledge requires a prohibitively long exploration and training phase and therefore creates a serious bottleneck to realistic robotic applications. .

2. Fuzzy & Expert System Techniques in Robot System

Fuzzy Logic FL and Expert System ES are well established as useful technologies that complement each other in powerful hybrid system. Hybrid intelligent systems are now part of the repertoire of computer systems developers and important research mechanisms in the study of Artificial Intelligent. The integration of ES and FL has proven to be a way to develop useful real-world applications, and hybrid systems involving robust adaptations. In order to reach a goal, learning vehicles rely on the interaction with their environment to extract information. ES and FL have been recently recognized to improve the learning and adaptation where information is inaccurate, uncertain and imprecise. Particularly, the use of this integration (FL and ES) is necessary to bring Intelligent Autonomous Vehicle (IAV) behavior near the human one in recognition, learning, decision-making, and action. Thus, several integrations of FL and ES based navigation approaches have been developed. The interest in FL_ES aims to understand principles of the human thinking and to build machines that are able to perform complex tasks requiring massively parallel computation. Essentially, this approach deals with cognitive tasks such as learning, adaptation, generalization and optimization.

Fuzzy Logic*:* Fuzzy models can obviously be made to work very well indeed. The big advantage of a fuzzy model is that it is relatively simple to construct and is in itself a simple structure. It does not require the modeler to have a deep mathematical insight, but relies more on experience of the process. Its greatest value must be, therefore, in those areas where such qualitative process knowledge is predominant and essential for understanding. The theory has shown that the fuzzy models can be successfully constructed; the overall concept needs a considerably more detailed investigation before its true worth can be evaluated. . [3, 6, 7].

Expert System*:* An ES is a computer program that functions, is in a narrow domain, dealing with specialized knowledge, generally possessed by human experts. ES is able to draw conclusions without seeing all possible information and capable of directing the acquisition of new information in an efficient manner.

3. Neuro-fuzzy Techniques in Robot System

From a historic perspective, neuro-fuzzy systems became the first representative of hybridization in soft computing. Neuro-fuzzy systems incorporate the knowledge representation of fuzzy logic with the learning capabilities of artificial neural networks. Both methodologies are concerned with the design of intelligent systems albeit from different directions. The power of neural networks stems from the distributed processing capability of a large number of computationally simple elements. In contrast fuzzy logic is closer related to reasoning on a higher level. Pure fuzzy systems do not possess the capabilities of learning, adaptation or distributed computing that characterize neural networks. On the other hand, neural networks lack the ability to represent knowledge in a manner comprehensible to humans, a key feature of fuzzy rule based systems. Neuro-fuzzy systems bridge the gap between both methodologies, as they synthesize the adaptation mechanisms of neural networks with the symbolic components of fuzzy inference systems, namely membership functions, fuzzy connectives, fuzzy rules and aggregation operators. Ahrns et al apply neuro-fuzzy control to learn a collision avoidance behavior. Their approach relies on reinforcement learning for behavior adaptation. The learner incrementally adds new fuzzy rules as learning progresses and simultaneously tunes the membership functions of the fuzzy RBF-network. Godjavec et al present a neuro-fuzzy approach to learn an obstacle avoidance and wall-following behavior on a small size robot. Their scheme allows it to seed an initial behavior with expert rules, which are refined throughout the learning process. During training the robot is controlled either by a human or a previously designed controller. The recorded state-action pairs serve as training examples during supervised learning of neuro-fuzzy control rules. The robot successfully imitates the demonstrated behavior after 1500 iterations Ye et al propose a neuro-fuzzy system for upervised and reinforcement based learning of an obstacle avoidance behavior. The scheme follows a two-stage tuning approach; in a first phase supervised learning determines the coarse structure of input-output membership functions. The second reinforcement learning stage fine-tunes the output membership functions [1, 3, 7].

