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Software Packages to Deal with Fuzzy Systems

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Abstract. This paper investigates currently available software packages dealing with fuzzy inference systems (FIS). Fifteen packages are investigated and are described here. Some comparisons are created. At the end there are some conclusions.

Keywords: Fuzzy inference systems, software, fuzzy, expert systems, inverse problem.

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INTRODUCTION

Nowadays fuzzy inference systems (FIS) become more and more popular. This causes the appearance of a lot of software packages dealing with them. Since the architecture and functionality of each package depends on its purpose, every package has its advantages and disadvantages in different situations. This paper is focused on giving, as much as possible, objective opinion on the current available software packages for dealing with fuzzy systems. Most of the popular packages are described here as well as some not so popular but better in some purposes.

PACKAGES

Fuzzy Logic Toolbox For MATLAB [1]

This package has three types of tools. These are Command line functions, GUI (Graphical User Interface) tools and Simulink blocks.

It supports Mamdani and Sugeno type of FIS which makes it the only package in this paper, able to work with Sugeno type of FIS.

All fuzzy inference systems defined by this package can be exported and imported. The exported files are easy to understand text files (with extension .fis) which can be edited with any text editor.

The package also has a Simulink [2] library (called fuzblock). It contains the “Fuzzy logic controller”, the “Fuzzy logic controller with receiver” and one sub library with blocks for the build-in membership functions (MFs).

The ANFIS (Adaptive Neuro Fuzzy Inference System) function and the ANFIS GUI editor are used in case we want to obtain some of the parameters of a fuzzy system automatically. In this case we need to use some training data. Fuzzy Toolbox for MATLAB also has built-in clustering functions which uses Fuzzy C Means [3].

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In addition Fuzzy Logic Toolbox for MATLAB has the ability to output stand alone C code.

FuzzyTECH [4]

FuzzyTECH is a standalone application with a lot of features. As a software package, it is designed to be complete solution for every kind of fuzzy inference systems.

The GUI of FuzzyTECH is complete tool for design of fuzzy systems. It has great number of different views for design and analyzes purposes.

As in Fuzzy Toolbox for MATLAB we can see the execution of the systems in real time. All changes happening during execution can be followed in all analyze views.

This package can be easily integrated with other software products. It has “plug and play” type interfaces for many products like Simulink, InTouch, Excel, Access, VisualBasic, etc. For every other program FuzzyTECH provides standard interface techniques such as DDE (Dynamic Data Exchange), DLL (Dynamic-Link Library), and ActiveX. In addition FuzzyTECH can generate source code which can be included in other programs. This code can be portable C code, assembly source code for microcontrollers, or function blocks for programmable logic controllers. In a joint development projects with microchip manufacturers such as Motorola and Intel, the compactness and execution speed of the FuzzyTECH generated code is highly optimized. In addition FuzzyTECH can generate stand-alone runtime libraries of every fuzzy system formed with it.

Another good feature is the build-in documentation generator and a revision control system. The documentation generator produces complete documentation for ISO 9000 compliant development in RTF (Rich Text Format). The revision control system lets you rewind to earlier development stages and can document the progress. The entire structure of documentation follows the IEC (International Electrotechnical Commission) 1131-7 [5] standard on fuzzy logic development.

FuzzyTECH is distributed in number of editions divided in three groups. These are “General Purpose” Editions, “MCU Pack for Embedded Control” and “IA Editions” for Industrial Automation. Each edition has different purpose and different features.

Two add-on modules are provided with FuzzyTECH. First is the “NeuroFuzzy Module” with which users can generate or optimize every part of a fuzzy system. Second add-on module is the “HyperInference” module. More information about HyperInference can be found in [6]

Finally, FuzzyTECH has the rich examples library.

Fuzzy Sets For Maple [7]

This package is constructed by four sub packages. These are “Fuzzy Logic”, “Real Fuzzy Sets”, “Finite Fuzzy Sets” and “Tools” sub package. They are described below.

Fuzzy Logic sub package is a simple set of functions intended to do simple fuzzy logic operations. These are `and`, `implies`, `not` and `or` for logical operations and booleanum, evalb, evalfz for some conversion operations.

