Fuzzy Logic vs Machine Learning: An Investigation
Project Summary

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http://www.ug.cs.usyd.edu.au/~kpulo/ai/fuzzyml-summary.html

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Introduction

Fuzzy logic is a mathematical methodology (and a philosophical ideology) that is similar in construct to boolean algebra, but more general in fundamental ideas. The basic tenet with the traditional boolean thinking is that things either are or are not, true or false, 1 or 0. However, fuzzy logic extends this to include the continuous region between 0 and 1. Things are now no longer just black and white, but all the shades of grey in between as well. Half-truths are allowed, and indeed encouraged. Rules may be expressed in ways such as "If the room gets hotter, spin the fan blades faster" where the temperature of the room and speed of the fan's blades are both imprecisely (fuzzily) defined quantities, and "hotter" and "faster" are both fuzzy terms. Fuzzy logic has the potential to add of human-like subjective reasoning capabilities to machine intelligences, which are usually based on bivalent boolean logic.

Fuzzy logic has had a great deal of success where it has been applied in the real world, and is often touted as a means of making machines smarter. However, for the most part, fuzzy logic has actually been used in control systems as a way of providing more human-like behaviour. For example, many household appliances (notably whitegoods such as washing machines and refrigerators) now contain fuzzy control systems that allow the machine to adjust to the specific circumstances currently presented to it, as with the fan example in the previous paragraph. While this does improve the machines and their behaviour, it isn't really an advance in the areas of general intelligence on arbitrary domains and machine learning. Only (relatively) recently is the area of fuzzy machine learning being developed, with the most popular approach being fuzzy neural networks (often abbreviated to simply neuro-fuzzy) to allow machine intelligences to learn from empirical data and experiences.

Project Overview

For the most part, the fuzzy rules that are used in control systems are hand-crafted by the designers of the systems. As such, it can be argued that this human input into the system's design constitutes a homunculus, and that such systems can never be independantly intelligent. My project aims to exploit this in order to investigate the effectiveness of machine learning algorithms compared to human ones. The fuzzy rules will be used as they are an excellent means of compactly representing what the human has learned in a way that is both accuratly human-like and subjective, and can be used in controlled experiments to be compared against standard machine learning algorithms.

The project will comprise a series of controlled experiments on the performance of various algorithms on a standardised set of datasets (most likely from the USI repository). The performance is how many correct conclusions an algorithm draws based on given data and conclusions. There are three different categories of algorithms that will be examined. First, some standard ML algorithms, second, some hand-crafted fuzzy rules based on a human's examination of the dataset, and third, if time permits, some neuro-fuzzy ML algorithms. It is hoped that at least two different datasets will be used, with as many as five datasets (depending on availability of dataset results and implementations).

Where possible, existing results on the datasets will be used (ie. as obtained by researchers, probably the implementors of algorithms). If results are not available, implementations will be sourced to process the datasets, with preference to those that require the smallest amount of coding (as the point of the project is to analyse the results, not to construct the system). For the standard ML and neuro-fuzzy ML algorithms, this will require finding complete implementations of the ML algorithms that can be run on the datasets; for the hand-crafted fuzzy rules this will require finding fuzzy logic toolkits that can be used as a basis for constructing the fuzzy rules that can be used to process the datasets. When constructing the fuzzy rules, the human will be actively encouraged to take advantage of all human thought processes and percepts through the use of tools helping to reveal the hidden internal structure of the dataset, such as scientific visualisation software.

Expected Outcomes

The main expected outcome from this project is some insight into the relative strengths, weaknesses and overall effectiveness of human and machine learning methods. This will be obtained from examining the performance of the human generated, hand-crafted fuzzy logic rules against some typical ML algorithms, applied to one or more standardised datasets. Furthermore, if the hand-crafted rules outperform the standard ML techniques then the ways and areas in which they do may be used to suggest ways and areas in which to improve the standard ML techniques.

Another outcome will be the effectiveness and suitability of fuzzy logic methods and ideologies with respect to machine learning. Again, this will be obtained from a comparison of the hand-crafted fuzzy logic rules and the ML algorithms. In addition, if time permits, the results of some fuzzy ML algorithms (most notably neuro-fuzzy techniques) on the standardised datasets may be compared to the hand-crafted fuzzy rules and standard ML algorithms.