4. Genetic Algorithm Technique in Robot System

Characteristics of present computer methods inspired by biological evolution are classified as evolutionary computation. Evolutionary computation is the name given to a collection of algorithms based on the evolution of a population toward a solution for a specific problem. These algorithms can be used successfully in many different applications that require the optimization of a certain multi-dimensional function. The population of possible solutions evolves from one generation to the next, ultimately arriving at a satisfactory solution to the problem. These algorithms differ in the way anew population is generated from the present one, and in the way the members are represented within the algorithm. The three main elements of evolutionary computation are: *Evolution Algorithms (EA)*; *Genetic Programming (GP)*; 3) *Genetic Algorithms (GA)*. Each of these three techniques imitates the processes observed in natural evolution, and provides efficient search results [7].

A Fuzzy Logic Controller (FLC) is viewed as an individual. A population includes a group of FLCs. The running of the robot with the FLCs is the evaluation process. As the antecedents of an FLC are pre-defined, only the FLC consequences are encoded as chromosomes. There are *M* rules in one FLC in one FLC. Therefore, one chromosome has *M* genes. The first gene corresponds to the first rule's consequence. Each gene could be one of fuzzy singletons *ck* and illustrated in figure 1.

c^{k_1}	c^{k_2}	……	c^{k_M}

Figure 1: Chromosomes.

The operations used in the GA include:

- *Initialization*: The first generation is initialized randomly. Each gene in each chromosome is chosen from the *K* fuzzy singletons evenly.
- *Reproduction*: The best individual in current generation is automatically copied into next generation.
- *Selection*: Individuals are copied into next generation as their offspring according to their fitness values. The individuals with higher fitness values have more offspring than those with lower fitness values.
- *Crossover*: The crossover will happen for two individuals in offspring with the crossover probability *pc*. One point crossover is used to exchange the genes.
- *Mutation*: The mutation is taken for one gene of an offspring with the mutation probability *pm*. The operator randomly chooses one fuzzy singleton from the allowed set to replace the current gene.

The results showed that it is feasible to use GA learning because the learning task can be decomposed into the learning of individual behaviors

5. Swarm Intelligence Technique in Robotics

Intelligent robot is a robot whose behavior is neither random nor predictable. Intelligent swarm is a group of non-intelligent robots forming, as a group, an intelligent robot. In other words, a group of "machines" capable of forming "ordered" material patterns "unpredictably"[8]. SI systems are typically made up of a population of simple agents interacting with one another and with their environment. The group of individuals acting in such a manner is referred to as a swarm. One individual modify the environment, which in return modifies the behavior of other individuals. Individuals within the group interact by exchanging local information such that the problem is solved more efficiently than it would be done by a single individual. Problem-solving behavior that emerges from such interactions is called swarm intelligence.The two best known SI algorithms are:
Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO).
a. ***Particle Swarm Optimization (PSO)*** was originally inspired by the crowd behavior of birds. In terms of this bird flocking analogy, a particle swarm optimizer consists of a number of particles, or birds, that fly around and search sky, for the best location. .
b. ***The Ant Colony Optimization (ACO)*** represents the model of the collective act of searching food behavior of ants. Deneubourg et al.showed that path selection to a food source is based on self organization. In the Binary Bridge experiment, two ants are taking the paths of different length from the home to a food source. The ant that will return first to the source is the one taking the shorter path.[9]

6. Conclusion

Soft computing approaches are more preferable over conventional methods of problem solving, for problems that are difficult to describe by analytical or mathematical models. Autonomous robotics is such a domain in which knowledge about the environment is inherently imprecise, unpredictable and incomplete. Therefore, the features of fuzzy control, neural networks and evolutionary algorithms and swam intelligence are of particular benefit to the type of problems emerging in behavior based robotics and multi-agent robotics. The references in the text on all these techniques in robotics do not claim to be complete but rather intend to provide overview of the basic utility of soft-computing techniques for behavior based robotics.
Swarm Intelligence is a new way to solve the problem whose domain ranges around multi-agent behavior of robots. The knowledge representation of fuzzy rule based systems combined with the learning capabilities of artificial neural networks and evolutionary techniques like genetic algorithm opens a new promising way towards more intelligent and robust robotic systems. Soft computing techniques contribute to one of the long term goal in robotics, to solve the problems that are unpredictable and imprecise namely in unstructured real-world environments

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