A Survey of Fuzzy Logic Tools for Fuzzy–based System Design

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ABSTRACT
In Fuzzy logic and its applications are now well-established and arguments for and against it have reached a steady state. There is a vast amount of literature on the topic making it a difficult task for a practicing engineer, beginner researcher, or an advanced student to grasp the topic and then apply the acquired knowledge with only a small investment of time and money. With the growing acceptance of fuzzy logic control, more and more fuzzy logic software and hardware products have appeared in the market This paper is intended to present a quick review on the software tool available for fuzzy logic based embedded systems design.

General Terms
Fuzzy Logic, Development software's.

Keywords
fuzzy logic, software tools, embedded system.

1. INTRODUCTION
We Fuzzy sets theory proposed by Lotfi Zadeh in 1965.It bases on the assumption that everything is true with an appropriate degree of truth [1], [2]. In this way, it exceeds the classical, binary logic, which admits only two values 0 and 1 (false and true). In fuzzy logic the degree of truth of an expression or statement can vary between 0 and 1. During 1970 to 1980, decision supporting fuzzy systems found their ways besides engineering in to management and business. This is marked by linguistic description of human judgments in the Expert Systems for medical diagnosis, access structural damage and strategic planning [3]. These Expert Systems exploited the uncertain knowledge acquired to help user in the domain of interest. Then Fuzzy Logic Control (FLC) appeared that was meant to control the complex technical processes ranging from camera and vacuum cleaner [2] to cement kiln [4], model car [5] and train [2].

Software design tools help the system designer in the design and coding and achieve quick implementation of fuzzy based system. Good number of tools exits today. Modern sophisticated tools provide graphical animation and offer interactive on-line development capabilities, instead of pre-compiling using programming languages like prolog, C, C++ etc [6,7-9]. Interactive tools are efficient as they allow monitoring direct consequences of modifications of design parameters such as rules, fuzzy subsets, shape of membership functions, and display output in tabular form or plot them. With such tools tuning phase becomes far easy and quick. The "fuzzyTECH" tool developed by INFORM and a graphical tool "CubiCalc" [Hyperlogic Corp. of Escondido, California] can be used for on-line optimization of a fuzzy system. The TIL-shell the Computer Aided Software Engineering (CASE) form Togai Ifralogic helps building expert systems with C-language. Apart from accelerating design process; today's graphical tools can be effectively used for training purpose on the laboratories [10-13].

A good software tool supports all development phases-design, simulation, optimization, verification and implementation. Another way is to use a fuzzy logic pre-compiler created using standard programming language like C, C++, Prolog, and LISP. The fuzzy logic description language FTL (Fuzzy Technology Language) helps creating a graphical model of the system and finally compiled in to software package [14]. The primary benefit of commercially available tools is their support in debugging as almost 80-90 % of system development time is spent on simulation, optimization and validation.

2. FUZZY LOGIC SOFTWARE DEVELOPMENT TOOLSSIZE
The purpose of fuzzy logic software tools, mostly used for the development of fuzzy controllers, is to take over the implementation problem, and leave only the design problem to the user. Most of the tools can simulate and debug the designed fuzzy systems and are able to generate executable code in for example C-language. Table 1 shows a review of some recently available fuzzy logic software.

2.1 MATLAB
The term "MATLAB" is familiar to every Engineering graduate. MATLAB is a high-level technical computing language and an interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas. Mathworks Inc. owns the proprietary software. MATLAB is a scientific computational package that has been widely in use ever since its inception in the early nineties. In the beginning it was limited to the research arena but later it gained a prominent place in the Engineering course syllabus, especially the Electrical and Electronics branches.

Table 1. A partial list of fuzzy logic software table

Software Tool	Developer	Special Feature	Available
Fuzzy Logic Toolbox for MATLAB	MathWorks, Natick, Massachusetts, U.S.A.	Fuzzy logic simulation (Windows)	Demo Not Available
PID and Fuzzy Logic Toolkit for NI LabVIEW	National Instruments Corporation, Austin, TX.	Fuzzy logic simulation and code generation for Embedded System (Windows)	Trial Available
SCILAB	SCILAB Enterprises	Fuzzy logic simulation and code generation	Free
fuzzyTECH	Inform Software, Aachen, Germany	Fuzzy logic simulation and code generation (Windows)	Demo available
FuzzyCOPE	Nikola Kasabov & TM, Dept. of Information Science University of Otago Dunedin New Zealand	Fuzzy-neural network simulation environment (Windows)	Free
Jfuzzy	Jeremiah K. Jones	real-time NW packet analysis	Free
TIL-Shell	Togai Infra Logic, Irvine, CA	C code generator (Windows)	Na
FIDE	Aptronix, Inc., Palo Alto, CA	Fuzzy logic simulation and code generation (Windows)	Demo available
FuzzyCLIPS	NASA's Johnson Space Center	Fuzzy logic simulation and code generation (Windows, Linux)	Na
FLDE	Syndesis Ltd, Iofondos 7 Athens, Greece.	Fuzzy logic simulation and code generation for Embedded System (Windows)	Demo available
FLINT	Logic Programming Associates	Fuzzy logic simulation, Prolog and Flex. (Windows)	Demo available

