Introduction

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1.1 Overview of Thesis

In our day to day lives we often need appropriate advice to guide ourselves to reach our goals. We take these advices from experts having in depth of knowledge about the regarding subject and the present situation for the knowledge application. For example we need medical advice from a doctor to keep our self healthy; students require teacher's guidance to enhance their academic progress. Hence in many different ways we require different kind of advice, suggestions and guidelines to handle particular situation which may come across in our day to day life.

There are certain important decisions to be made which will prove decisive for carrier advancement and future development. However it is not always possible to get in detail guidance or proper guidance due to various reason and causes.

The thesis “Design of Neuro-Fuzzy Advisory System Using Type 2 Fuzzy Logic” contributes to development of neuro-fuzzy intelligent systems whose decision and advice aids in solving routine problem & dilemmas which otherwise would require many expert domain to carry out the same task. The systems generated through proposed design will applicability of expert’s domain knowledge in respective fields; this would result in saving time and also much less manual efforts. The advantage of the system’s generated thorough proposed methodology is that, the systems would interact with their uses using GUI features and provides virtually real experience of presence of the domain expert. These systems would continuously work for social welfare without major human biological limitations. A course advisory system entitled “Neuro-Fuzzy Decision Support System for Course Selection” is developed with proposed design to show the impact and usage of neuro-fuzzy hybridization approach.

In the field of artificial intelligence, neuro-fuzzy refers to combinations of artificial neural networks and fuzzy logic. Neuro-fuzzy hybridization results in a hybrid intelligent system having human like inference style of fuzzy logic and learning capabilities of artificial neural networks. Furthermore the reasoning
approach of fuzzy logic is extended to type 2 fuzzy logic to provide much better reasoning capability for fuzzy based computer systems.

Design and development of such neuro-fuzzy system is a complex, tedious and time taking process. Designing neuro-fuzzy system requires immense coding. After proper development, the system has to be trained with high degree of efforts along with proper training sets for artificial neural networks. Furthermore fuzzy rule base has to be applied with artificial neural network. Hence development of such system for a specific domain could take up to several years of development and training effort.

With growth of modern technologies such systems are gaining popularity in different domain areas and there is increase in demand for intelligent systems. These systems are substitutes for domain experts and provide much better solutions and have following advantages over a human domain expert.

(i) Biological Limitations: Any human domain expert has biological limitation. The human domain expert cannot work continuously for twenty four hours a day and seven days a week for years to come, but it is always possible for computer based intelligent systems.

(ii) Better Availability: The scope or coverage area of human domain expert is limited and cannot handle many clients simultaneously; whereas computer based intelligent system working on web can access any region of the world and can handle substantial large number of clients around the world.

(iii) Biasness: No matter how good the human expert may be, there is always an element of doubt for biasness of experts advice, this is often seen when an interview or selection procedure is made. However there is no risk of partiality when the selection procedure is made by computer based intelligent systems.

(iv) Flexibility: Computer based intelligent systems interacts with all kind of its users and can be accessed through hand held digital devices like cell phones at any place and at any times, whereas there are protocols followed by society while interacting with human domain expert.
(v) Accuracy: With very high speed processors, computer based intelligent systems could process large number of data with accurate precision, which is nearly impossible with human domain expert.

(vi) Reliability: Neuro-fuzzy based intelligent system applies inference and training of many domain experts, and thus advice or decision generated by such system is more reliable than that of human expert.

(vii) Security: With computer based intelligent system there is safety of personal and important data, also users feels more secure while interacting with computer based intelligent systems than human domain expert.

(viii) Consistency: Consistent services are provided by computer based intelligent system without any change of temperament or mood swings like human domain experts, neuro-fuzzy systems provides critical decision support repeatedly and continuously without altering advice generated, hence a user can interact with these systems repeatedly for decision support.

(ix) Database: The user of neuro-fuzzy advisory systems have to enter their detail only once and the system will store the details in form of records on physical disk drives; this information can be accessed even after decades, whereas due to biological limitation of human brain this is not possible for human domain expert. The database is not only used for storing user’s information but also helps in documenting domain expert’s knowledge.

(x) Ease of Use & Social Service: The developed neuro-fuzzy systems through the framework are more interactive with its users due to its fuzzy interface. Also the services will be provided free of cost, hence a common man is benefited from the developed system.