Real Fuzzy Sets sub package is intended to deal with fuzzy sets with real domain. It includes four classes of functions: constructors of fuzzy sets, plot function, operators and functions for working with fuzzy sets.

Fuzzy Sets for Maple has one default and some additional constructors. The default constructor constructs piecewise-like functions. Other constructors are for constructing MFs with different shapes. There are four types of additional constructors. These are Gamma, L, Lambda and Pi constructors. Any of these shapes have different models and arguments, so we have one rich collection of shapes for modeling our fuzzy sets.

The plot command in Maple is overloaded to plot fuzzy sets.

Defined operations are union, intersection, implication, membership, set minus and subset. In addition there is the Arithmetic Subpackage which allows sums, differences, and products. User defined functions can be used for every operation.

Also Fuzzy Sets for Maple includes functions for complement, convert fuzzy sets to piecewise functions, defuzzify, cut, core, support, height, concentrate, dilate and intensify contrast.

Finite Fuzzy Sets sub package has almost same set of features like the Real Fuzzy Sets sub package. In addition it has different sets of functions to work with numeric and nonnumeric universal sets.

Tools sub package holds different functions to work with T-Norms and S-Norms, Implications, Complement, Associated classes (a triplet s-norm s, t-norm t and negation n) and Models.

Fuzzy Logic For Mathematica [8]

This package is quite complete system to operate with fuzziness. It has some unique features. It is a collection of notebooks and packages for Mathematica environment. The packages can operate with fuzzy sets, relations and operations. In addition it has good visualization tools. One interesting feature is the built-in abilities for working with Lukasiewicz sets and logic. It also supports fuzzy clustering.

Basic familiarity with Mathematica is assumed for use of this package.

The notebooks provided with this package demonstrate how the various fuzzy logic functions are used, and they contain many work examples showing how this package can be used in real-world applications.

mbFuzzIT [9]

This software package is written in Java. It is supposed to be a tool for producing and testing complex controller structures. It can be used like a programming language extension or through build in GUI. In this system a fuzzy controller can be created by arrange different blocks and connect them. In this manner even complex controllers can be produced easy. This package can create only Mamdani type of fuzzy controllers.

It has four types of fuzzyfiers and two types of defuzzyfiers. Only piecewise functions can be used for the linguistic variables.

Since this package is written in Java it is multi platform (like all Java packages described below). In addition it is free and open source.

mbFuzzIT has poor documentation.

jFuzzyLogic [10]

This is another written in Java, free, open source package. Since it is an open source package, it can be used and extended by another programs. Being written in Java it is multi platform. It is designed like a programming extension (or library) and is supposed to be used in other programs. It has good graphical forms like tree view, or MFs view.

jFuzzyLogic supports three parametric optimization algorithms.

The package is implementation of FCL (Fuzzy Control Language) [5].

It has a built-in example which is the famous *tipper*, and has comparatively good documentation (part if it is created with javaDoc [24] software).

FLINT Toolkit [11]

FLINT is designed as a subsystem of Prolog [12] and flex [13]. FLINT supports the conception for fuzzy variables, fuzzy quantifiers as well as the conception for fuzzy modifiers. FLINT also supports Bayesian updating and Certainty factors models.

The package has complete documentation and some examples.

FuzzyJ Toolkit [14]

FuzzyJ Toolkit is a software package developed by National Research Council of Canada's Institute for Information Technology. It is set of Java classes. It has standalone API (Application Programming Interface) and integration with Jess [15], called FuzzyJess.

Interesting approach for modeling of the MFs is chosen here. There are three types of MFs. Left sided, right sided and double sided. They can be linear or non linear and can be combined. For example you can choose linear left side and non linear right side.

There are eleven built-in modifiers available. Custom modifiers are also supported.

The package is well documented and a set of examples is available.

Free Fuzzy Logic Library (FFLL) [16]

The Free Fuzzy Logic Library (FFLL) is an open source fuzzy logic class library and API which is optimized for speed critical applications, such as video games. This library is designed to be as fast as possible.

FFLL can be easily extended with other features. It is supposed to be used in another software packages through the supported API.