The one great problem with MATLAB is that it is proprietary software and thus involves a huge licensing fee which may even run down to thousands of dollars. Another setback with the package was that that its source code was not public. MATLAB have a Fuzzy Logic Tool Box that provides tools to create and edit fuzzy inference systems within the framework of MATLAB, or to integrate the fuzzy systems into simulations with Simulink [15].This toolbox relies heavily on graphical user interface (GUI) tools. The toolbox provides three categories of tools: Command line functions Graphical interactive tools Simulink blocks and examples.

2.2 NI LabVIEW

The NI LabVIEW PID and Fuzzy Logic Toolkit is an add-on to the LabVIEW graphical development environment that can be used to add sophisticated control algorithms to our LabVIEW programs. By combining this toolkit with NI data acquisition, FPGA-based, and other I/O hardware, we can create complete automated control applications. The LabVIEW PID and Fuzzy Logic Toolkit help to deploy deterministic proportional integral derivative (PID) control algorithms to stand-alone embedded hardware targets. The implement single- or multi-channel PID control algorithms in hardware on NI FPGA-based hardware devices can be possible by using LabVIEW FPGA Module along with PID and Fuzzy Logic Toolkit [16].The NI LabVIEW PID and Fuzzy Logic Toolkit have following key features

- Integrate P, PI, PD, and PID control algorithms into LabVIEW applications
- Use the Fuzzy System Designer and Fuzzy Logic VIs to design, adapt, and control fuzzy systems
- Auto tune gains online and offline based on different algorithms to improve control performance
- Take advantage of advanced features including gain scheduling and integral ant windup

2.3 SCILAB

It’s an open source software package developed at INRIA (France), for system control and signal processing applications. It also features a wide variety of tools for various Engineering and Mathematical applications. It was introduced as an Open source alternative to MATLAB. It is also a vector based program. It has constantly undergone vital changes ever since its inception in 1994. The first version of SCILAB was launched in 1994 and since then it has been constantly updated and is available for download via the Internet. Sadly the SCILAB package has not received the share of success it ought to have got. Though available for free, it has not been able to build a great user community. In the article [17]; the comparative study of MATLAB and its open source alternative SCILAB is reported.

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2.4 FuzzyTECH

For FuzzyTECH is a leading family of software development tools for fuzzy logic and neural-fuzzy systems [18]. The software supports both English and German languages. Moreover, the documentation is available in the English, German, and Mandarin Chinese languages. FuzzyTECH families of particular interest here include:

FuzzyTECH Editions for General Target Hardware including fuzzyTECH Professional and fuzzyTECH online editions.

- FuzzyTECH MCU-HC05/08 Edition: Supports all microcontrollers of the 68HC05 and 68HC08 families from Motorola.
- FuzzyTECH MCU-HC11/12 Edition: Supports all microcontrollers of the 68HC11xx and 68HC12xx families from Motorola. Utilizes the special fuzzy logic instruction set of the HC12. RTRCD functionality included.
- FuzzyTECH MCU-MP Edition: Supports all microcontroller families of Microchip Technologies Inc. (PIC16C5X, PIC16CXX, and PIC17CXX).
- FuzzyTECH MCU-51 Edition: Supports all microcontrollers of the 8051 and 80251 families. Special libraries for 80517 included. RTRCD functionality included.
- FuzzyTECH MCU-96 Edition: Supports all microcontrollers of the MCS®-96 family from Intel (8096, 80C196, ...). RTRCD functionality included.
- FuzzyTECH MCU-166 Edition: Supports all microcontrollers of the C16x family from Siemens. RTRCD functionality included.
- FuzzyTECH MCU-320 Edition: Supports all digital signal processors (DSP) of the TMS-320 C2x/3x/4x and 5x families from Texas Instruments.