For providing different solutions for various problem domains many such systems are required. To develop such systems a generic library of source code is designed and developed, the library contains an open source codes for different types for artificial neural network, fuzzy logic and type 2 fuzzy logic.
1.2 The Research Problem

The problem under research is to generate generic design for generation of neuro-fuzzy intelligent systems. The developed generic design should provide a model that will support the development of neuro-fuzzy systems with high accuracy and less time period for development. To carry out this task following procedures are required to be carried out:

- Detailed study on neuro-fuzzy systems, architecture and methods of hybridization.
- Study on practical limitation of implementing artificial neural network, fuzzy logic & type 2 fuzzy logic.
- Design of a generic hybridizing strategy, having advantage over existing neuro-fuzzy model like Takagi-sugeno, Mamdani etc.
- Modify and develop algorithms for faster processing of artificial neural network.
- Modify and develop knowledge base, rule base & membership functions for fuzzy logic.
- Bridge the gap between fuzzy logic and type 2 fuzzy logic and to provide an interactive user interface for the developed system using proposed generic design.
- Simulation and test runs of methods and procedures developed for the library and comparing the results with existing methods to show the need of generic design for development of neuro-fuzzy systems.
- Demonstrate the practical applicability with an example of developed neuro-fuzzy system using the proposed design.
- To impart flexibility in the developed framework in such a manner that allows hybridizing of various different techniques developed in future.

To provide solutions for the research problem mentioned above the thesis is organized into various chapters. Each chapter is focusing on detailed aspects of developing a generic design for neuro-fuzzy systems. Hence the entire thesis is organized as shown in Figure 1.1.
1.3 Organization of Chapters

Chapter 1: Introduction to Neuro-Fuzzy System
- Aims, Objectives, Introduction to ANN, Fuzzy Logic (Type 2) and Neuro-Fuzzy Systems

Chapter 2: Literature Survey
- Study in Area of ANN, Fuzzy Logic and Neuro-Fuzzy Systems, Limitations, Solutions

Chapter 3: Design of Library
- Structure of the System, Classification of Neuro-Fuzzy Architectures, Class Libraries

Chapter 4: Detail Design of the Neuro-Fuzzy Framework
- Implementation of Library to Design and Develop the Framework

Figure 1.1: Organization of Chapters

Chapter 1: Introduction to Neuro-fuzzy Systems: This chapter introduces to the problem under research providing a background of underlying architecture and designed methodology. The chapter also discusses about the main objectives of thesis and provides overview of the methodology that is used to solve the problem. The chapter focuses on the need and usage of neuro-fuzzy advisory systems in day to day life.
Chapter 2 Literature survey in the field of Neural, Fuzzy and Neuro-Fuzzy Systems: The chapter focuses on the studies carried out in the field of neural, fuzzy (type 2) and neuro-fuzzy systems at national and international level. Literature survey presented in this chapter enlists different tools/technique/software to design intelligent systems. These tools/software are further categorized into commercial products, public domain software and few source codes which are either licensed or freely available. The survey also evaluates the enlisted tools and software for their utility in terms of ease of development and utilization of intelligent systems.

Chapter 3 Design of the Library for the Framework: This chapter focuses on design to develop a library which includes source codes for artificial neural network and fuzzy logic. This design of library works as a key instrument to develop the interactive framework which automatically develops three different types of systems in the respective areas of artificial neural network, fuzzy (type 2) logic and neuro-fuzzy advisory systems. Further, the chapter also focuses on detail design for every components of the library. Above this, the library incorporates the facility of hybridizing the two components to produce expert neuro-fuzzy advisory system in the given domain area.

Chapter 4 Detailed Design of Neuro-Fuzzy Development Framework: This chapter focuses on detailed development approach of a generic framework based on the library developed. The chapter illustrates interface designing of the framework, detailed database design for framework, validations and check points to be noted while developing a neuro-fuzzy advisory system. The chapter also focuses on the key mechanism of hybridizing artificial neural network with fuzzy logic practically. The chapter also discusses various applicable areas where the generated systems from the framework are applicable.

Chapter 5 Generation of Artificial Neural Network (ANN) Based Systems: This chapter focuses on practical applicability of the developed framework to develop artificial neural network based applications and systems. The chapter focuses on the technical details while developing the artificial neural network
based systems. It includes designing of artificial neural network by specifying input and output broad categories, selection of learning algorithm, parameters and an activation function to be used by learning algorithm.

