DEVELOPING KNOWLEDGE BASED SYSTEM FOR PREMEDICAL TRIAGE USING FUZZY INFERENCE RULE BASED APPROACH: THE CASE OF MENELIK II HOSPITAL

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This is to certify that the thesis prepared by Mulatu Dagnachew entitled: Developing Knowledge Based System for Premedical Triage Using Fuzzy Inference Rule Based Approach: the Case of Menelik Ii Hospital and submitted in partial fulfillment of the requirements for the Degree of Master of Information Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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List of Acronyms

AI: Artificial Intelligence

ED: Emergency departments

ENA: Emergency Nurses Association

FIS: Fuzzy inference system

FL: Fuzzy Logic

GPS: General Problem Solver

GUI: Graphical User Interface

HIV/AIDS: Human Immune Virus/ Acquired Immune Deficiency Syndrome

KA: Knowledge Acquisition

KBS: Knowledge Base System

MCI: Mass casualty incidents

MD: Medical doctor

MF: Membership Function

TB: Tuberculosis

ABSTRACT

Hospitals and other health centers are organized to help patients because; human health problem is a serious issue in day to day life. Since the aim of health organizations is to make people to be productive and healthy, the services that are given by the health centers should be fast and efficient enough. But there are some gaps observed in the health centers like, low patient handling capacity of the hospitals, low skill of the triage staff because of lack of experience, lack of good judgment quality, less tolerance of the patients, lack of enough knowledge etc.

In the case of Ethiopia different problems are observed in health care centers. From different perspectives, one is the problems observed in the triage system. So the objective of this research is developing knowledge based system for premedical triage using fuzzy inference rule based approach.

Interview and document review have been used as a data collection methods. The researcher has interviewed the domain experts by using unstructured interview, because unstructured interview is used to get unlimited idea from the domain experts. In order to develop the system, fuzzy inference logic has been used as a tool. Fuzzy logic is a precise problem solving methodology which is able to simultaneously handle numerical data and linguistic knowledge. In fuzzy logic, a statement can assume any real value between 0 and 1, representing the degree to which an element belongs to a given set.

Hierarchical tree have been used in order to represent the knowledge that are collected from the domain experts. The hierarchical tree diagram provides the analysts with an effective visual condensation of the clustering results. The hierarchical tree diagram is one of the most commonly used methods of determining the number of clusters in this case number of selected diseases. The numbers at the top and bottom of the hierarchical tree diagram represent equally spaced values of the criterion function. It gives a pictorial representation of the criterion function information.

Finally the researcher has tried to develop the system using fuzzy inference system, and the user acceptance of the system is evaluated by the domain experts. The system gives a significance contribution for the domain area because the domain experts rated the user acceptance test of the system as 74.28%. This is because the since the symptoms of the patients are subjective, it is difficult for fuzzification. In addition to that there is no universal agreement on fuzzifing the symptoms. The developed system can be able to identify the diseases based on the query given by the user. The user in this case the triage nurse gives each fuzzified values of the symptoms, and then the system recommended the possible result in ranking by using percentage. The system can be able to provide suggestions on the basis of symptoms what will be the recommended disease and to where further diagnosis will be.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Hospitals and other health centers have the responsibility to help patients as they arrive to the health organizations. Patients wait in the reception room until their turn for examination. Before they enter to the examination room, the patients are ordered to go to the triage room.

Triage is the practice of prioritizing patients based on their need for immediate attention and chance of recovery to ensure a maximum number of recuperation [1]. If the hospitals and any health organizations have a good triage system, it helps them to decide the severity of the disease and helps the patients to become healthy. Triage is the prioritization of care based on illness/ injury, severity, prognosis, and resource availability. Triage identifies patients who cannot wait to be seen, prioritizes all patients, and initiates diagnostic and therapeutic measures. Sorting patients based on their symptoms makes the diagnostic process easy, because the triage result suggests the specific department which able the patients to take further examination.

The term triage originated from the French verb Trier which means to sort. During the time of Napoleon, the French military used triage to serve as a battlefield clearing hospital for wounded soldiers. The U.S. military's first use of triage was during the Civil War. Triage on the battlefield was a distribution center from which injured soldiers were sorted or distributed to various hospitals. For the military during World Wars I and II, triage was the procedure that determined which injured soldiers were able to be returned to the battlefield. Military triage continued to evolve during the Korean and Vietnam wars with the tenet of doing the "greatest good for the greatest number of wounded and injured [2]. Other situations, in which the triage process has been employed, in addition to the battlefield, are during disasters, following mass casualty incidents (MCI), and in emergency departments (EDs). Triage during a disaster involves field triage, which sorts disaster victims into categories ranging from the walking wounded to those with injuries who are salvageable to the unsalvageable and the dead.

In recent years, knowledge based system has been used to solve many complex problems by developing intelligent systems and fuzzy logic has proved to be a powerful tool for decision-making systems, such as expert systems and pattern classification systems. Fuzzy set theory has already been used in some medical knowledge based systems. In traditional rule-based approach, knowledge is encoded in the form of antecedent-consequent structure. When new data is encountered, it is matched to the antecedents clauses of each rule, and those rules where antecedent match a data exactly are fired, establishing the consequent clauses. This process continues until desired conclusion is reached, of no new rule can be fired. In the past decade, fuzzy logic has proved to be wonderful tool for intelligent systems in medicine. Knowledge-based systems at the department of medical computer sciences pursues methodological research in and practical development of knowledge based computer systems to assist in the decision-making processes for all areas of medical application [3]. Using fuzzy logic becomes the current trends of researchers. According to P. Hajek [3] fuzzy logic is useful for real world problem where there are different kinds of uncertainty. One kind of uncertainty is fuzziness that is no sharp transition from complete membership to non membership. In human reasoning much of the logic is not based on two values, it is not even multi-valued but fuzzy truth. In conventional logic everything is considered true or false, black or white but nothing in between. Fuzzy logic on the other hand takes into consideration all values in between. This types of uncertainty is mostly observed in medical cases during diagnosis, because the symptoms and related signs of the patients are subjective, which are not able to be expressed in the conventional logic. In one symptom, there are different levels of measurements in between. Because of this fuzzy logic is appropriate for medical cases. Fuzzy logic is based on fuzzy sets; a fuzzy set is a class of objects with continuum grades of membership" [4].

A fuzzy set is an extension of a conventional set. It has elements belonging to it to some degree of membership. This degree varies from 0 to 1. In conventional logic the degree of membership is either 0 for non membership or 1 for complete membership. Fuzziness results from imprecise boundaries of fuzzy sets [4]. It is based on emulating human thinking where elements are linguistic variables. Linguistic variables are variables whose values are sentences not numbers. Fuzzy sets are actually properties and fuzzy logic provides a way of finding conclusions for ambiguous inputs. Fuzzy sets represent common sense linguistic labels like slow, fast, small, large, heavy, low, medium, high, tall, etc. A given element can be a member of more than one fuzzy set at a time.

Various types of fuzzy membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions.

According to Siler and Buckley [5], fuzzy knowledge base systems are categorized into two types. First is fuzzy control system, which accepts inputs as numbers. The input number is then translated into a linguistic term. In fuzzy control systems the application domain is defined. The second type is fuzzy reasoning, which are system that attempt to emulate human thinking where the domain is not defined. Such a system deals with numbers and linguistic variables. So now a day fuzzy logic is an appropriate tool in order to develop knowledge base systems for conditions with different uncertainty or values in between, like linguistic variables.

But in Ethiopia there is no national computer based triage standard. Each hospital in Ethiopia uses their own triage system which is implemented manually by the help of nurses or doctors based on the status of the hospital profile. In addition to that as much as the researcher has been reviewed there is no any fuzzy logic knowledge base system which is developed for triage system. This study is investigated on the case of Menelik II hospital in Addis Ababa. In Menelik II hospital the hospital nurses have acted as a triage and sending to the concerned doctor for diagnosis based on the type of disease that the patients have. Still now in this hospital the triaging system is practicing manually.

1.1.1 The Triage Process

The nurse assesses and determines priority of care (triages) based not only on the patient's physical, developmental, and psychosocial needs but also on parameters of patient flow in the emergency care system and of health care access. According to the Emergency Nurses Association (ENA) [6], triage should be done by an experienced nurse with competency in triage. The nurse should accomplish the following during triage: take history appropriate to the severity of the complaint, obtain vital signs, ask predetermined ED/hospital enquired screening questions, and assign patient priority [7].

Triage may be either focused or comprehensive. Comprehensive triage refers to taking a complete history, checking vital signs, determining allergies, and, where appropriate, performing a physical examination. Focused triage is generally used for more minor illnesses or injuries and includes a more limited history and screening prior to assessing patient priority [8].

Generally according to Gottschalk [9] the following are a description of the triage process:

- A nurse measures the patient's vital symptoms and physiological parameters. The most essential of these are Systolic Blood Pressure (SBP), Heart Rate (HR), Temperature (T°),Respiration Rate (RR) and related vital signs
- Each of these vitals results are scored manually.
- These scores are then summed and the total defines the triage classification.
- This information is recorded on paper by the nurse, the patient then enters to the diagnosis based on the result that the triage nurse perceives.

1.1.2 Triage categories

A most commonly used triage acuity classification for patients uses four levels [10].

- **Class 1: Critical:** life- or limb-threatening illness/injury that needs immediate care.
- **Class 2: Acute**: significant alteration in physical or mental health that could potentially become life or limb threatening and needs intervention as soon as possible.
- **Class 3: Urgent:** significant physical or mental health problems that are not life threatening and need intervention in a timely fashion.
- **Class 4: Non urgent:** may receive care when convenient [11].

1.1.3 Customer Service at Triage

Customer service has become an increasingly emphasized aspect of the provision of emergency medical care, and is especially pertinent to the care of children. Every hospital in the country does not have the same patient satisfaction, which is used to assess the patient's and family's perception of the care that they received. Triage nurses and other personnel assisting in the process should be trained in the importance of delivering customer service excellence at the earliest appropriate time. Mayer and Cates [12] have suggested that this comprises three elements.

- Making the customer service diagnosis as well as the clinical diagnosis
- Negotiating agreement and resolution of expectations
- Building moments of truth into the clinical encounter.

1.2 Research Background

In the Information era where computer has affected almost every corner of our lives, medical field also cannot afford to be left behind computerization. The use of information system is to improve the quality of services, not only activities in emergency department. The number of people attending the emergency department is increasing from time to time.

Therefore, managing patients in hospitals and clinics become more and more challenging. Using artificial intelligence is the current trend in developing a system in medical field. Knowledge base systems have quickly evolved from an academic notion into a proven and highly marketable product. Knowledge based systems provide powerful and flexible means for obtaining solutions to a variety of problems that often cannot be dealt with other orthodox methods [13].

