ADAPTIVE SYSTEMS, NEURAL NETWORKS AND FUZZY SYSTEMS *

Horia-Nicolai Teodorescu* and Dan Gâlea**
*Polytechnic Institute and I.I.S.
**Institute for Information Science (I.I.S.) and I.P.I.
Iasi, ROMANIA

Abstract: Three modern ways to cope with uncertainty and complex tasks: adaptive systems, neural networks and fuzzy systems, are analysed and contrasted. The authors argue that each of these classes of systems substantiate a meta-algorithm.

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1. Introduction

In recent years, a new technological environment has emerged and quicly entered in those fields which previously were considered to be reserved to human beings. The new tasks imposed new requirements, arising from both the problems which are spesific to the tasks, and from the new technological env - vironment itself (e.g. the high electromagnetic noise levels).

The task-dependent requirements are mainly belonging to two classes: those regarding the use of imprecision, and those regarding the use of 'intelligent' techniques.

The high uncertainty and great variety of situations the present days systems have to deal with ask for adaptability, flexibility and even for the capability of decision when conditions are rather unpredictable. They also ask for the ability to deal with incomplete information, or approximate information. Thus, the systems asked to perform some complex tasks could be required to be able to acquire information and knowledge -- as human beings do, and moreover, to deal with them as human beings use to do.

Three kind of approaches are basical in developping systems fulfilling these requirements: adaptive systems (and very close to them, robust systems), (artificial) neural networks,(A)NN, and fuzzy systems, FS. All are to be included, or at least should be considered to have close connections to the (very) large field of artificial intelligence.

A natural question asked by both newcomers and experienced researchers is how close these three types of systems are, and when to use one of them instead of the others.

It is the purpose of this paper to suggest some possible answers to these questions by contrasting the three types of systems.

2. What AS, NN and FS are?

Although it is well known what adaptive systems (AS), neural networks (NN) and fuzzy systems (FS) are, a brief glance to the background could be useful in the discussion.

Consider we are given a device (system), and that its prospect is bad written: it does not specify the type of system.* Is it possible to determine the type of system from scarce information on its behaviour?

To simplify the problem, let us suppose the output of the system is on a display, and that the system can be asked on the suitability of the signals we input to it.

To determine the kind of system, first check its necessary inputs (see Table 1). Any usual (non-adaptive, crisp, serial) system will accept only 'signals' at its input(s). Any complementary information will be rejected as unprocessable. An adaptive --or robust-- (crisp) system, if it is well designed, will ask you to obey some requirements for the inputed signals, such as the system is able to

*Or, the company do not want to reveal it. Once, in a conference, I listened a researcher presenting a paper on a fuzzy system, without pronouncing the word 'fuzzy':the research was done for an army. During the brake, he confessed me that it was a fuzzy system, indeed, that he has presented.

TABLE 1

Type of system	Inputs	How it processes the inputs	Output
Usual crisp fixed system	'signals' $f(x):\mathbb{R} \to \mathbb{R}$	-basically serial processing -process signals as numbers	signals (no specific information)
Adaptive or robust	'signals' + global infromation	-basically serial processing -according to the acquired and/or imbeded information	signals
ANN	'words',i.e. parallel signals dealed as information	-massive parallel processing -according to the information content -high degree of associativity between pieces of information	information (semantical data) expressed by words
FSS	quantitatively uncertain data; linguistic data knowledge	-by doing inferences -uses'approximate reasoning'methods -uses knowledge	qualitative data approximate information/knowledge

make use of the information it got on how to process specific classes of signals. Or, it can ask you some information on the class to which the signal belongs. Or, it can impose some constraints on the signal (e.g. the minimal number of periods) such as it is able to learn (i.e. to get information). However, the needed information is rather global.

A neural network-type system, e.g. a classifier, will explicitelly ask for information, for example he will ask you to train it. If the system is complex and well designed, it will dialogue with you on your requirements. It will accept only words (parallel inputs), not discrete, uncorrelated data.

Finally, a fuzzy system will ask you for linguistic data, and for knowledge, expressed as rules, ways of inference a.s.o. It will be delighted to receive qualitative --rather than quantitative-- data at the input.

Maybe your system in hand is not enough smart to say you in a clear manner what it would like at its input. (But in this case too, you can guide yourself by using the errors messages at the output, provided for unsuitable inputs). If the information on the input is not enough, have a look at the output. An adaptive (or robust) system will provide just a signal (of course, an altered version of the input signal). A neural network is generally built to output information on the input signal (e.g. the class to which the input signal belongs, or the --completly different-- signal to which the input signal is associated --see the associative memories). Finnally, a fuzzy system will output some qualitative/approximate information, or some decision, or some knowledge.

Thus, there are some major differences between the systems from the three classes even at the superficial level of the input and output. Of course, more pronounced differences exist in the way the systems process the inputs.

Usual (fixed, crisp) system process'information' as raws of uncorrelated pieces of data. The process is bassically serial.

Adaptive systems process the input signals in accordance to some embeded, or acquired information. Their 'memory' is generally not trivial. Processing is mainly serial.

NN are characterized by massive parallelism and high degree of associativity. They extensivelly use specific ways of memorizing, and need specific pieces of information (which is maybe imbeded in the structure).

FS process data and knowledge in an approximate, qualitative way. Pieces of knowledge can be embedded in their structure. Thus, a FS is some kind of basical, specific, problem-oriented expert system, able to make use --maybe to acquire-- uncertain, qualitative information and knowledge.

From this discussion, no clear connection obviates between the three kind of systems. They look to be quite different. On the other hand, it is well known that there are problems which can be solved by any of these systems with almost the same performances. Moreover, all seem to have been designed to cope with the same kind of general problem in mind: to perform well under uncertain conditions. From this point of view, how much they differ?

3. A unifying standpoint

It is probably worth to consider that all the three types of systems, as discussed above, are just originated by three different approaches to problems. The three basical approaches are instantiated now by these types of systems, but other ways to instatiate the three approaches could exist and will probably be developped in the future.

The three approaches, which can be viewed as *meta-algorithms*, are:

1. 'devide-and-conquer', the 'split-the-problem-and-structure-data', or analytical approach;

2. 'deal-together', or 'interconnect', or 'synthesize' approach; and

3. 'deal-qualitativelly', or 'deal-approximatevelly' approach.

We can play finding attributes to characterize more intuitivelly the three approaches (see Table 2), but there is no use. Just note that the three meta-algorithms differ indeed, but are not mutually excluding. It is the intimate nature of the probleme dealed with which can ask for the use of the three ways, instead of the others. However, choosing the meta-algorithm --and thus the type of system-- that better fits the problem is yet an art rather than a science. And this is due to our limitted understanding of the nature of the three approaches.

TABLE 2

FEATURES OF THE THREE APPROACHES

Meta-algorithm	Characteristics
Devide-and-conquer	- dissociate (split the problem) - structure data - analyse - use distributivity of sub-problems - build algorithms based on serial processing - use of bivalente logic - representation of data by numbers
Deal-together	- interconnect - associate data - use innate parallelism - synthesize - highly non-linear processing - distribute information in the structure - learns
Deal-qualitatively	- use knowledge - infering systems - robustness to 'details' - high degree of AI incorporated - even the crisp information is dealed as an approximate one - numbers are rather unsuitable to represent uncertain data - new mathematical foundation - simulates intuition