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INTEGRATION OF NEURAL NETS, FUZZY SYSTEMS AND EVOLUTIONARY COMPUTING IN SYSTEM DESIGN

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Thank you for this opportunity to speak in the Third Asian Fuzzy Systems Symposium. I will present the research undertaken in the Knowledge-based Intelligent Engineering Systems Centre (KES) on the integration of neural nets, fuzzy systems and evolutionary computing in system design. The neural nets, fuzzy systems and evolutionary computing techniques have accomplished substantial gains but there are problems associated with them. The trend is to integrate these techniques for offsetting the demerits of one technique by the merits of another technique. Our most recent work on landmine detection is also presented.

1.Introduction

The knowledge-based systems are designed to mimic the performance of a human expert by transferring his/her expertise to the computer in a specific field [1]. Artificial neural networks can mimic the biological information processing mechanism in a very limited sense. The fuzzy logic provides a basis for representing uncertain and imprecise knowledge and forms a basis for human reasoning. The trend is to fuse these novel paradigms for offsetting the demerits of one paradigm by the merits of another [2]. Some of the techniques are integrated as follows.

Neural net in designing fuzzy system

Fuzzy system in designing neural net

Evolutionary computing in designing fuzzy systems

Evolutionary computing in automatically training and generating neural net architecture

Neural net and fuzzy system in automatically determining the parameters of evolutionary computing techniques

2.Research Projects

The Knowledge-based Intelligent Engineering Systems Centre is involved in developing techniques for the design and diagnosis of information systems using artificial intelligence. In the past few years, our work on electronic system design using expert systems, neural networks, fuzzy logic systems and genetic algorithms has become well known internationally. The following is a list of some of the research projects being undertaken.

- Neuro-fuzzy system for wheelchair control
- Evaluation of neural network classifiers
- Skylight light intensity data logging system
- Automatic generation of a neural network architecture using evolutionary computation
- The application of fuzzy logic and genetic algorithms to ill-defined optimisation problems
- The development of software for implementing back propagation, BAM, Hopfield, Kohonen, radial basis function, and adaptive resonance theory networks for use in general research in KES
- The development of suitable techniques for training neural networks for the diagnosis of system faults
- The development and evaluation of techniques for enhanced range resolution for SAR systems in a knowledge-based environment
- The integration of circuit design with diagnosis in an expert systems environment
- The development of a tool for designing analogue and digital and other circuits in an intelligent environment
- The development of intelligent tool for designing dc power supply circuits using a Prolog based environment
- The development of a knowledge-based filter design system
- The use of entropy to focus ISAR images in an intelligent environment
- The development of an efficient SAR algorithm in an intelligent environment.

3.Case Study - Landmine Detection System

The Knowledge-based Intelligent Engineering Systems Centre is involved in developing landmine detection system using the integration of neural net, fuzzy system and evolutionary computing. There are over 50 million landmines that have been abandoned in over 60 countries around the world but they are still active. While these mines remain uncleared, they will continue to kill 10,000 civilians every year and disable many more. Landmines pose problems for the military by restricting their mobility, and for civilian populations, who are at risk long after conflicts have passed. A large number of these land-mines were simply thrown from aeroplanes and helicopters, and due to their small size and earthy colours blend well into the surrounding vegetation and soils. Many of the systems under development employ two or more types of sensors with their outputs fused together to maximise the detection performance while minimising false alarms. Sensors are often vehicle-mounted, or even

possibly operated from a low flying helicopter. The primary requirement of any landmine detection system is a high probability of detection (Pd) and a low false alarm rate (FAR).

One of the aims of this study is to provide a quantitative demonstration of the benefits of using multiple sensors for the detection of surface landmines from a distant platform. In particular it will show a reduction in the FAR through the fusion of two sets of imagery from an infrared sensor with a rotating polariser attached and a digital multispectral camera.

The goal of this work is to investigate the detection of surface landmines, given multiple registered images of the mined area obtained from a suite of visible to infrared wavelength sensors. We will be looking into the automatic detection of surface landmines. The novel approach takes the outputs from two different imaging sensors; a thermal (infrared) imager fitted with a rotating polariser and a multispectral (optical) camera. The target information from the two images is fused together using a fuzzy rule based system..We have used the novel architecture which combines sensors and signal processing algorithms using neural networks and a fuzzy rule based fusion algorithm to detect all the land-mines and reduce the false alarm rate

Our investigations show using a MLP neural network and an ART2 (with novel modifications) neural network classifiers on the input textural and spectral characteristics of selected multispectral bands (using a Genetic Algorithm tool) gave false alarm rates at around 3%.

4.Conclusion

The fuzzy logic has a sound mathematical basis.The neural networks have shown real promise in solving problems but there is not yet a definitive theoretical basis for their design. I see a need for integrating neural net, fuzzy system and evolutionary computing in system design] that can help us to handle complexity. Evolutionary computation techniques possibly offer a method for doing that and at the least, I would hope to see us gain some insight into alternative approaches to neural network design.

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Keynote Address

RESEARCH IN THE KNOWLEDGE-BASED INTELLIGENT ENGINEERING SYSTEMS CENTRE

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Thank you for this opportunity to speak in the Third Asian Fuzzy Systems Symposium. I will present the research in the Knowledge-based Intelligent Engineering Systems Centre (KES). The knowledge-based systems are designed to mimic the performance of a human expert by transferring his/her expertise to the computer in a specific field. Artificial neural networks can mimic the biological information processing mechanism in a very limited sense. The fuzzy logic provides a basis for representing uncertain and imprecise knowledge and forms a basis for human reasoning. The trend is to fuse these novel paradigms for offsetting the demerits of one paradigm by the merits of another. The research projects undertaken in the KES Centre are listed.