Most of the systems were developed to assist clinicians in the process of diagnosis, typically with the intentions that it would be used to the patients during the clinical assessment. Same goes to the triage assessment to the emergency department patients. Triage is a continuation process where patients are sorted, prioritized, and distributed based on their need for first aid. By using a knowledge based system to triage the patients, the medical staff can diagnose the patient based on the symptoms as shown by patients or as defined by patients. In the manual task, the triage nurses observe the symptoms of the patients, then they tried to categorize into the appropriate department for further investigation and examination. In recent years, computational intelligence has been used to solve many complex problems by developing intelligent systems. And fuzzy logic has proved to be a powerful tool for decision-making systems, such as expert systems and pattern classification systems. Fuzzy set theory has already been used in some medical expert systems. In this study, the researcher would like to discuss how fuzzy set theory and fuzzy logic can be used for developing knowledge based systems in medicine. Fuzzy logic is an appropriate tool for developing a medical knowledge based systems, because fuzzy considers all uncertainties and considered values in between two ranges. There are different methods which are used for developing such type of systems, like rule base system and case based system. But in this study the researcher had selected fuzzy logic because of the following limitations of rule based and case based system.

According to Berghofer and Garcia [14], Rule based system is depends on the specific rule that is given by the user. If there is a value which is related to that rule it displays the result, unless if there is a condition which is not specific but related to the given rule, the system does not give the result. Rule based system does not consider values in between the ranges. So this type of system is not suitable for triage system. Because symptoms does not identified in specific rule (yes or no) questions and answers.

On the other hand case based system is a methodology to model human reasoning for building intelligent systems. It store previous experience (cases) in memory and solve new problems by Retrieving, experience about similar situations, reusing the experience in context of new situation, use all or part, or adapt, test and storing or learn new experience in memory. But case base reasoning has limitations like, cases may not cover domain, most appropriate cases may not be retrieved, still need similarity, adaptation, and verification knowledge. So the system may retrieve cases which are not appropriate for the result. Because of these reasons fuzzy logic has been selected for this study.

1.3 Statement of the Problem

Medical treatment usually enables people to return to an active health status and economically productive life, often with no disability. By making people non-infectious through medical treatment, transmission can be prevented and the global burden of the disease considerably reduced. For this purpose in health centers triage system have played a significance role. The aim of triage department of hospitals is to reduce the amount of waiting time and increase the quality of services for the patients [15].

Triage decisions are made in response to the patient's signs and symptoms. There are two types of triage decisions [16]. These are primary and secondary decisions. Primary triage decisions are decisions that are given by observing the symptoms and signs of the patient and directly assign to the triage category. Secondary triage decisions are decisions which are made by the triage nurse by observing the symptoms and signs of the patients and taking some measurements if the category is not clear by only observing the symptoms. This is depends on the initiation of nursing interventions in order to expedite emergency care and promote patient comfort. The triage nurses may be measure the weight of the patient or may measure the temperature etc for further knowledge for better categorization.

The skill required by the triage staff includes clinical experience, good judgment quality, sense of humor, stress-tolerance, knowledge of available resources, problem solving ability and sense of anticipation. Identifying and triaging patient accurately and efficiently was a challenging task. Particularly, many health care institutions are increasingly overcrowded and this leads to longer waiting time of patient and increase treatment delay [17].

In Ethiopia Triage examination is commonly completed by a triage nurse. The triage nurse collected the required pillar symptoms and relevant information during patient history talking. Based on the acquired information that the triage have got from the patient, then the triage nurse categorizes the patient into the categories of the triage system for further examination. Accessibility of this information would help the human expert to make a proper decision regarding the patient's health problem.

Triage is the main gateway to process the patients' health problem in the hospital. Therefore, building a sound knowledge based system would help the general practitioner to provide effective and efficient health care services in the institution. But currently, there is no standardization of triage system in Ethiopia which can be used to facilitate the triage department medical experts and staff nurses.

The major problem which is common for all health care institutions regarding triage treatment is that the professional level of expertise mostly nurses is assigned for triage. But those nurses may not have enough knowledge and experience for triage categorization. The triage nurses should have general knowledge about every symptom of each disease. But this is not really observed in the domain area. So when patients come in to the hospital miss categorization of triage is occurred. The triage nurses ask the patient's problem in order to categorize the patient into appropriate department. But triage nurses categorize the patients depending on one or two major symptoms. But those symptoms may not enough for better categorization. In most cases like in injured patients, the triage nurses become frustrated and this leads them to miss calcification. In addition to that the overcrowded number of patients may enforce the triage nurses to miss-categorize the patient into different triage categories.

In medical problems, using fuzzy logic system is more recommended, because it can able to solve problems like which are more subjective. The symptoms of the patients are difficult to identify by using other reasoning mechanisms like rule based and case based. The problem is that those reasoning mechanisms are depends on the specific rules given or on the specific cases developed. Conditions in between the two ranges cannot be identified by rule based and case based rather it is easy in fuzzy logic. Fuzzy logic is able to consider values in between and linguistic expressions. For that reason, fuzzy logic for triage system is proposed.

Developing a knowledge based system would reduce the repetition of task, the burden of human expert and waiting time of patient in the hospital. The knowledge based system could be used to assist human expert by providing the required knowledge at the right time for decision making.

Basically, in this study an attempt was made to answer the following research questions:-

- What types of knowledge the human expert use in the diagnosing process of patient health problem?
- What is the suitable model, which is applicable to the proposed knowledge based system?
- How to develop knowledge base system for Triage system using Fuzzy inference system?
- How to evaluate the user acceptance of system that is developed for medical triage?

1.4. Objectives of the Study

1.4.1. General objective

The general objective of this research is to develop a fuzzy logic expert system for medical triage using fuzzy inference engine in order to provide better triage system for patients at Minelik II Hospital in Addis Ababa Ethiopia.

1.4.2. Specific objectives

To achieve the general objective, the following specific objectives are formulated.

- ✓ To acquire the necessary knowledge about triage system from primary and secondary sources using interview, and document analysis.
- ✓ To identify the type of knowledge that the human experts have used for triage system.
- ✓ To identify and use the appropriate model for triage system.
- ✓ To develop knowledge base system using fuzzy inference rule-based system.
- ✓ To test and evaluate the user acceptance of the developed prototype.
- ✓ To suggest recommendation for future work in the application of expert system using fuzzy logic.

1.5 Scope and limitation of the study

The study is limited to develop a knowledge based system for triage services in order to categorize the patient based on the identified symptoms. The knowledge based system is limited to identify patients' diseases and provide possible suggestion of triage categorization.

For the purpose of this study a sample of six diseases were taken based on the severity of the diseases currently have on the patients. Such diseases include TB, common cold, typhoid fever, pneumonia; HIV AIDS and Poisoning are selected based on the decisions made by experts, because since human health problems are unlimited in number, the study does not cover all patient cases. The prototype is limited to classify (triage) the proposed diseases based on the symptoms of the patient and then categorize the patient in ranking order. It does not include further examinations processes, it consider only the triage.

Some of the major challenge during system development is since the medical knowledge is described by its scientific name and the symptoms are subjective, so this makes the knowledge elicitation process and fuzzification somehow difficult. Interview does not consider patients; the researcher purposively selected the domain experts based on the recommendation of the medical director of the hospital, for knowledge acquisition, because they have experience and domain knowledge on the selected area. So the researcher have interviewed Doctors and Nurses who have enough knowledge on the process of triage system and symptoms of diseases who are recommended by the Medial director of the hospital.

1.6 Significance of the study

The expert systems have valuable asset to any institutions as a substantial source to support decisions making. In other word accessibility of knowledge strengthen institutional competency. Researchers in the area of expert system view knowledge in a broad sense as a state of mind, an object, a process and an access to information. Knowledge based system try to solve problems in a human expert like by using stored knowledge elicited from domain expert. Therefore, the proposed expert system has the following significance in the triage service.

- ❖ The system can help the triage to make better decision during patient categorization based on their symptom.
- ❖ The proposed system can be used as quick reference for the triage nurses to identify the patient health problem.
- ❖ The system is developed for the purpose of supporting or assisting decision maker. Therefore, propose system can used to fill gap of lack of human expert in the domain area.
- ❖ The proposed knowledge based system can be used as teaching instrument for medical students how to identify patient symptoms and to provide appropriate recommendation.

So generally the system has significant advantages for triage nurses, doctors, medical students, and indirectly for patients by minimizing their time lost.

1.7 Methodology of the Study

There are different types of methodologies used in research. The most common are design science, qualitative and quantitative types of methodology. Design science is a research methodology, which offers specific guidelines for evaluation and iteration within research projects. Design science research focuses on the development and performance of (designed) artifacts with the explicit intention of improving the functional performance of the artifact. Design science research is typically applied to categories of artifacts including (but not limited to) algorithms, human/computer interfaces, design methodologies (including process models) and languages. In order to achieve the objectives of this research the following methods and techniques have been used.

1.7.1 Knowledge Acquisition Methods

In this study to acquire the desirable knowledge both secondary and primary source of knowledge have been used. Primary knowledge was gathered from Domain Experts (Doctors, Nurses) in Menelik II Hospital by using interview with purposively selected doctors and nurses, and secondary knowledge was gathered by referring different written materials on dangerous diseases and symptoms.

The interview has been made on 6 purposively selected diseases which are currently serious and are the cause of death for most people. Those diseases are selected by the recommendation of the domain experts in Menelik II Hospital.

The following were some of the reasons which lead the researcher to conduct in order together the primary and secondary knowledge.

1. **Interview:** the primary knowledge has been collected using interview. The purpose of conducting interviews is to collect information from a single person through a systematic and structured format. Because interviews have the following advantages [18]:
    - Interviews typically allow for more focused discussions and follow-up questions.
    - Individuals may offer information in interviews that they wouldn't offer in a group context.
    - Interviews can be an excellent source for stories and context.
    - The interviewer can observe the nonverbal behaviors of an interviewee
    - Useful for getting quotes and stories.

On the other hand secondary source of knowledge have been collected by using document analysis and by using internet.

2. **Document Review:** Document review is a way of collecting data by reviewing existing documents. The documents may be internal to a program or organization such as records of what components of management program were implemented or may be external such as records served by management program. Documents in hard copy and electronic copies like reports, program logs, performance ratings, funding proposals, meeting minutes, newsletters, and marketing materials were included.
    Document reviews have the following advantages.
    I. **To gather background information:** Reviewing existing documents helps you understand the history, philosophy, and operation of the program you are evaluating and the organization in which it operates.

    II. **Gives additional information to develop other data collection methods:** Reviewing existing documents to better understand the organization that the researcher uses which helps to formulate questions for interviews, questionnaires, or focus group or develop an observation guide.
    III. **Useful to answer "what and how many" evaluation questions:** reviewing documents is useful for answering basic evaluation questions related to the number and type of participants, number and type of organization personnel, and program costs.

1.7.2 Sampling Techniques

As a sampling technique Purposive sampling technique were used to select experts (Doctors and Nurses) for knowledge acquisition. The selection criteria of domain experts for the study were based on their profession and their immediate position and those doctors and nurses have been suggested by the medical director of the hospital. As discussed before the interview has been made on 6 diseases, those diseases also selected based on purposive sampling which are expected as they are the source of death for most patients based on the recommendation of the domain experts.

Purposive sampling is one of the most common sampling techniques in qualitative research in which participants are decided to preselected criteria relevant to a particular research question. The experts are purposely selected for the sake of gaining relevant information [19].