It supports four types of MFs. The build in S-Curve MFs is not limited to bell shaped curves, and can represent fairly complex curves.

This package is designed to be games programming package. Because of this it is not so much in to the diversity, but it is focused on the speed and multi threading. It is a part of [17] book.

Open Source Fuzzy Engine For Java [18]

This package is a set of classes allowing performing fuzzy reasoning into Java software where all evaluations are performed by the fuzzy engine, while manipulation of the control flow and input-output operations are performed in Java. The engine supports evaluation of fuzzy rules in the symbolic form; fuzzy and/or/not operations; arbitrary nesting of fuzzy expressions in the left part of a rule; multiple assignment operations in the right part of a rule; predefined and user-defined modifiers; unconditional assignment operations; dynamically weighted rules; evaluation of single rules or rule blocks.

The package has poor documentation with one example.

TILShell [19]

TILShell is a Windows-based software development tool providing users with a way to design, debug and test fuzzy logic expert systems, including embedded control systems.

The TIL Shell family has abilities for real-time on-line debugging and tuning of rules, membership functions and rule weights, including addition and deletion of rules. It has graphical object-based "point and click" CASE (Computer-Aided Software Engineering) tool and can work with user-defined inference methods.

The TILShell family is available in 3 editions. They are "Professional Edition", "Standard Edition" and "Basic Edition".

Special programming language is designed for TILShell called FPL (Fuzzy Programming Language). The build-in CASE tool actually produces FPL.

TILShell has Neural Network Tool to train a fuzzy system which supports three learning methods. Documentation is available.

Fuzzy .NET [20]

This package is a set of classes written in C#. It contains four classes: FuzzyNumber, FuzzySet, FuzzyDecision, and FuzzyDecisionSet. As a set of classes it can be used or extended by programmer.

It has poor options and poor documentation. One example is available.

XFuzzy 3.0[21]

Xfuzzy 3.0 is a development environment for fuzzy-inference-based systems. It is composed from several tools covering the different stages of the fuzzy system design process, from their initial description to the final implementation. Its main features are the capability for developing complex systems and the flexibility of allowing the user to extend the set of available functions. The environment is completely programmed in Java.

The description stage includes graphical tools for fuzzy system definition. There is set of tools for simulation, monitoring and representing graphically the system behavior. The tuning stage is divided into tools generating high-level algorithms.

Finally, there are synthesis stage languages descriptions for software or hardware implementations.

In the package a special programming language called XFL3 (XFuzzy Language version 3) is presented. XFuzzy 3.0 has nine different operators to form rules. In this package we can form rules like *If variable1 = label1 and variable2 != label2 and variable3 < label 3 then ...*

Fuzzy Extension For Conventional Programming Languages [20]

This project is designed as multi-language package with wide abilities to deal with fuzzy systems. It is implemented for C++, .NET and Delphi frameworks. Its purposes is to propose a tool with as many build in features as possible. In that way it has some unique or rare features. It supports great amount of MFs (24). In addition this package supports four modifiers and rule weights. The documentation [20] of the package is complete. A lot of examples are provided.

Fuzzy Calculus [22]

This package is actually a demonstration CD to the book [22]. It is supposed to be an application of the theory in it. The software package is developed for MATLAB programming language. In fact Fuzzy Calculus Software is a very different from the other presented in this paper packages. It is only a package to deal with fuzzy algebra. Its uniqueness is that it has abilities to solve the inverse problem in fuzzy algebra.

Fuzzy Calculus Software has complete documentation (and book with the theory) and a lot of examples. It can be downloaded from [23].

COMPARISON

A table of comparisons is provided in this section. Because of the different nature of Fuzzy Calculus software, it will not be included in the table.