Chapter 6 Generation of Fuzzy (Type 2) Logic Based Systems: This chapter focuses on development of fuzzy logic based systems which include extendibility of the fuzzy logic to type 2 fuzzy logic. The chapter focuses on technical details of fuzzy logic based systems, which includes its component like fuzzifier, defuzzifier, inference engine, rule base, applicability of rule base to generate a knowledge base, and a type reducer for type 2 fuzzy logic. The chapter elaborates on fuzzification and defuzzification methods, membership functions, fuzzy sets, linguistic variable and their applicability to deduce fuzzy rule to infer advice from the knowledge base for the application under development.

Chapter 7 Generation of Neuro-Fuzzy Based Systems: This chapter focuses on the development of neuro-fuzzy advisory systems in various domain areas. The chapter highlights the importance of the hybridization of artificial neural network with fuzzy logic, which is responsible in generating the optimal advice in the given domain area. The user has to specify the input and output broad categories of artificial neural network along with fuzzy rules. To hybridize the two core technologies, the framework provides an interface which allows the user to organize fuzzy rules and its linguistic variables with artificial neural network broad categories.

Chapter 8 Application of the Library in Other Areas: This chapter focuses on the usage of library functionalities which are useful in development of various advisory systems and algorithms. The chapter elaborates the possible modifications in algorithms and activation functions of artificial neural network to enhance the performance of existing algorithms.

Chapter 9 Conclusion: The chapter focuses on the research contribution made by thesis in the field of computer science and society as whole. The chapter mentions the advantages of using the generated framework using the
generic library in order to generate various intelligent systems in respective domain areas. The chapter reflects how the framework actually reduces the manual effort of developing a neuro-fuzzy system, which otherwise requires months or years of development by a team of programmers. The chapter also highlights such possibilities of future research and use of the framework for the benefit of society and industry. Finally the chapter concludes with the aims and objectives achieved by thesis.

1.4 Aims & Objectives

As stated, the objective of this thesis is to present design and development of generic design for generation of different kinds of neuro-fuzzy system in various domain areas like education, investment, engineering, medical diagnosis. The generic library discussed in the thesis generates a framework that helps in automating the development of fuzzy, neuro or neuro-fuzzy system on demand in respective domain area by interactively acquiring different parameters. The thesis presents generic architecture and detailed methodology used for development. To demonstrate practical usability, an example of neuro-fuzzy course selection system with its input output screens. The main objective of this system is to give carrier related advice based on the skills, qualification and areas of interest of individual combined with expert’s knowledge about the proper implication of potentials and capacity of an individual. Hence a generic neuro-fuzzy library is generated which will meet the following requirements:

- Generic library is the basis of generic framework for development of neuro, fuzzy and neuro-fuzzy systems, which in turn creates user friendly web based and desktop based (windows supported) system in Neural Network, Fuzzy and Neuro-fuzzy area with respective problem domain.
- Object oriented programming approach helps in reusability of the code for new development and modification in current systems.
- The generic library can undergo update with future developments in areas other than artificial neural network and fuzzy logic.
• The generic library used for development of framework, contains library of functions and algorithms that will help to develop other major computerized systems in the various domain areas.

• Modular design of the library helps in modification and addition of other extended code in the modules of artificial neural network and fuzzy logic respectively.

• The generic framework allows documentation of developed systems as packages, hence it becomes easy to modify the developed system on demand. It also allows saving neural network configurations, training set data, and fuzzy rules for future use. Hence an expert’s knowledge can be stored and applied whenever required.

• The system developer who is using the framework will specify broad outlines of requirements for the system to be developed.

• Due to generic library, the developer will be able to concentrate on working of the system rather than encoding the system and hence total man power required to build neuro-fuzzy system is reduced and it will also save time and save manual programming work.

• The neuro-fuzzy system generated from the framework in respective domain area will be used by layman to solve their daily dilemma and help their life better with proper guidance.

• The generated neuro-fuzzy system combines different expert’s knowledge, and hence offers advantage of having expert’s knowledge at finger tips of the user of generated system.

• The generated system using generic framework has no retirement date conceptually. Once the system is in stable state the developer can continuously monitor and improve its performance by changing parameters and adding rules to the system.

• The proposed generic library and framework are developed using Microsoft’s Dot Net technology (Visual Studio 2010) and this can be updated easily to future release of versions.

To demonstrate the working of the generated library and the framework, “Neuro-Fuzzy Decision Support System for Course Selection” is developed. The system is meant for general welfare for all, especially for fresh graduates.
and their parents showing detail of how to channel individual’s effort in right directions and what are the future opportunities lying ahead. The application of the project is not bounded for any organization; it can be used for common pupils at different level. Hence it also provides a social service to the society.