To get the necessary data from the domain experts, unstructured interviews were conducted with four experts (two Doctors and two Nurses).

1.7.3 Knowledge modeling and representation methods

Models are used to capture the essential features of real systems by breaking them down into more manageable parts that are easy to understand and to manipulate. Models are very much associated with the domain they represent [20]. That domain defines their practicing communities, modeling languages and the associated tools used. *"A model is a simplification of reality"* [21].

Real systems are large entities consisting of interrelated components working together in a complex manner. Models help people to appreciate and understand such complexity by enabling them to look at each particular area of the system in turn. Models are used in systems development activities to draw the blueprints of the system and to facilitate communication between different people in the team at different levels of abstraction. People have different views of the system and models can help them understand these views in a unified manner. In this study the hierarchical knowledge modeling technique have been used.

1.8 Implementation tool and Techniques

Fuzzy Logic in Matlab tool is used as an implementation tool for this research. Fuzzy logic is a precise problem-solving methodology which is able to simultaneously handle numerical data and linguistic knowledge. It is a technique that facilitates the control of a complicated system without knowledge of its mathematical description. Fuzzy logic differs from classical logic in that statements are no longer black or white, true or false, on or off [22].
In traditional logic an object takes on a value of either zero or one. In fuzzy logic, a statement can assume any real value between 0 and 1, representing the degree to which an element belongs to a given set.
Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multi valued logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree.
The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated in parallel, and the

order of the rules is unimportant.
In the case of this research, this fuzzy logic is selected because the triage is identified the patients by using symptoms, so the symptoms are used as an input, and then by applying the rules of if-then it displays the output.
The major advantage of fuzzy reasoning is the ability to reply to a **yes-no** question with a not quite **'yes' or 'no'** answer. Humans do this kind of thing all the time (think how rarely you get a straight answer to a seemingly simple question), but it is a rather new trick for computers.
So in the case of triage system of symptom identification since different diseases have similar symptoms it is difficult to say strictly 'say' or 'no', so fuzzy logic is a good choice to handle this types of problems with some degree of certainty.

1.9 Literature Review

Knowledge-based system (KBS) is a computer program that is derived from a computer science field of study known as Artificial Intelligence (AI). The aim of AI is understanding intelligence by developing computer programs that show intelligent behavior. It deals with methods of inferring mechanisms using the computer and in what way knowledge can be represented using different techniques for inferring.
In this research Related literatures, journal articles and books have been reviewed which leads the researcher to have understanding on knowledge based systems, principles, techniques and tools which are significant for this research that are specifically applied in the triage system for patient categorization process.

1.10 Organization of the Thesis

The study is organized into five chapters. The first chapter deals with the introduction, which contains the background of the study, statement of problem, objectives, scope and limitations of the study, the significance of the study, research methodology, data collection methods and implementation tool that is used for this research. The second chapter provides, review of literature on the knowledge based systems, architecture of knowledge based system, Definition and related concepts about Fuzzy inference system have been included. The third chapter discusses about knowledge acquisition, conceptual modeling and knowledge representation. Chapter four deals with knowledge based system implementation and development. The fifth chapter finally gives conclusion of this research and recommendations for future work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of knowledge base system

The concept of knowledge base system is derived from the field of artificial intelligence. It is one of the main family members of the artificial intelligence. Artificial intelligence intends understanding of human intelligence and building of computer programs that are capable of simulation or acting one or more of intelligent behavior. Intelligent behavior includes cognitive skill like thinking, problem solving, learning, understanding, emotion, consciousness, intuition and creativity, etc.

Now days, some of the behaviors such as problem solving, learning and understanding are handled by computer programs. Knowledge base system is a computer program that can solve and simplify the problems that is encountered in human expert by using knowledge about the application domain and problem solving techniques. Human experts use their knowledge about the domain and techniques that lead how to use the knowledge to solve problems. Computer knowledge base systems handle problems in the same way as humans do. The system represents knowledge about a specific application domain and uses one or more techniques that guide to use knowledge to solve problems [23].

Knowledge base system is the general term used for the process of eliciting, structuring and representing knowledge from some knowledge source mostly from human experts and developing a computational problem solving model, specifically a program to be used in some consultative or advisory role [24].

Industries and societies are becoming knowledge oriented and dependent of decision making ability of expert. Knowledge base system can act as an expert on demand; can save money by leveraging experts; allowing users to function at higher level and promoting consistency [23]. Knowledge base systems increase productivity, document when there is shortage of knowledge for future use, enhances problem solving capability and this leads to increase quality in problem solving process.

As discussed by Sajja & Akerkar [23], Knowledge based systems are more useful than the traditional computer based information systems when:

- There is shortage of experts
- Expertise is to be multiplied and stored for future use.
- There is more group of platform than one experts' knowledge.
- Intelligent assistance is important for decision making.

However, the scarcity and nature of knowledge make the knowledge base system development process difficult and complex. Some of the limitations of knowledge base system are due to the following reasons [23].

- ✓ Large volume of Knowledge Acquisition, representation and manipulation.
- ✓ Limitations of cognitive science and other scientific methods.

- ✓ Abstract nature of the knowledge.

Knowledge base systems are systems which are capable of offering solutions to specific problems in a given domain or which are able to give advice, both in a way and at a level comparable to that of experts in the field.

The problems in the fields for which knowledge based systems are being developed are those that require considerable human expertise for their solution. Examples of such problem domains are medical diagnosis of disease, financial advice, products design, etc. Most of the present day knowledge based systems are only capable of dealing with restricted problem areas. Nevertheless, even in highly restricted domains, knowledge base systems usually need large amounts of knowledge to arrive at a performance comparable to that of human experts in the field [25].

The first program that actually constructed a mathematical proof of a theorem in number theory was developed by **M. Davis** as early as 1954 [26].

The best known system is GPS (General Problem Solver), developed by **Newell, Simon and Shaw** [27]. A given problem is represented in terms of an initial state, a wished for final state and a set of transitions to transform states into new states. Given such a representation by means of states and operations, GPS generates a sequence of transitions that transform the initial state into the given final state when applied in order. GPS has not been very successful. First, representing a non-trivial problem in terms which could be processed by GPS proved to be no easy task. Secondly, GPS turned out to be rather inefficient. Since GPS was a general problem solver, specific knowledge of the problem at hand could not be exploited in choosing a transition on a given state, not even if such knowledge indicated that a specific transition would lead to the solution of the problem more efficiently [28]. In each step GPS examined all possible transitions, thus yielding an exponential time complexity. Although the success of GPS as a problem solver has been rather limited, GPS initiated a significant shift of attention in artificial intelligence research towards more specialized systems. This shift in attention from general problem solvers to specialized systems, in which the reasoning process could be monitored using knowledge of the given problem, is generally viewed as a breakthrough in artificial intelligence.
For problems arising in practice in many domains, there are no well-defined solutions which can be found in the literature. The knowledge an expert in the field is generally not laid down in clear definitions or unambiguous algorithms, but merely exists in rules of thumb and facts learned by experience, called heuristics. So, the knowledge incorporated in an expert system is highly domain dependent. The success of expert systems is mainly due to their capability for representing heuristic knowledge and techniques, and for making these applicable for computers. Generally, knowledge base systems are able to comment upon the solutions and advice they have given, based on the knowledge present in the system. Moreover, knowledge base systems offer the possibility for integrating new knowledge with the knowledge that is already present, in a flexible manner.

A knowledge base system typically comprises the following two essential components:

- A knowledge base capturing the domain-specific knowledge, and
- An inference engine consisting of algorithms for manipulating the knowledge represented in the knowledge base.

The best-known expert system in medicine, developed in the seventies, is MYCIN. The development of this expert system took place at Stanford University; especially **Shortliffe** [29] played an important role in its development.

MYCIN advises the administration of a number of drugs that should control the disease by suppressing the indicated organisms. The interaction of the prescribed drugs among themselves and with the drugs the patient already takes, possible toxic drug reactions, etc. are also taken into account. Moreover, MYCIN is able to comment on the diagnosis it has arrived at, and the prescription of the drugs. The MYCIN system clearly left its mark on the expert systems that have been developed.

2.2 Architecture of a Knowledge Base System

Architecture of a Knowledge Base System is tool, or shell, is a software development environment containing the basic components of KBS. The core components of KBS are the knowledge base and the reasoning engine. The following Figure 2.1 shows the main building blocks of knowledge base system [30].

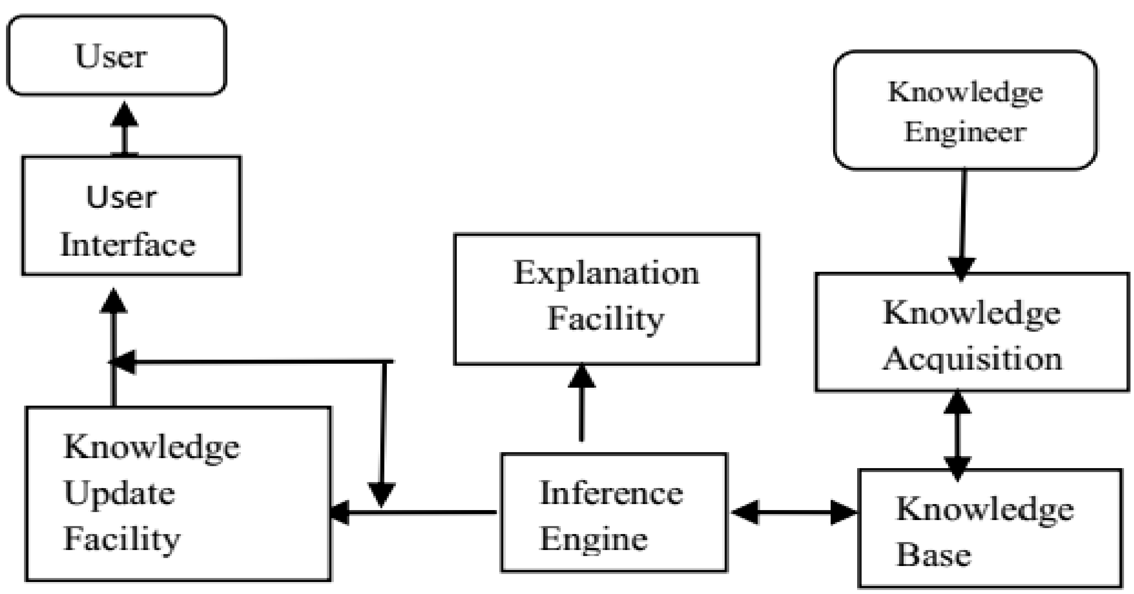


Fig 2.1: Architecture of knowledge base system [31].

Knowledge base: the knowledge base contains necessary knowledge about the domain that is required for understanding, formulating and solving the problems. Knowledge can acquire from human expert, documents, books, novice and others [32].

Inference engine: inference engine is a brain of KBS, it also known as rule interpreter. It is a software program and problem solving component, which infers the knowledge available in the knowledge base. It compares the user's information with the knowledge in knowledge base, and derives whatever conclusions may logically follow. It allows new inferences to be made from the case specific data and the knowledge in the knowledge base.

