PREFACE

The main objective of this thesis is to establish the mathematical models depending on the concepts of fuzzy that associated with the various techniques, with a particular focus on modeling the various problems that dealing with human life. Here, apply and investigate all the proposed fuzzy mathematical models using different medical applications. This thesis is composed of seven published papers in international journals. They cover the following topics: type-1 fuzzy model, fuzzy clustering, fuzzy classification, and type-2 fuzzy model at continuous domain, the derivative of the steepest descent model that depends on trigonometric function, an interval type-2 singleton, and non-singleton type-2 FLS modeling. Apply the various topics on a different medical data set such as Liver Disorders, medical diagnosis of general diseases, lung cancer, and heart diseases. For the theoretical contributions, this thesis introduces the development and extension of type-1 and type-2 fuzzy model in order to provide a noval mathematics fuzzy model with the defferent techneques such neural network, clustering, classification, extension of domain, tuning parameters, etc. For the experimental studies, the defferent data sets recorded from the medical system are use to verify the efficiency results for the proposed models when compared with the actual results. The fuzzy model of the experimental results is compared to each other in order to show the differences and errors rate between predicted results and actual results. This thesis is organized into six Chapters.

Chapter 1 provides an introduction in the fuzzy modeling, which consists four parts. The first part contains the definition and concepts of the fuzzy modeling, which provided the basic mathematical terms of the fuzzy modeling that associated with the type1 and type-2 fuzzy logic, neural network, fuzzy clustering, fuzzy classification, etc. Second part presented
the background and literature survey. In third part, we provide the objectives of the thesis, while through the last part of this Chapter; the structure of the thesis is presented. Chapter 2, 3, 4, 5, and 6 results from modeling and observation of the mathematical fuzzy modeling process are presented and discussed. This Chapter starts by provides a broad background for type-1, type-2 fuzzy modeling, it is various modeling processes, preliminary mathematics, and broad overview of fuzzy modeling.

Chapter 2 consists of four parts. First part introduces the fundamental concepts and principles in the general field of fuzzy theory that are useful in FSs and ANFIS. Second part provides the detailed mathematical formulas of the FIS, and constructs interfaces between the FIS and the environment using fuzzifier and defuzzifier models. In the first subpart of this part proposes and extends the model of the FS from 2-dimensions to $N$-dimensions using Mamdani's minimum implication with the minimum inference system, the singleton fuzzifier, and center average defuzzifier. Second subpart provides the theorem that extended for accuracy of a proposed model. As well as, adaptes the structure of the FS and modeled of an adaptive FS using a neural network presented through the third part. Therefore, applied all the previous concepts and models on a medical application to Liver Disorders. We have structured the applied model, thus provide discussion and results for the models of the FS with Mamdani and ST models and the adaptive FS using neural network, respectively. Therefore, compare the results of the FISs with the Mamdani and ST models, and the results of the ANFIS with their errors. Consequently, obtained good results of the models, and created programs for the different models using ‘MATLAB’.

Chapter 3 deals with a mathematical structure of fuzzy modeling of medical diagnoses by using clustering models and propose the generation
of an adaptive neuro-fuzzy inference system model using different fuzzy clustering models. It presents a general model of a fuzzy-cluster system and shows how a mathematical structure of the applied TS rule-based model depends on clustering. Thus, describe a fuzzy clustering of TS models that consist of two models, a subtractive fuzzy clustering (SFC) model and a fuzzy c-mean clustering (FCM) model that are applied to a modeling problem. Therefore, explain steps of SFC and FCM models, and then build the structure of ANFIS with the TS model that depends on SFC and FCM, which use the "back-propagation learning rule. Consequently, apply all these models on a real data to medical diagnosis and perform a system at 50 epochs to obtain the average testing error of training data and the average testing error of checking of ANFIS-SFC, ANFIS-FCM, and ANFIS without clustering. The performance of the models is measured by the square root of the mean squares prediction error RMSE that obtained very small errors, and the smallest value of Average RMSE with ANFIS-FCM.