1.5 Overview of Research Methodology

**Artificial Neural Network:** An Artificial Neural Network (ANN), usually called "neural network" (NN), is a mathematical model or computational model that tries to simulate the structure and/or functional aspects of biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. In more practical terms neural networks are non-linear statistical data modeling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data.

There is no precise agreed-upon definition among researchers as to what a neural network is, but most would agree that it involves a network of simple processing elements (neurons), which can exhibit complex global behavior, determined by the connections between the processing elements and element parameters. The original inspiration for the technique was from examination of the central nervous system and the neurons (and their axons, dendrites and synapses) which constitute one of its most significant information processing elements [15].

**Fuzzy Systems:** Fuzzy systems are categorized into two major parts based on their operational ability they are as follows:

**Type 1 Fuzzy System (T1FS):** A type 1 fuzzy system or fuzzy system is constructed completely by type 1 fuzzy sets. It contains four components -- rule base, fuzzification, inference engine and defuzzification, as shown in Figure 1.2. Type 1 fuzzy sets are generalizations of crisp sets whose
membership grades can only be 0 or 1. “If $X$ is a collection of objects denoted generically by $x$, then a fuzzy set $A$ in $X$ is defined as set of ordered pairs: $A = \{(x, \mu_A(x)) \mid x \in X\}$, where $\mu_A(x)$ is called membership function for fuzzy set $A$ that takes values in the interval $[0; 1]$”[6].

![Figure 1.2: Block Diagram of Type 1 Fuzzy Systems](image)

The rule base is a collection of IF-THEN statements. The IF-part of a rule is its antecedent, and the THEN-part is its consequent. Fuzzy sets are associated with terms that appear in the antecedents or consequents of rules, and with the inputs to and output of the FLS. Membership Functions (MFs), provides measure of the degree of similarity of an element to the fuzzy set.

**Type 2 Fuzzy Systems (T2FS):** The concept of type 2 fuzzy system was initially proposed as an extension of ordinary (type 1) fuzzy system by Prof. Zadeh [7]. The refined definition of type 2 fuzzy set is proposed by Mizumoto and Tanaka[8]. Recently, Mendel and Karnik[3], [4], [10], [14] have developed a complete theory of type 2 fuzzy logic systems. Type 2 fuzzy systems allow to handle the uncertainty using membership functions that generalize type 1 fuzzy systems.

Type 2 fuzzy systems were characterized by IF-THEN rules, but their antecedent or consequent sets are type 2. A type 2 fuzzy set can represent and handle uncertain information effectively. That is, type 2 fuzzy sets let us model and minimize the effects of uncertainties in rule-base fuzzy systems. According to [3], [4], there are at least four sources of uncertainties which cannot be handled by type 1 fuzzy systems, which are given as follows:
(i) antecedents and consequents of rules,
(ii) measurement noise,
(iii) training and fine tuning, and
(iv) noise cancellation.

All of these uncertainties can be translated into uncertainties about fuzzy membership functions. The type 1 fuzzy sets could not treat it because the membership functions are crisp. That is, type 1 membership functions are of two-dimensional, whereas type 2 membership functions are of three dimensional [5], [9]. It is the new third-dimension of type 2 membership functions that make it possible to model the uncertainties [2]. The block diagram of type 2 fuzzy system is demonstrated in Figure 1.3. In addition to basic component rule base, fuzzification, inference engine and defuzzification, type 2 fuzzy system also include a component called as type reducer. Type reducer allows conversion of type 2 fuzzy sets of the system to conventional type 1 fuzzy sets by generalizing them using membership functions. Hence type reducer provides a channel to interact between type 1 and type 2 fuzzy sets.

![Figure 1.3: Block Diagram of Type 2 Fuzzy Systems](image-url)
In type 2 fuzzy systems uncertainty is conveyed by the union of all primary memberships called as the *footprint of uncertainty* (FOU) [16]. The *footprint of uncertainty* (FOU) is shown as the shaded region. It represents the uncertainties in the shape and position of the type 1 fuzzy set. The *footprint of uncertainty* (FOU) is bounded by an *Upper Membership Function* and a *Lower Membership Functions*; both of which are type 1 membership functions. Consequently, the membership grade of each element in a type 2 fuzzy set is a fuzzy set \([l; r]\), where \(l\) and \(r\) are membership grades on the lower and upper membership functions. Type 2 sets are extremely useful in circumstances where it is difficult to determine the exact MF for a fuzzy set [5], [9], [21]; hence, they are useful for incorporating uncertainties.