There are two common inference methods:

> **Backward-chaining:** Inference Engine guesses a conclusion or the result and then attempts to prove that this guess is correct after it makes some decision.
>
> **Forward-Chaining:** Inference Engine compares the facts with the IF part of a rule, and decide a conclusion from the THEN part of that rule.

In the case of this research the system has used the forward chaining as the main inference engine mechanism, because the system tries to make decision based on the facts, so after analyzing those facts the system gives the result. Forward chaining starts with the available data and uses inference rules to extract more data until a goal is reached. An inference engine using forward chaining searches the inference rules until it finds one where the antecedent (If clause) is known to be true. When such a rule is found, the engine can conclude, or infer, the consequent (Then clause), resulting in the addition of new information to its data. In the case of this research, the inference engine starts from the fuzzified symptoms of the disease, and then based on the rules and membership functions designed for the system; it recommends the possible diseases as a result. So it is a forward chaining principle.

In the case of this research the inference engine is called fuzzy inference engine. Fuzzy Logic Toolbox software provides a stand-alone C code fuzzy inference engine.

Fuzzy inference engine can perform the following tasks:

- Perform fuzzy inference using a FIS structure file and an input data file.
- Customize the fuzzy inference engine to include your own membership functions.
- Embed the executable code in other external applications.

Knowledge Acquisition: Knowledge acquisition is the accumulation, transfer and transformation of problem-solving expertise from experts and/or documented knowledge sources to a computer program for constructing or expanding the knowledge base. It is a subsystem which helps experts to build knowledge bases. The knowledge acquisition, techniques used are, interviews and document reviews.

Explanation: It is a subsystem that explains the system's actions. The explanation can range from how the final or intermediate solutions were arrived at to justifying the need for additional data. Here user would like to ask the basic questions why and how and serves as a tutor in sharing the system's knowledge with the user.

User interface: It is a means of communication with the user. It provides facilities such as menus, graphical interface etc., to make the dialog user friendly. Responsibility of user interface is to convert the rules from its internal representation (which user may not understand) to the user understandable form. [33].

Domain expert: individuals who currently are experts in solving problem of the domain area. Domain expert has special knowledge, judgment, experience and methods to give advice and solve problems.

User: individuals who consults with the system to get advice with the system which would have been provided by the expert.

2.3 Expert System Life Cycle

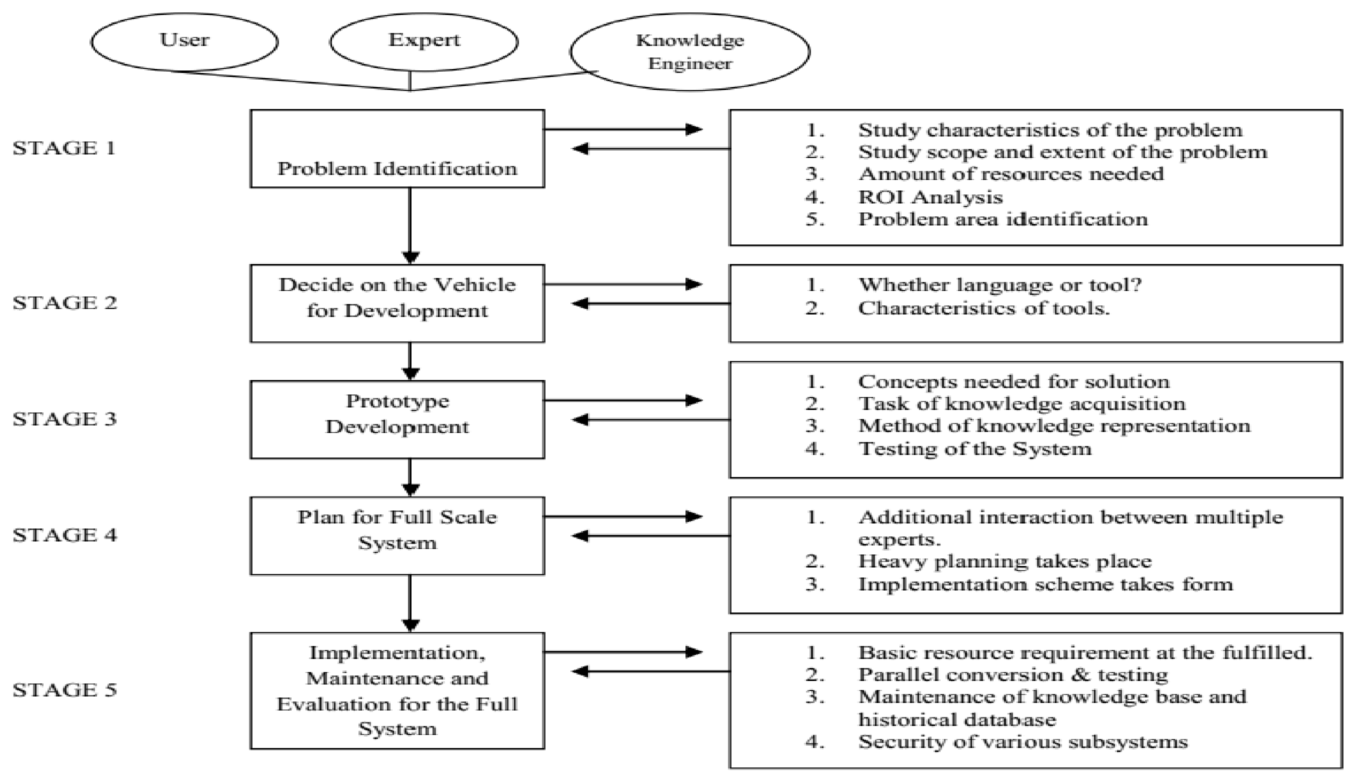


Fig. 2.2: Expert system life cycle [34].

There are five major stages in the development of a knowledge based system. Each stage has its own unique features and a correlation with other stages.

1. **Identification of the problem:** In this stage, the expert and the knowledge engineer interact to identify the problem. The major points discussed before for the characteristics of the problem are studied. The scope and the extent are considered. The amount of resources needed, e.g. men, computing resources, finance etc. are identified. Areas in the problem which can give much trouble are identified and a conceptual solution for that problem and the overall specification is made.
2. **Decision about the mode of development:** Once the problem is identified, the immediate step would be to decide on the vehicle for development. The knowledge engineer can develop the system from scratch using a programming language or any conventional tool or adopt a shell for development. In this stage, various shells and tools are identified and analyzed for the suitability. Those tools whose features fit the characteristics of the problem are analyzed in detail. For the case of this research Fuzzy inference system tool using Matlab environment is identified and used.
3. **Development of a prototype:** Before developing a prototype, the following are the prerequisite activities:
   - Decide on what concepts are needed to produce the solution.
   - After this, the task of knowledge acquisition begins. The knowledge engineer (researcher) and the domain expert interact frequently and the domain-specific knowledge is extracted.
   - Once the knowledge is acquired, the knowledge engineer decides on the method of representation. In the identification phase, a conceptual picture of knowledge representation would have emerged. In this stage, that view is either enforced or modified.
   - When the knowledge representation scheme and the knowledge are available, a prototype constructed. This prototype undergoes the process of testing for various problems and revision of the prototype takes place.
4. **Planning for a full-scale system:** The success of the prototype provides the needs impetus for the full-scale system. In prototype construction, the area in the problem which can be implemented with relative ease is first chosen.
5. **Final implementation, maintenance and evaluation:** This is the final life cycle stage of an expert system. The full scale system developed is implemented at the site. The basic resource requirements at the site are fulfilled and parallel conversion and testing techniques are adopted. The final system undergoes rigorous testing and later handed over to the user. Maintenance of the system implies tuning of the knowledge base because knowledge, the environment and types of problems that arrive are never static. The historical database has to be maintained and the minor modifications made on inference engine have to be kept track off. Evaluation is a difficult task for any AI programs. As mentioned previously, solutions for AI problems are only satisfactory. In

the most of knowledge based systems, the human experts are used for the evaluation of the system.

2.4 Definition of Fuzzy logic system

The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated in parallel, and the order of the rules is unimportant. The rules themselves are useful because they refer to variables and the adjectives that describe those variables. Before one can build a system that interprets rules, it is a must to define all the terms that is plan on using and the adjectives that describe them. For example to say that the water is hot, you need to define the range that the water's temperature can be expected to vary as well as what we mean by the word hot [35].
Fig 2.3 provides a roadmap for the fuzzy inference process. It shows the general description of a fuzzy system on the left and a specific fuzzy system on the right.

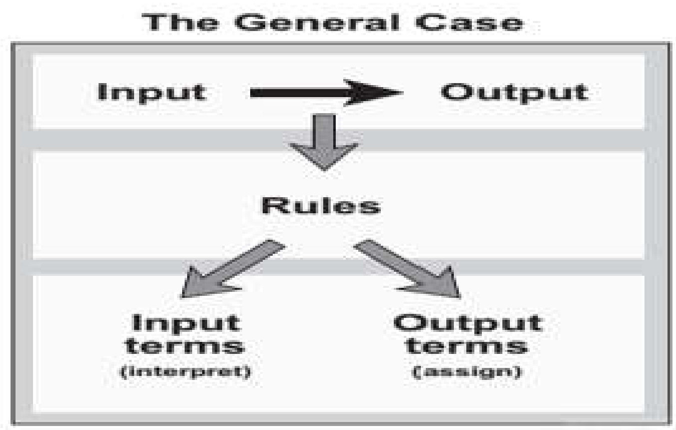


Fig 2.3: Fuzzy inference process [35].

Fuzzy inference is a method that interprets the values in the input vector and, based on some set of rules, assigns values to the output vector.
In fuzzy logic, the truth of any statement becomes a matter of degree. Any statement can be fuzzy. The major advantage that fuzzy reasoning offers is the ability to reply to a yes-no question with a **not quite-yes-or-no** answer. Humans do this kind of thing all the time (think how rarely you get a straight answer to a seemingly simple question) [36].
How does it work? Reasoning in fuzzy logic is just a matter of generalizing the familiar yes-no (Boolean) logic. If you give true the numerical value of 1 and false the numerical value of 0, this value indicates that fuzzy logic also permits in-between values like 0 and 1.

2.5 Membership Functions

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is referred to as the universe of discourse, a fancy name for a simple concept. For example let’s take fever, in this case, the universe of discourse is all degree of fever, say from 35 to 42^{o}C, and the word fever would correspond to a curve that defines the degree to which any value that passes through the curve. In this case fever has three membership functions, namely ‘low’, ‘normal’ and ‘high’. Each membership functions have its parameters which are included in the range. So for fever the range is determined from 36°C to 42°C. The membership function called ‘low’ have parameters between 35°C to 36°C, including any number between 35°C and 36°C. Similarly membership function called ‘normal’, have parameters from 37 to 38°C, and membership function called ‘high’ have parameters from 39°C to 42°C including every number between the parameters. Figure 2.4 shows the membership function of fever with its respective parameters.