Also, one philosophical question which may be addressed is that of the existance of an impervious gap between human and machine intelligence. Put simply, can the human brain see, identify and interpret patterns in data

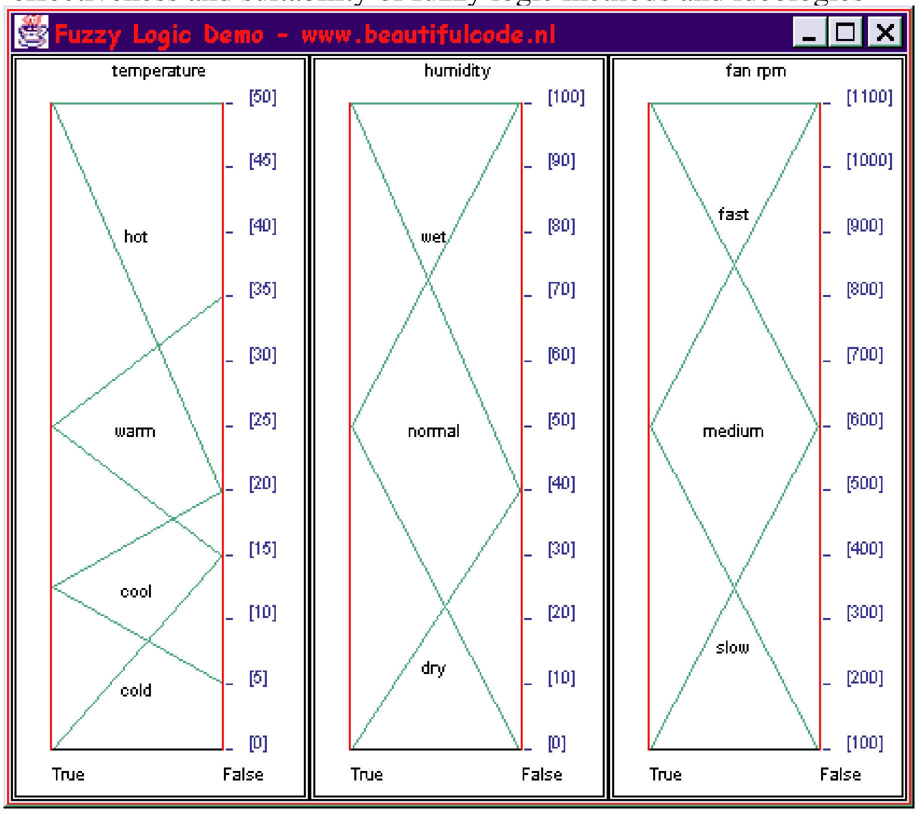

Figure 1 – Fuzzy rules

(constructed or sensory), and subsequently draw conclusions and generalisations, in a way that machines cannot? And if so, would machines need to make a kind of "quantum leap" into some form of consciousness in order to be as effective in these tasks as humans?

Method

The first step will be a brief literature survey and investigation of existing ML aglorithms and their performance on some standard datasets. This will be used to try to gauge what is the current "state of the art", in order to select the most appropriate algorithms for the study. After this the exact datasets to be used will be selected. They will be chosen based on their size and complexity (nothing too large or complex), the availability of results and implementations of the standard ML datasets and of their suitability to be analysed by a human. The performance of the standard ML algorithms will then be obtained, either from previously run experiments on the datasets by other researchers or by choosing a suitable implementation and running it over the datasets. If time permits, some suitable neuro-fuzzy ML algorithms may also be run in the same fashion as the standard ML algorithms.

The bulk of the project will be the construction of the fuzzy rules for each of the datasets. The rules will be constructed in a suitable fuzzy toolkit to allow the rules to be aptly expressed using fuzzy logic notions and human-like expressions, while still allowing them to be run over a dataset to produce predictions. Several tools will be utilised in order to analyse the datasets and construct the rules, most notably scientific visualisation software such as AVS and IBM Data Explorer (IBM DX). Other investigations may look at properties such as the statistical makeup of the dataset or sorting the dataset by different attributes in order to attempt to locate trends or constants (or almost-constants) in the dataset.

The problem with these kinds of datasets is that they contain many variables, meaning that the problem is in a high dimensional space. A problem with two variables has the problem space of a square, three variables a cube, and from four variables onwards simple visualisation becomes a problem. Fuzzy rules are usually drawn in a fashion similar to those in Figure 1, and ultimately this is what the hand-crafted fuzzy rules will look like. However, arriving at those pictures will not be as easy for a lot of variables as it is for three variables (as in Figure 1), and this is why a more advanced analysis of the datasets will be needed.

Finally, an environment such as Delve (Data for Evaluating Learning in Valid Experiments, http://www.cs.utoronto.ca/~delve/) may be used to ensure that all the tests and datasets are standardised and well documented. Further, this would allow the extension of comparing the results in a consistent fashion to other learning methods that use Delve.

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1. Figure 1 courtesy of Beautiful Code, http://www.beautifulcode.nl/fuzzy/images/example.gif