2.5 FuzzyCOPE

Do FuzzyCOPE is a hybrid connectionist software environment for MS Win32 platforms intended for research and teaching. It provides for the creation, training and validation of connectionist structures to be used in the development of intelligent systems. Its functionality may be accessed interactively (through a GUI), from the DOS prompt (through several command line tools), and from provided Dynamic Link Librarary. The FuzzyCOPE /3 GUI provides a user friendly interface to the functionality of the system, while the Dynamic Link Libraries that form the core of the system may be used to develop Windows based intelligent systems through the use of the provided programming libraries. The availability of command line tools allow for the creation, training and validation of connectionist structures from the DOS prompt, granting developers the option of training modules in batches, as opposed to the one at a time approach of the GUI [17]. The FuzzyCOPE /3 have following features

- Multilayer Perceptrons
- Kohonen Self Organizing Maps
- Fuzzy Neural Networks
- Data manipulation and transformation functions (data
- Shuffling, normalization, renormalization)

2.6 JFUZZY

JFUZZY is a Java-based version open source software of FUZZY - the network packet analyzer. JFUZZY will provide several features that FUZZY currently does not. JFUZZY will allow for real-time packet analysis and can be integrated into other Web-based Network Tools (OpenNMS).

2.7 TILShell

TILShell 3.0 is a software development tool used for

- Designing fuzzy logic systems,
- Testing these systems through simulation,
- Online testing (compiled code), and
- Compiling the resulting system into any of several variants of C code or
- Compiling the resulting system into target code for supported fuzzy co-processors or microcontrollers.

The resulting fuzzy system can either take the shape of a stand-alone application or it can be embedded into an existing application.

2.8 FIDE

Fuzzy Inference Development Environment (FIDE) is a development environment for fuzzy logic systems from Aptronix, Inc., Santa Clara, USA. The software can automatically generate fuzzy algorithms in Java, ANSI C, MATLAB M-file, and assembly code for a variety of microcontrollers. Chips supported include: Motorola: 68HC05, 6805, 68HC08, 68HC11, 68HC12, 68HC33x, Intel 80C196 and 80C296 architectures, Siemens:

Free demos of FIDE and example files are available for downloading. The demo allows the creation and simulation of fuzzy logic models and it helps to learn about the fuzzy inference process. The demo is useful for educational purposes and as a preview of the full version. The compiler and code generator are disabled in the production environment of demo version.

2.9 FuzzyCLIPS

FuzzyCLIPS is a fuzzy logic extension of the CLIPS (C Language Integrated Production System) expert system shell from NASA [19]. It was developed by the Integrated Reasoning Group of the Institute for Information Technology of the National Research Council of Canada and has been widely distributed for a number of years. It enhances CLIPS by providing a fuzzy reasoning capability that is fully integrated with CLIPS facts and inference engine allowing one to represent and manipulate fuzzy facts and rules. FuzzyCLIPS can deal with exact, fuzzy (or inexact), and combined reasoning, allowing fuzzy and normal terms to be freely mixed in the rules and facts of an expert system. The system uses two basic inexact concepts, fuzziness and uncertainty. It has provided a useful environment for developing fuzzy applications but it does require significant effort to update and maintain as new versions of CLIPS are released. FuzzyCLIPS offers the following functionality:

- Combines fuzzy reasoning capability with conventional rule based technology
- Retains the flexibility and portability of the CLIPS environment
- Targets development of both stand-alone and embedded systems
- Extends rule syntax and user definitions of membership function types

2.10 FLDE

Fuzzy Logic Development Environment (FLDE) is a tool specifically for embedded systems with two features. The first is portable ANSI C code generation which is a self contained, strictly deterministic, re-entrant subset of C that supports all standard C data types, allowing the code to be targeted to wide range of microcontrollers. The second is a debugging facility which allows embeddable source-level debugging of compiled fuzzy logic and features tracing, break-points, watch, and profiling of all fuzzy logic entities. Embedded fuzzy logic programs which may be integrated with other C user code can thus be debugged at the fuzzy logic level.

2.11 FLINT toolkit

FLINT is a powerful sub-system which augments the decision-making power of both Prolog and Flex. Flint provides a comprehensive and versatile set of facilities for programmers who wish to incorporate uncertainty within their expert systems and decision support applications. FLINT provides support for where the domain knowledge is not so clear cut. FLINT supports three treatments of uncertainty, namely: Fuzzy logic, Bayesian updating and Certainty factors. FLINT does this by augmenting the normal backward-chaining rules of Prolog and, where Flex is present, by extending the KSL of Flex [20].

3. CONCLUSION

In the present article we have made an attempt to address the system design software especially for creation of the fuzzy logic system. The researchers, academician should develop in-depth knowledge of the system domain for amalgamation with software support.

The MATLAB have powerful simulation and rich in GUI and easy to use with fast development process, but its main disadvantage is that its high cost. NI LabVIEW supports lots of feature for real time hardware testing and embedded system design but it's also have high pricing. SCILAB is another tool similar to MATLAB available free of cost, but there is lack of product help as compared to MATLAB. LabVIEW, FUZZYTECH, FLDE, FIDE and TIL-Shell can able to generate the embedded code for fuzzy logic. However SCILAB is very attractive tool for academician and individual developers.

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