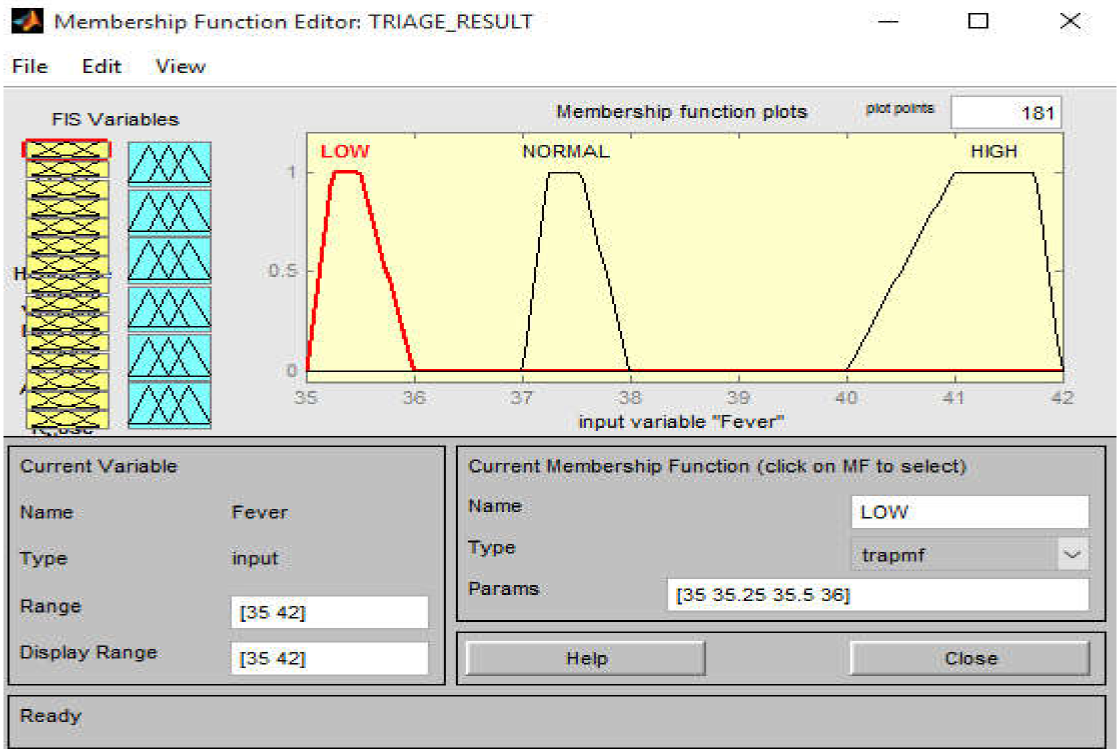


Fig 2.4 Membership functions of fever

2.5.1 Types of Membership Functions

The only condition a membership function must really satisfy is that it must vary between 0 and 1 or between the ranges given depending on the case. The function itself can be an arbitrary curve whose shape we can define as a function that suits our problem from the point of view of simplicity, convenience, speed, and efficiency [37].

By convention, all membership functions have the letters **mf** at the end of their names. The types of membership functions are described as follows.

1. **Triangular Membership Function**

The simplest Membership function which is formed by using three straight lines and it has the function name **trimf.** This function is nothing more than a collection of three points forming a triangle. Triangular membership functions are used for 3 membership functions. Figure 2.5

shows the structure of triangular membership function for fever with the membership functions of 'low', 'normal' and 'high'.

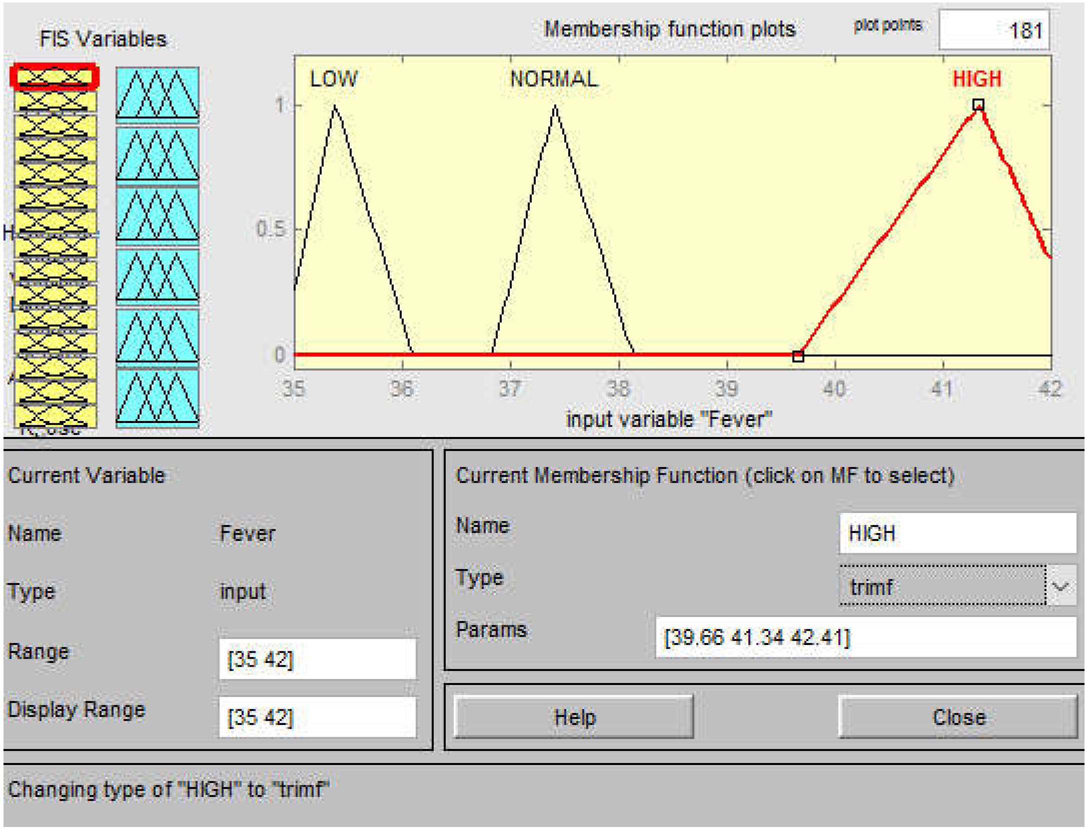


Fig 2.5: Triangular membership function

2. The trapezoidal membership function

The Trapezoidal membership function which is represented as **trapmf** has a flat top and really is just a truncated triangle curve. These straight line membership functions have the advantage of simplicity. This type membership functions is used for three values for which the values have a continuous gap between them. The following figure 2.6 shows trapezoidal membership function

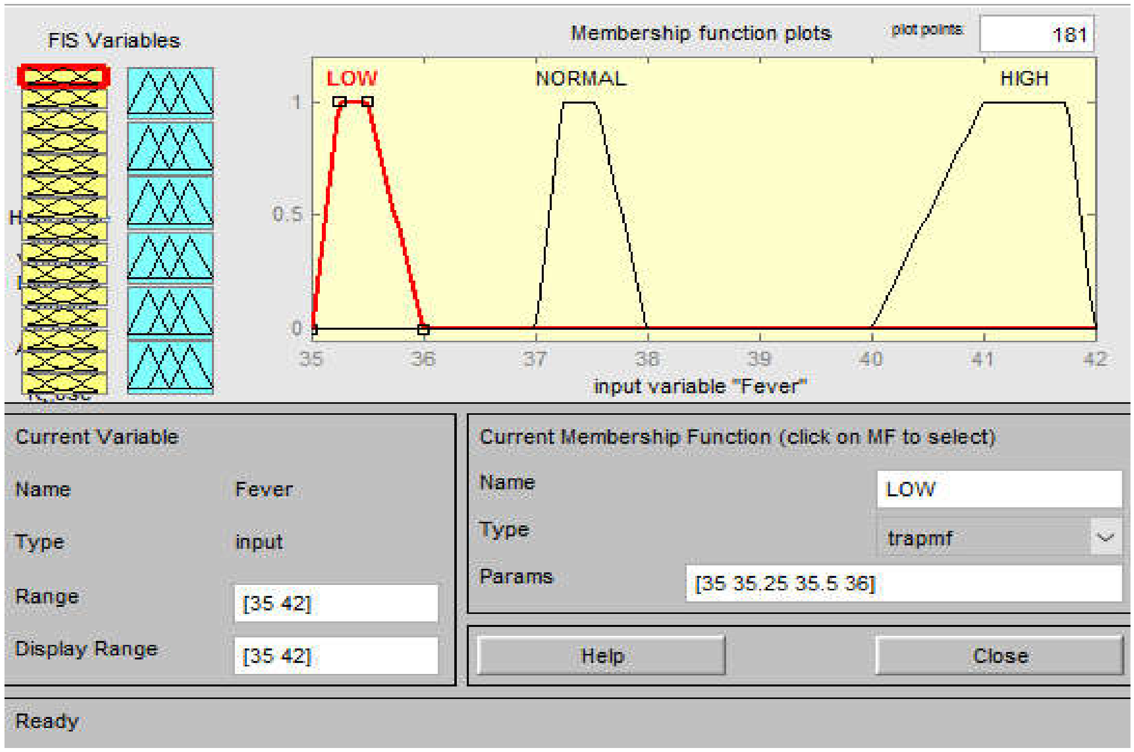


Fig 2.6 Trapezoidal membership function

3. **Gaussian curve Membership function:** There are two membership functions are built on the Gaussian distribution curve: a simple **Gaussian curve** and a **two-sided** composite of two different Gaussian curves. The two functions are **gaussmf** and **gauss2mf.**

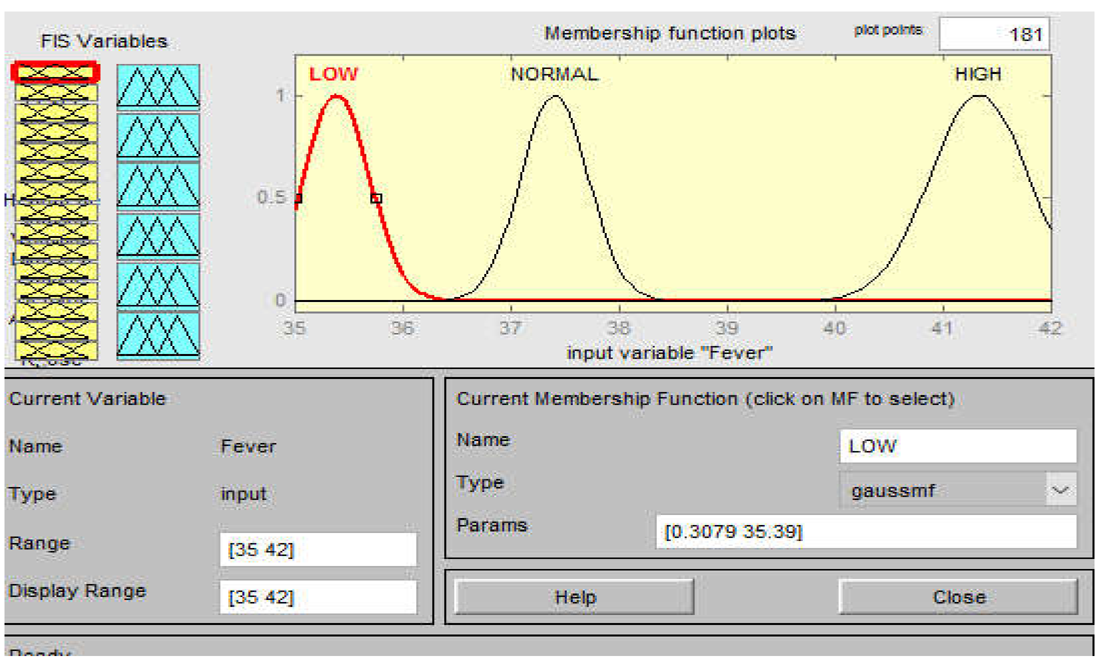


Fig 2.7: Gaussian Membership function

4. **Bell shaped membership Function:** it is specified by three parameters and has the function name **gbellmf**.