**Neuro-Fuzzy Systems:** In the field of artificial intelligence, neuro-fuzzy refers to the hybridization of artificial neural networks and fuzzy logic. Such hybridization results in a an intelligent system that synergizes these two techniques by combining the human-like reasoning style of fuzzy systems with the learning and connectionist structure of neural networks. Hybridization of artificial neural network and fuzzy logic based system can be done in following fashions [1], [11], [12], [13]:

(i) **Cooperative Neuro-Fuzzy Model:** In the cooperative systems pre-processing phase is executed where the neural networks mechanisms of learning determine some components of the fuzzy system.

(ii) **Concurrent Neuro-Fuzzy Model:** In the concurrent systems the neural network and the fuzzy system work together continuously. Hence, the neural networks pre-process the inputs or post-process the outputs of fuzzy system.

(iii) **Hybrid Neuro-Fuzzy Model:** Here, neural network is used to learn some parameters of the fuzzy system in an iterative way.

Neuro-fuzzy system incorporates the human-like reasoning style of fuzzy systems through the use of fuzzy sets and a linguistic model consisting of a set of IF-THEN fuzzy rules. The main strength of neuro-fuzzy systems is that
they are universal approximators with the ability to solicit interpretable IF-THEN rules. The base artificial neural network offers advantages of self learning from the domain data provided. Hence, the neuro-fuzzy systems offer dual advantages of self learning and fuzzy interface.

**Advantages offered by a neuro-fuzzy system:** Neuro-fuzzy system has following advantages:

- It bridges the gap between human thinking and computation and offers dual advantages of self learning and fuzzy inference.
- With the fuzzy interface, the system becomes more user-friendly and interactive, which leads to improved satisfaction of users.
- The system permanently documents one or more expert’s knowledge for problem solving and future use.
- The system offers valuable domain knowledge irrespective of time and place. The system if placed on platform like World Wide Web, it can serve multiple users any time anywhere in customized fashion.

In spite of the above advantages, there are some difficulties associated with neuro-fuzzy system. The neuro-fuzzy system requires high effort and long time for the training and development. Further, it should be noted that the quality of such system depends on the training data set provided.

### 1.6 Proposed System Design

![Figure1.4: Proposed Architecture of Neuro-Fuzzy (Type 2) System](image)
The design of the system will be divided into several phases. Figure 1.4 shows the proposed system design. When the user first interacts with the system, user can give its own requirements in human understandable instruction. This instruction will be passed on to the first phase of the system i.e. type 2 interface. Here the fuzzy values passed by the user will be divided into several intervals [5], [9], these intervals will be passed into inference engine for type 2 where data will be processed by applying rule bases and membership functions for type 2 fuzzy system. The output of the first phase has to pass from type reducer in order to make data sensible for type 1 fuzzy interface [9]. Type 1 interface will again process the data by converting them into fuzzy logic sets and pass to the inference engine for type 1 fuzzy system. Here also separate rule base and membership functions will be applied. The output from type 1 fuzzy interface has to be defuzzified (Process of converting fuzzy value to crisp value) before passing it to neural network. The defuzzified crisp value is then processed by neural network. The neural network has to be trained accordingly by applying appropriate training set data in order to obtain accurate results. The output of the neural network is fed back to type 1 fuzzy interface and then to type 2 fuzzy interface. Hence the end user can see the results in human understandable form. The development process will be carried out through object oriented programming making each phase divided into modules which contains definitions for it’s functioning. This design is the proposed design of the system; changes could be made at development time for better justifying the system. Design of an academic neuro-fuzzy system has been carried out to verify the design of the developed neuro-fuzzy system [11].

1.7 Conclusion

From the study made in this chapter, it is clear that neuro-fuzzy system is a hybrid system that consists of the two major components of soft computing i.e. artificial neural network and fuzzy logic. Here it can be observed that fuzzy logic systems can be categorized into type1 and type 2 fuzzy systems. Type 2 fuzzy systems overcome the limitation of handling uncertainty. As type 1 fuzzy systems can handle only limited uncertainty which is generalization of crisp
data. The chapter also provides overview of existing models for hybridization of the two components artificial neural network and fuzzy logic.

References