Chapter 4 provides a fuzzy mathematical model for detection of lung cancer using a multi-NFClass. It makes to clarify the general concept of a Multi-NFClass with the definition of a multi-fuzzy system, a fuzzy classifier, and multi-layers of fuzzy perceptron with extension of this concept from three layers to L layers. Thus, shows the structure of a Multi-NFClass model and a network of a Multi-NFClass processing structure and describe the concept of classical classifiers using a neural network model that depends on a fuzzy Bayesian classification. Therefore, describe some concepts to represent the results of classification by confusion fuzzy matrices model that are used to find the values of sensitivity and specificity, then use the receiver operating characteristics (ROC) curve to represent the results. Consequently, apply the previous models on real data of lung cancer, and obtain very good results with smaller values of the
misclassification rate. This misclassification measurement is a good tool for determining the quality of a classifier and it is sometimes called “accuracy”.

Chapter 5 deals with the mathematically concepts of type-2 fuzzy set and system, which provides a derivation of an interval type-2 fuzzy sets and systems that extend discreet domain to continuous domain. It provides a small set of concepts in a mathematically accurate way of general T2 FSs and IT2 FSs and proves the extension theorem (theorem 5.1) at continuous universes of discourse. Thus, derive the formulas of the extension intersection and union of N-IT2 FSs that is base on different concepts: i) the concept of embedded IT2 FSs (such as theorem 5.2); ii) the concept of extension principle (such as theorem 5.3). Additionally, derive the formulas of the extension meet and join of N-IT2 FSs (such as theorem 5.4). Therefore, describe an IT2 FLS, T2 singleton fuzzification (SF) and T2 non-singleton fuzzification (NSF), and present the derivation of all of the formulas that are related with an IT2 FLS at continuous domain with multiple rules. Each rule has multiple antecedents that are activate by a crisp number (the case of SF), therefore, show how those results can be extended (the case of NSF). Consequently, derive the relationship between the consequent and the domain of uncertainty (DOU) of the T2 fired output FS that summarized by the extension theorems 5.5 and 5.6 for SF and NSF, respectively. Thus, shows the computation of the continuous version of type-reduction that is used in going from fired-rule IT2 FSs to the defuzzified number at the final output of FLS and provide the derivation of the general form that extend for continuous domain to calculate the different kinds of type-reduced. Consequently, a medical application of IT2 FLS’s to heart diseases (HDs) is apply and provide a Matlab performance of IT2 FLS. A comparison of HDs between IT2 FLS using the IT2FLS in
MATLAB and the IT2FLS in Visual C# models with T1 FISs (Mamdani, and Takagi-Sugeno) are present.

Chapter 6 provides mathematical formulas and algorithm in order to calculate the derivatives that being necessary to perform Steepest Descent models to make T1 and T2 FLSs much more accessible to FLS modelers. The major purpose of this Chapter is to learn how to model non-singleton type-1 fuzzy logic systems (NS-T1 FLSs) when a set of training data is available. It focus on an interval type-2 non-singleton type-2 FLS (IT2 NS-T2 FLS) in order to clearfy how to assign all the parameters of the antecedent and consequent MFs and provides an application to derive the steepest descent model that depends on trigonometric function (SDTFM), where Generalized bell-shaped MF is chosen for the antecedent and the consequent. It also focuse on an IT2 NS-T2 FLS in order to clearfy how to assign all the parameters of the antecedent and consequent MFs using the set of $n$ input-output and build mathematical formulas to calculate the derivatives $\partial \cosh(\alpha) / \partial \theta$ depend on general formula of SDTFM. Therefore, provide general formulas for the left and right end-points of the type-reduced set, and provides computation of $\partial \cosh(\alpha) / \partial \theta^i_{l,k}$ for antecedent and consequent parameters for derivatives of $\partial \cosh(\alpha)$ with respect to antecedent MF parameters. Thus, provided algorithm of the derivatives for antecedent parameters to calculate $\partial \cosh(\alpha) / \partial \theta^i_{l,k}$. Therefore, present the derivatives of $\partial \cosh(\alpha)$ with respect to consequent MF parameters. Consequently, explains an application for calculate $\partial \mu^i_{\hat{\alpha}}(x^i_{l,s}) / \partial \theta^i_{l,k}$ and $\partial \overline{\mu}^i_{\hat{\alpha}}(\overline{x}^i_{l,s}) / \partial \theta^i_{l,k}$ for antecedent Gaussian primary MFs with uncertain means and input measurement Gaussian primary MFs with uncertain standard deviations. A comprehensive and comparative study based on results obtained from computer simulations done using software VC# and MATLAB.