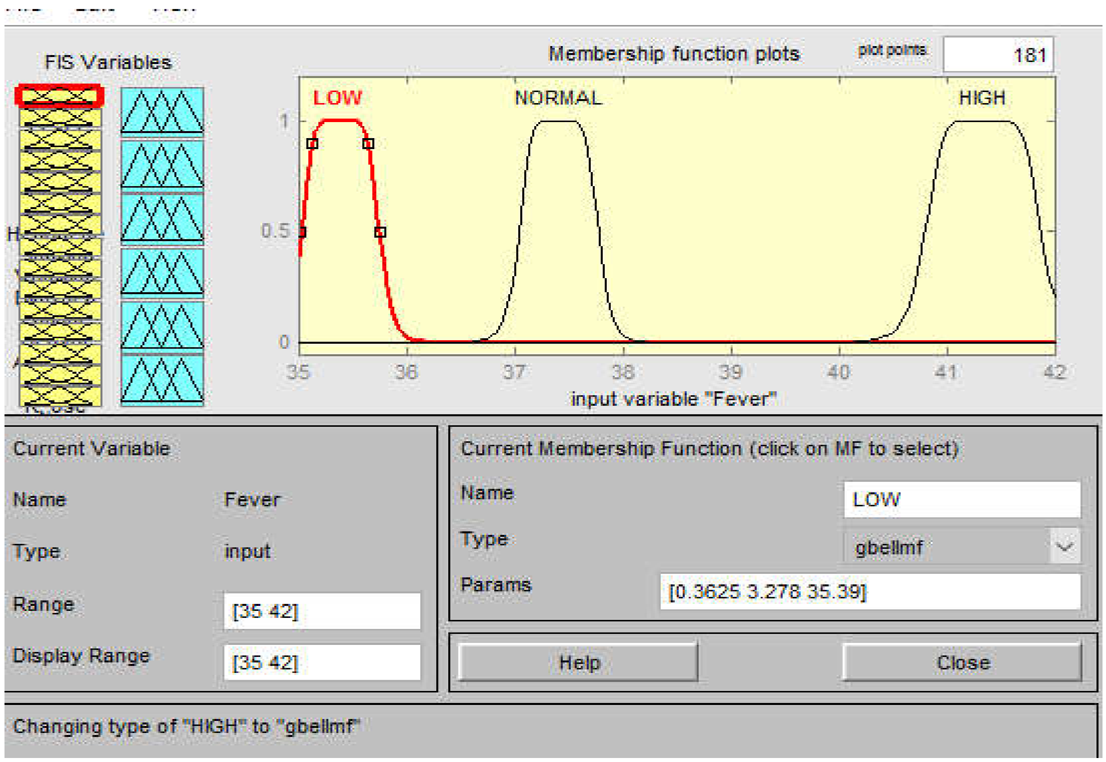


Fig 2.8: Bell shaped membership function

Although the Gaussian membership functions and bell membership functions achieves smoothness, they are unable to specify asymmetric membership functions, which are important in certain applications.

5. **Sigmoidal membership function:** Sigmoidal is either open left or right.

Asymmetric and closed (i.e. not open to the left or right)membership functions can be synthesized using two **Sigmoidal** functions, so in addition to the basic **sigmf,** you also have the difference between two **Sigmoidal** functions, **dsigmf,** and the product of two **Sigmoidal** functions **psigmf.**