	Fuzzy Logic Toolbox for MATLAB	FuzzyTECH	Fuzzy Sets for Maple	TILShell	FLINT Toolkit
Current Version	2.2.5	5.71d	1.1	3.0	4.7
Types	Mamdani, Sugeno	Mamdani	Mamdani	Mamdani	Mamdani
MFs	11 + Custom	4	5 + Custom	1	2
Conjunctions	3 + Custom	1	5 + Custom	1	2
Disjunctions	3 + Custom	1	5 + Custom	1	2
Complements	3 + Custom	1	4 + Custom	1	2
Implications	2 + Custom	1	17 + Custom	1	1
Aggregators	3 + Custom	1	5 + Custom	1	1
Defuzzifiers	5 + Custom	4	7	1	2
Modifiers	No	No	No	No	No
Import-Export	Yes	Yes	No	No	No
Optimization	Yes	Yes	No	Yes	No
Standalone Apps	No	Yes	No	Yes	No

Doc Builder	No	Yes	No	No	No
GIU	Yes	Yes	No	No	Yes
API	Yes	Yes	No	Yes	No
Documentation	Rich	Rich	Rich	Fair	Fair
Examples	Yes	Yes	Yes	No	Yes
Price	\$200	Unknown, Commercial	\$60 - \$480	Unknown, Commercial	Unknown, Commercial
	Fuzzy Logic for Mathematica	Extension for Conventional Programming languages	Free Fuzzy Logic Library	mbFuzzyIT	jFuzzyLogic
Current Version	2	1.0	2.2.1	1.1 beta 4	1.2.1
Types	Mamdani, Model, Scaled	Mamdani	Mamdani	Mamdani	Mamdani
MFs	8 + Custom	22 + Custom	4 + Custom	1	8 + Custom
Conjunctions	5	2 + Custom	2 + Custom	1	3 + Custom
Disjunctions	5	2 + Custom	2 + Custom	1	3 + Custom
Complements	3	1 + Custom	2 + Custom	1	1 + Custom
Implications	3	2 + Custom	2 + Custom	1	2 + Custom
Aggregators	18 + Custom	3 + Custom	1 + Custom	1	5 + Custom
Defuzzifiers	5	5 + Custom	2 + Custom	2	6 + Custom
Modifiers	0 + Custom	4 + Custom	No	No	No
Import-Export	Yes	No	No	Yes	No
Optimization	Yes	No	No	No	Yes
Standalone Apps	No	Yes	Yes	No	Yes
Doc Builder	No	No	No	No	No
GUI	No	No	No	Yes	No
API	Yes	Yes	Yes	Yes	Yes
Documentation	Rich	Rich	Rich	Poor	Fair
Examples	Yes	Yes	No	Yes	Yes
Price	£35 - £455	Free	Free	Free	Free
	Fuzzy .NET	Open Source Engine for Java	FuzzyJ Toolkit	XFuzzy	
Current Version	1.0	0.1a	1.10a	3.0	
Types	Mamdani	Mamdani	Mamdani	Mamdani	
MFs	1	1	6 + Custom	9 + Custom	
Conjunctions	1	1	1 + Custom	4 + Custom	
Disjunctions	1	1	1 + Custom	4 + Custom	
Complements	1	1	1 + Custom	5 + Custom	
Implications	1	1	1 + Custom	8 + Custom	
Aggregators	1	1	1 + Custom	8 + Custom	
Defuzzifiers	1	1	4 + Custom	10 + Custom	
Modifiers	No	3 + Custom	11 + Custom	4 + Custom	
Import-Export	No	No	No	Yes	
Optimization	No	No	No	Yes	
Standalone Apps	Yes	Yes	Yes	No	
Doc Builder	No	No	No	No	
GIU	No	No	No	Yes	
API	No	Yes	Yes	Yes	
Documentation	Poor	Fair	Rich	Fare	
Examples	No	Yes	Yes	Yes	

Price	Free	Free	Free for Education and research	Free
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CONCLUSION

Since the fuzzy inference systems become very popular nowadays there are a lot of software packages to deal with them. Almost every of the considered here packaged has its good sides. Some of them has good GIU other has better API, third has support for many MFs, etc.

One conclusion here is that the choice of software depends on our goal. Other conclusion is that there is still no software focused on solving the inverse problem in fuzzy reasoning (which is to find the inputted values if we only have a result), except the *fuzzy calculus* software [23], but it is still rudimental. So, next works can be focused on develop further the Fuzzy Calculus software, and use it to solve the inverse problem in Fuzzy Inference Systems.

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