1 Knowledge-based Engineering

As is typical with a new field of scientific research, there is no precise definition for Knowledge-based Engineering. Generally speaking, however, so called knowledge-based data and information processing techniques are those that are inspired by an understanding of information processing in biological systems. In some cases an attempt is made to mimic some aspects of biological systems. When this is the case the process will include an element of adaptive or evolutionary behaviour similar to biological systems, and like the biological model there will be a very high level of connectionism between distributed processing elements [1]-[6].

Intelligence is also not easy to define, however, we can say that a system is intelligent if it is able to improve its performance or maintain an acceptable level of performance in the presence of uncertainty. The main attributes of intelligence are learning, adaptation, fault tolerance and self-organisation. Data and information processing paradigms that exhibit these attributes can be referred to as members of the family of techniques that make up the knowledge-based engineering area. Researchers are trying to develop AI systems that are capable of performing, in a limited sense, "like a human being." [7]-[8].

In the following paragraphs the main KBE paradigms are mentioned; these being, artificial neural networks, evolutionary computing and fuzzy logic.

2 Artificial Neural Networks

Artificial Neural Networks (ANNs) [9] [16] mimic biological information processing mechanisms. They are typically designed to perform a non-linear mapping from a set of inputs to a set of outputs. ANNs are developed to try to achieve biological system type performance using a dense interconnection of simple processing elements analogous to biological neurons. ANNs are information driven rather than data driven. They are non-programmed adaptive information processing systems that can autonomously develop operational capabilities in response to an information environment. ANNs learn from experience and generalise from previous examples. They modify their behaviour in response to the environment, and are ideal in cases where the required mapping algorithm is not known and tolerance to faulty input information is required [10]-[12].

The underlying reason for using an artificial neural network in preference to other likely methods of solution is that there is an expectation that it will be able to provide a rapid solution to a non-trivial problem. Depending on the type of problem being considered there are often satisfactory alternative proven methods capable of providing a fast assessment of the situation.

3 Evolutionary Computing

Evolutionary computation is the name given to a collection of algorithms based on the evolution of a population towards a solution of a certain problem. [14] [15]. These algorithms can be used successfully in many applications requiring the optimisation of a certain multidimensional 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 a new population is generated from the present one, and in the way the members are represented within the algorithm. Three types of evolutionary computing techniques have been widely reported recently. These are Genetic Algorithms (GAs), Genetic Programming (GP) and Evolutionary Algorithms (EAs). The EAs can be divided into Evolutionary Strategies (ES) and Evolutionary Programming (EP).

Evolutionary Programming is currently experiencing a dramatic increase in popularity. Several examples have been successfully completed that indicate EP is full of potential. Koza and his students have used EP to solve problems in various domains including process control, data analysis, and computer modelling. Although at the current time the complexity of the problems being solved with EP lags behind the complexity of applications of various other evolutionary computing algorithms, the technique is promising. Because of the fact that EP actually manipulates entire computer programs, the technique can potentially produce effective solutions to very large scale problems. To reach its full potential, EP will likely require dramatic improvements in computer hardware.

4 Fuzzy Logic

Fuzzy logic was first developed by Zadeh in the mid 1960s for representing uncertain and imprecise knowledge. [9]. It provides an approximate but effective means of describing the behaviour of systems that are too complex, ill-defined, or not easily analysed mathematically. Fuzzy variables are processed using a system called a fuzzy logic controller. It involves fuzzification, fuzzy inference, and defuzzification. The fuzzification process converts a crisp input value to a fuzzy value. The fuzzy inference is responsible for drawing conclusions from the knowledge base. The defuzzification process converts the fuzzy control actions into a crisp control action.

Fuzzy logic techniques have been successfully applied in a number of applications: computer vision, decision making, and system design including ANN training. The most extensive use of fuzzy logic is in the area of control, where examples include controllers for cement kilns, braking systems, elevators, washing machines, hot water heaters, air-conditioners, video cameras, rice cookers, and photocopiers.

5 Research Projects

The Knowledge-based Intelligent Engineering Systems Centre is involved in developing techniques for the design and diagnosis of information systems using artificial intelligence. In the past few years, our work on electronic system design using expert systems, neural networks, fuzzy logic systems and genetic algorithms has become well known internationally. The following is a list of some of the research projects being undertaken.

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- The development of suitable techniques for training neural networks for the diagnosis of system faults
- The development and evaluation of techniques for enhanced range resolution for SAR systems in a knowledge-based environment
- The integration of circuit design with diagnosis in an expert systems environment

- The development of a tool for designing analogue and digital and other circuits in an intelligent environment
- The development of a tool for diagnosing faults and prescribing corrective action in a Fluke multimeter
- The development of a tool for designing dc power supply circuits using a Prolog based environment
- The development of a knowledge-based filter design system
- A framework for a knowledge-based approach for designing electronic circuits and systems
- The use of entropy to focus ISAR images in an intelligent environment
- The development of an efficient SAR algorithm in an intelligent environment.

6 Summary

The fuzzy logic has a sound mathematical basis.The neural networks have shown real promise in solving problems but there is not yet a definitive theoretical basis for their design. I see a need for automted design techniques [10] that can help us to handle complexity. Evolutionary computation techniques possibly offer a method for doing that and at the least, I would hope to see us gain some insight into alternative approaches to neural network design. The real gain of these paradigms will be evident in business, education, research, collaboration, engineering and health care [17].[18].

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