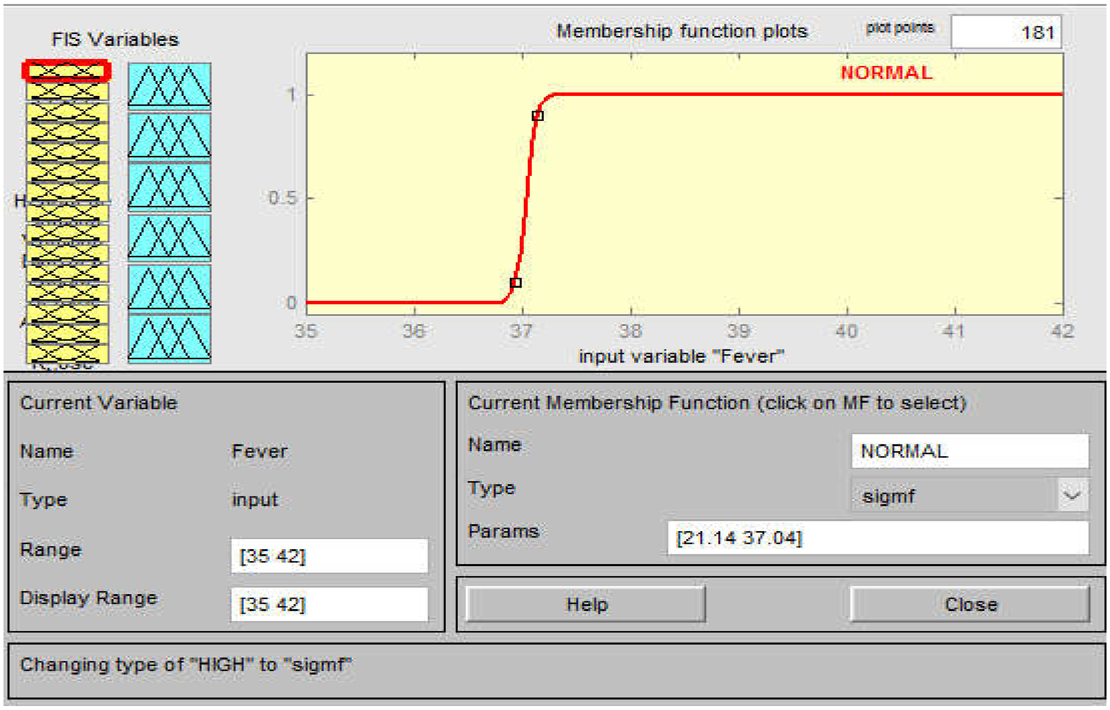


Fig 2.9 Sigmoidal membership function

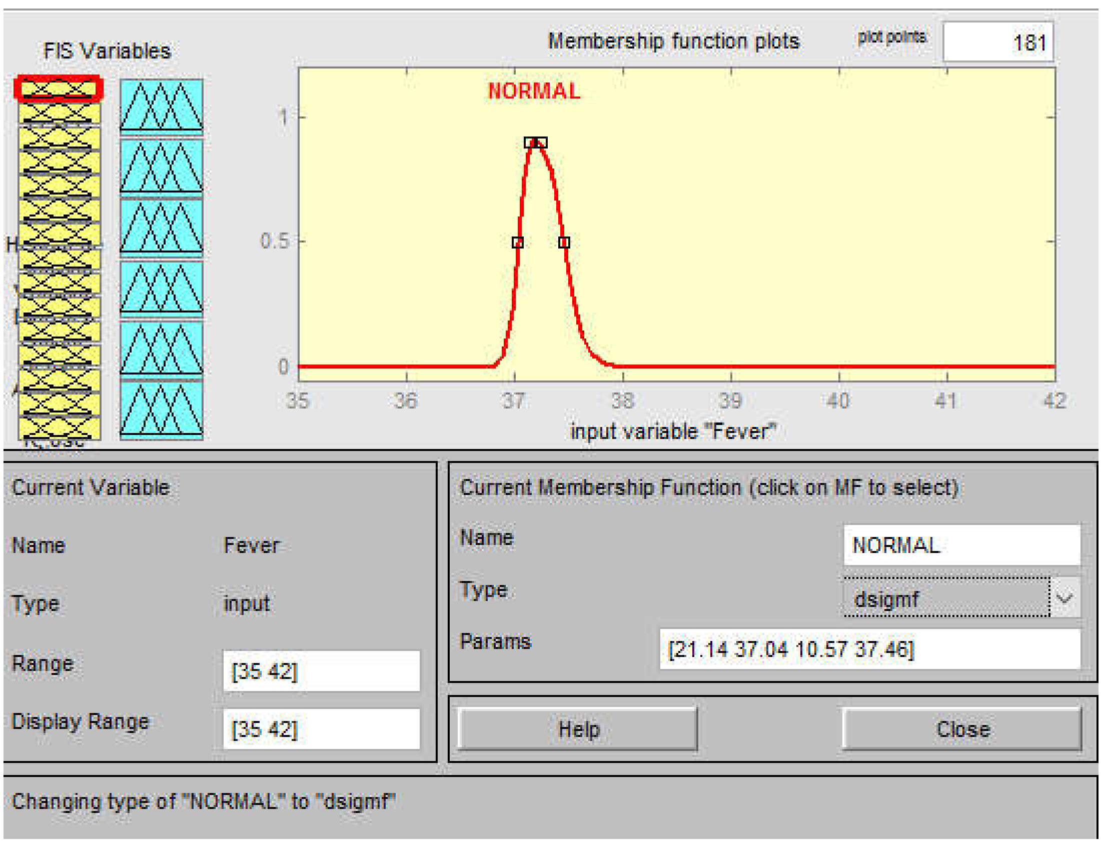


Fig 2.10 dsigmoidal membership function

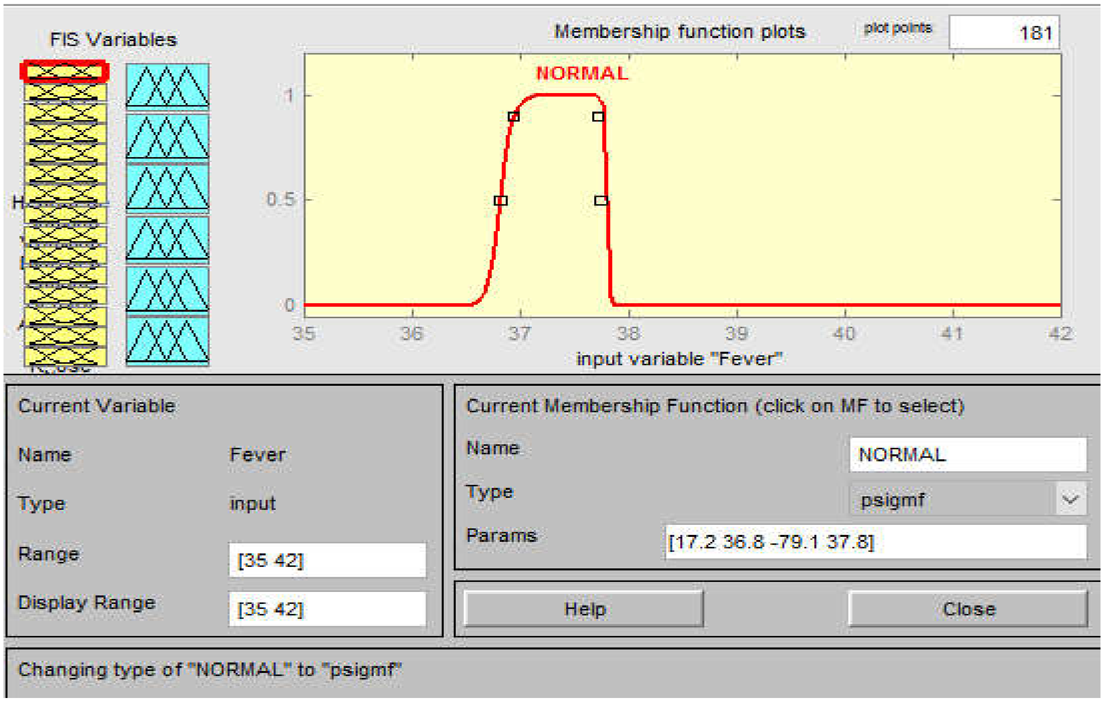


Fig 2.11 psigmoidal membership function

6. Polynomial based Membership function: curves account for several of the membership functions in the toolbox. Three related membership functions are the Z, S, and Pi curves, all named because of their shape. The function **zmf** is the asymmetrical polynomial curve open to the left, **smf** is the mirror-image function that opens to the right, and **pimf** is zero on both extremes with a rise in the middle.

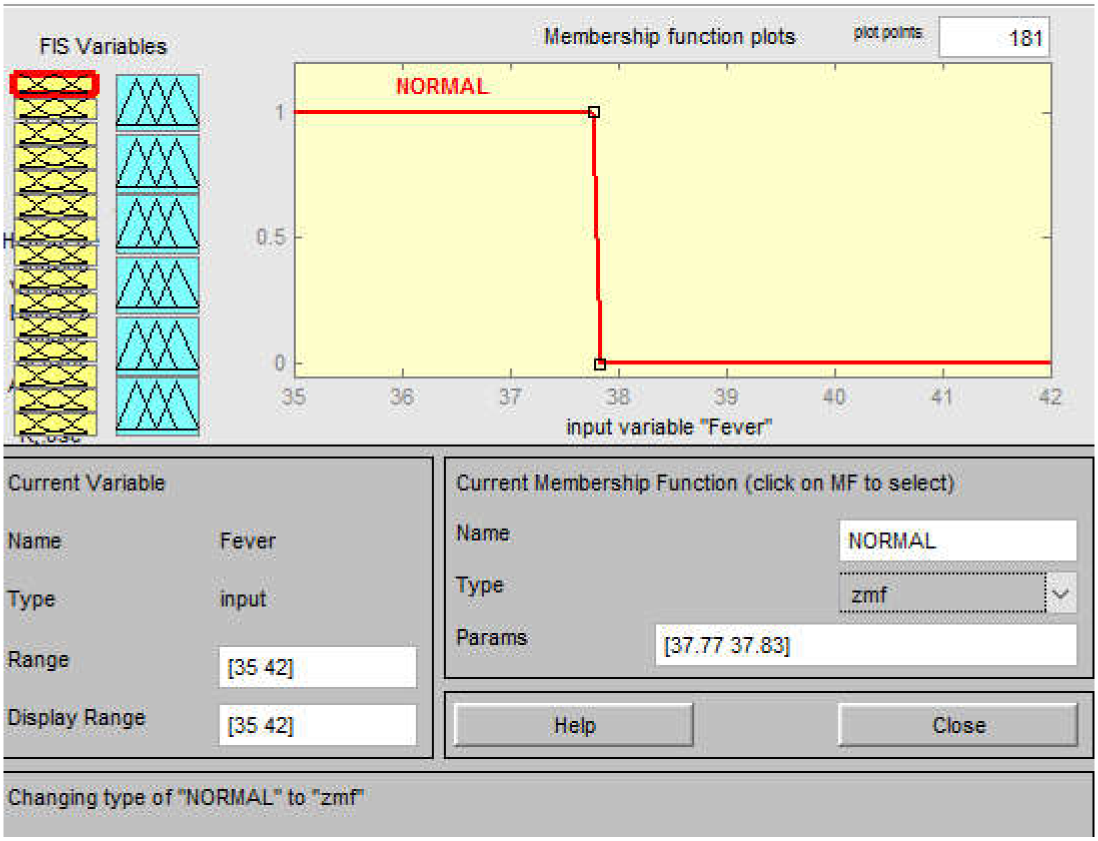


Fig 2.12 Z membership function

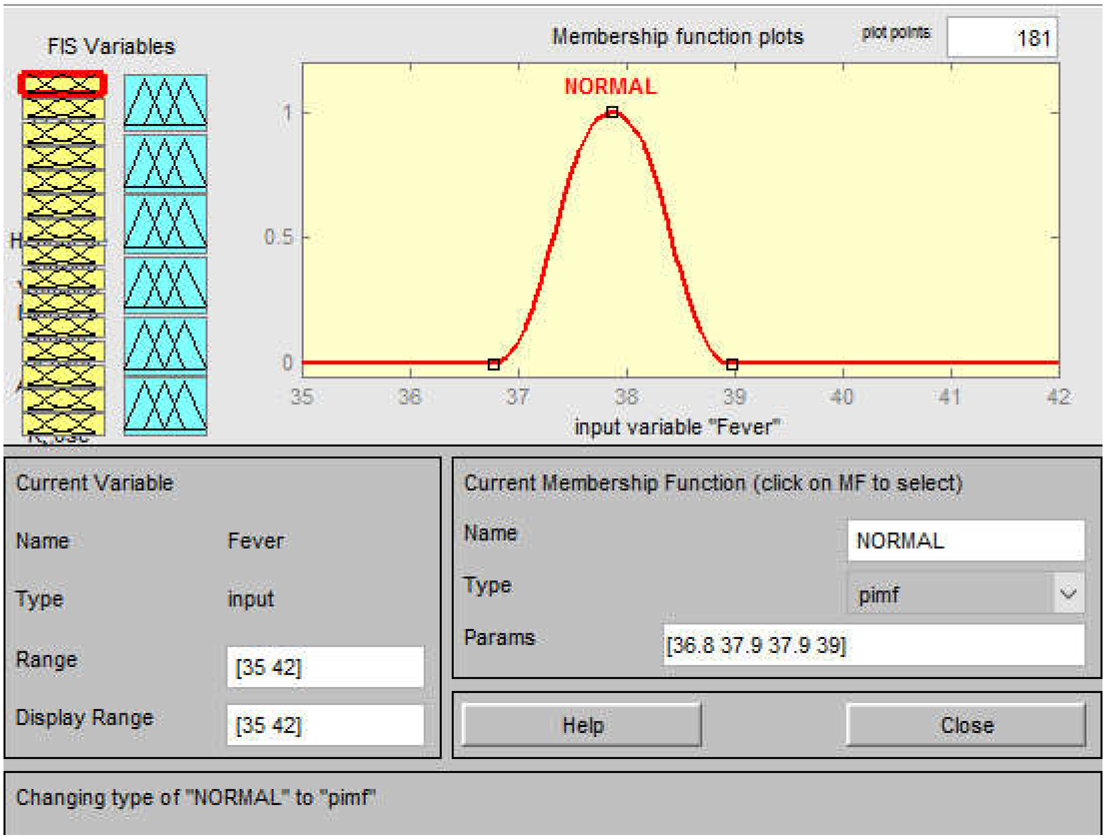


Fig 2.13 Pi membership function

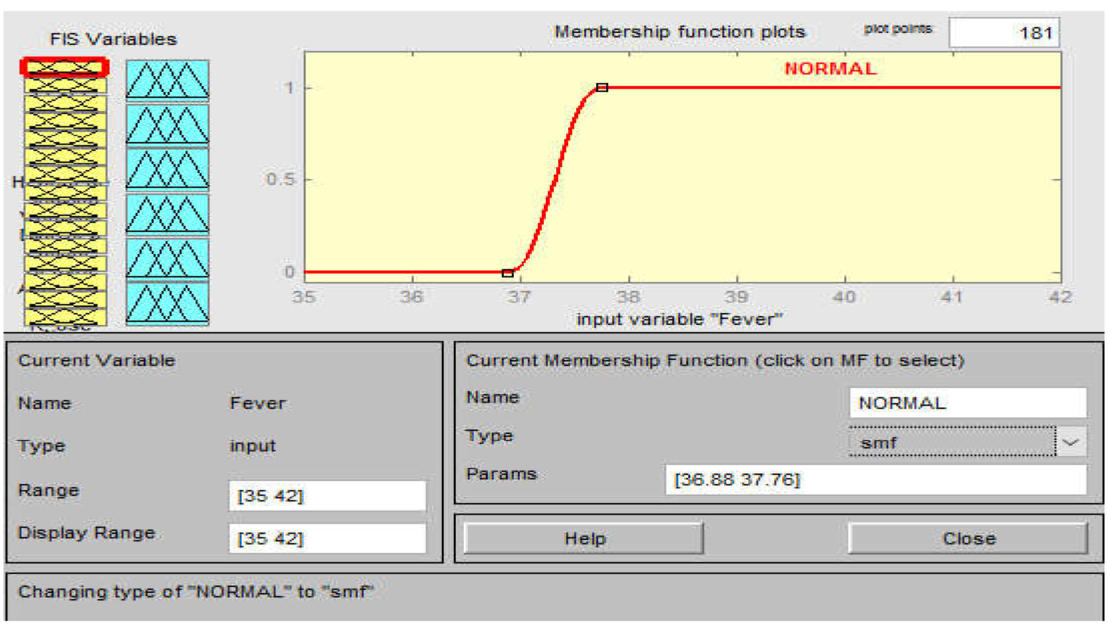


Fig 2.14 S membership function

There is a very wide selection to choose from when you're selecting a membership function. In addition to that it is also possible to create custom membership functions with the toolbox. However, if a list based on expanded membership functions seems too complicated, just remember that it could probably get along very well with just one or two types of membership functions, for example the triangle and trapezoid functions. The selection is wide for those who want to explore the possibilities, but expansive membership functions are not necessary for good fuzzy inference systems.
So the selection of the membership functions are depends on the properties of the variable that is used in the fuzzy inference. For example, if the variables have three values, it is recommended to use triangular **trimf,** and if the variables have no extreme **0** or **1** value, it is recommended to use Gaussian membership function. So the researcher has selected the appropriate membership function based on the variables that are used in the fuzzy inference system.

2.6 If-Then Rules

Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. These **if-then** rule statements are used to formulate the conditional statements that comprise fuzzy logic.
A single fuzzy if-then rule assumes the form [38].
if x is A then y is B
Where A and B are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule “x is A” is called the antecedent or premise, while the then-part of the rule “y is B” is called the consequent or conclusion.
An example of such a rule might be: *If fever is high then Disease is Typhoid.*

The concept good is represented as a number between 0 and 1, and so the antecedent is an interpretation that returns a single number between 0 and 1. Conversely, average is represented as a fuzzy set, and so the consequent is an assignment that assigns the entire fuzzy set B to the output variable y. In the if-then rule, the word gets used in two entirely different ways depending on whether it appears in the antecedent or the consequent.

In general, the input to an if-then rule is the current value for the input variable and the output is an entire fuzzy set. This set later defuzzified, assigning one value to the output.
Interpreting an if-then rule involves distinct parts:

- First evaluating the antecedent (which involves fuzzifying the input and applying any necessary fuzzy operators) and
- Second applying that result to the consequent (known as implication).

If the antecedent is true to some degree of membership, then the consequent is also true to that same degree.

2.7 Fuzzy Inference Process

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made. In this section the researcher is tried to describe the fuzzy inference process and uses the example of the two-input, one-output, and three-rule tipping problem [39].
Information flows from left to right, from two inputs to a single output. The parallel nature of the rules is one of the more important aspects of fuzzy logic systems. Instead of sharp switching between modes based on breakpoints, logic flows smoothly from regions where the system's behavior is dominated by either one rule or another.

Fuzzy inference process comprises of five parts [40].

Step 1: Fuzzify Inputs

The first step is to take the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. In Fuzzy Logic, the input is always a crisp numerical value limited to the universe of discourse of the input variable (in this case the interval between 0 and 10) and the output is a fuzzy degree of membership in the qualifying linguistic set (always the interval between 0 and1). Before the rules can be evaluated, the inputs must be fuzzified according to each of these linguistic sets.

Step 2: Apply Fuzzy Operator

After the inputs are fuzzified, you know the degree to which each part of the antecedent is satisfied for each rule. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number is then applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables. The output is a single truth value. Any number of well-defined methods can fill in for the AND operation or the OR operation. In the fuzzy logic, two built-in AND methods are supported: **min (minimum)** and **prod (product).** Two built-in OR methods are also supported: **max (maximum),** and the probabilistic OR method. The probabilistic OR method (also known as the algebraic sum) is calculated according to the equation.

Probor(a, b) = a + b - ab

In addition to these built-in methods, you can create your own methods for AND and OR by writing any function and setting that to be your method of choice.

Step 3: Apply Implication Method

To apply implication method, first the weight of rules should be determined. Every rule has a *weight* (a number between 0 and 1), which is applied to the number given by the antecedent. From time to time we may want to weight one rule relative to the others by changing its weight value to something other than 1. After proper weighting has been assigned to each rule, the implication method is implemented. A consequent is a fuzzy set represented by a membership function, which weights appropriately the linguistic characteristics that are attributed to it. The consequent is reshaped using a function associated with the antecedent (a single number). The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule. Two built-in methods are supported, and they are the same functions that are used by the AND method: ***min*** **(minimum),** which truncates the output fuzzy, set, and ***prod*** **(product),** which scales the output fuzzy set.

Step 4: Aggregate All Outputs

Because decisions are based on the testing of all of the rules in a FIS, the rules must be combined in some manner in order to make a decision. Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable, just prior to the fifth and final step, defuzzification. The input of the aggregation process is the list of truncated output functions returned by the implication process for each rule. The output of the aggregation process is one fuzzy set for each output variable. As long as the aggregation method is commutative (which it always should be), then the order in which the rules are executed is unimportant. Three built-in methods are supported:

i. **max (maximum)**
ii. **probor (probabilistic OR)**
iii. **sum (simply the sum of each rule's output set)**

Step 5: Defuzzify

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set. Perhaps the most popular defuzzification method is the **Centroid** calculation, which returns the center of area under the curve. There are five built-in methods supported: **Centroid**, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum.

2.8 Types of Fuzzy Inference Systems

There are two types of fuzzy inference systems in the toolbox [41].

- Mamdani
- Sugeno

These two types of inference systems vary somewhat in the way the outputs are determined.

2.8.1Mamdani's fuzzy: Mamdani Inference method is the most commonly seen fuzzy methodology. This method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani [42] as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on LotfiZadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes [43].

Mamdani-type inference, as defined for the toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. It is possible, and in many cases much more efficient, to use a single spike as the output membership functions rather than a distributed fuzzy set. This type of output is sometimes known as a ***singleton*** output membership function, and it can be thought of as a pre-defuzzified fuzzy set. It enhances the efficiency of the defuzzification process because it greatly simplifies the computation required by the more general Mamdani method, which finds the Centroid of a two dimensional functions rather than integrating across the two-dimensional function. To find the Centroid, it uses the weighted average of a few data points.

2.8.2 Sugeno-Type Fuzzy Inference

Sugeno, or Takagi-Sugeno-Kang, method of fuzzy inference is introduced in 1985 [44] it is similar to the Mamdani method in many respects. The first two parts of the fuzzy inference process, fuzzifying the inputs and applying the fuzzy operator, are the same. The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant [42].

Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. A typical rule in a Sugeno fuzzy model has the form:

If Input 1 = x and Input 2 = y, then Output is $z = ax + by + c$, for a zero-order Sugeno model, the output level z is a constant ($a = b = 0$).

2.8.3 Comparison of Sugeno and Mamdani Systems

Because it is a more compact and computationally efficient representation than a Mamdani system, the Sugeno system lends itself to the use of adaptive techniques for constructing fuzzy models. These adaptive techniques can be used to customize the membership functions so that the fuzzy system best models the data. Note you can use the MATLAB command-line function **mam2sug** to convert a Mamdani system into a Sugeno system (not necessarily with a single output) with constant output membership functions. It uses the Centroid associated with all of the output membership functions of the Mamdani system.

Advantages of the Sugeno Method

- It is computationally efficient.
- It works well with linear techniques.
- It works well with optimization and adaptive techniques.
- It has guaranteed continuity of the output surface.
- It is well suited to mathematical analysis.

Advantages of the Mamdani Method

- It is intuitive.
- It has widespread acceptance.

- It is well suited to human input.

Because of the above reasons for this research Mamdani type inference system has been selected. The output of the system is not being constant or linear; it may vary depending on the condition that gets from the input. So in this case using Sugeno type of inference is not advisable, because the outputs are linear or constant.

2.9 Features of fuzzy inference system

Fuzzy logic uses the following graphical tools to build, edit, and view fuzzy inference systems:

- **Fuzzy Logic Designer**: to handle the high-level issues for the system. How many input and output variables? What are their names?

Fuzzy Logic Toolbox software does not limit the number of inputs. However, the number of inputs may be limited by the available memory of your machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other tools.

- **Membership Function Editor:** to define the shapes of all the membership functions associated with each variable
- **Rule Editor:** to edit the list of rules that defines the behavior of the system.
- **Rule Viewer**: to view the fuzzy inference diagram. Use this viewer as a diagnostic to see, for example, which rules are active, or how individual membership function shapes influence the results.
- **Surface Viewer:** to view the dependency of one of the outputs on any one or two of the inputs that is, it generates and plots an output surface map for the system.

These GUIs are dynamically linked, in that changes you make to the FIS using one of them, affect what you see on any of the other open GUIs. For example, if we change the names of the membership functions in the Membership Function Editor, the changes are reflected in the rules shown in the Rule Editor. It is possible to use the GUIs to read and write variables both to the MATLAB workspace and to a file (the read-only viewers can still exchange plots with the workspace and save them to a file). As we can observe the fuzzy inference system, its features seems like the following figure 2.15.

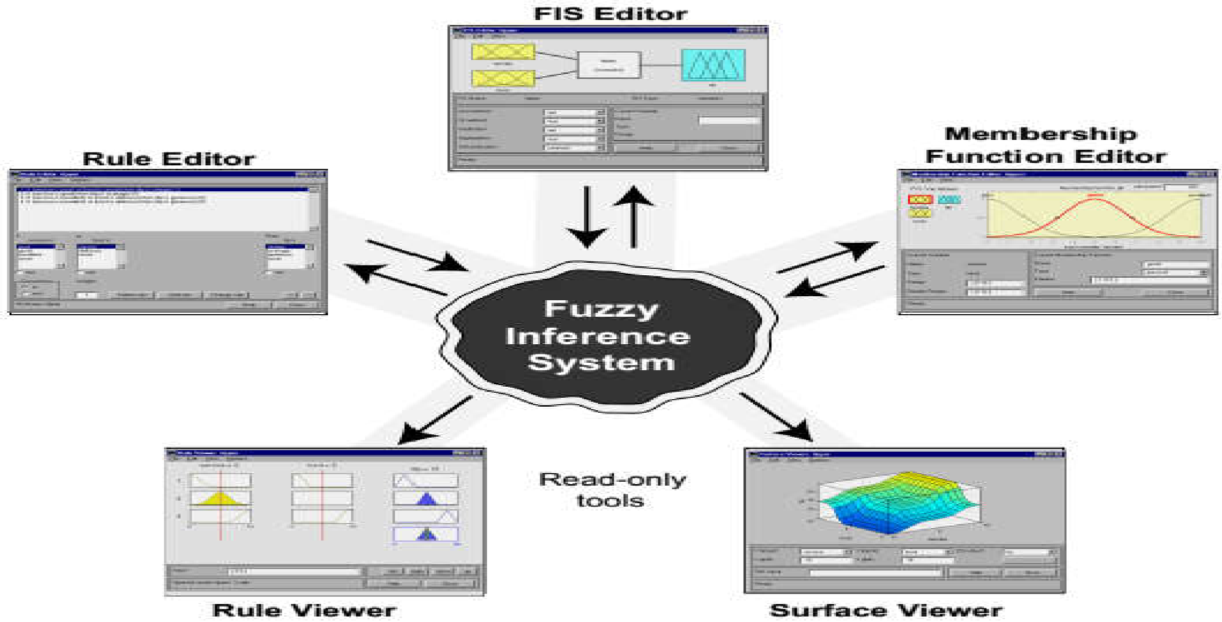


Fig 2.15. Structure of fuzzy logic inference system GUI

2.10 Advantage of rule based reasoning

Rule based reasoning approach have a numbers of good features. According to Prentzas [27] the major advantages of rule based reasoning in the development of knowledge based system are:

- **Compact representation of general knowledge:** Rules can easily represent general knowledge about a problem domain.
- **Homogeneity:** Rule based representation has uniform syntax. Hence, the meaning and interpretation of each rule can be easily analyzed.
- **Independent:** In rule based knowledge representation a new rule can be added without affecting the existing rules. Each rule is an independent piece of knowledge about the problem domain.
- **Naturalness of representation**: Rules are a very natural knowledge representation method with a high level of comprehensibility. Rules can emulate the expert's way of thinking in natural expression.
- **Modularity:** Each rule is a discrete knowledge unit that can be inserted into or removed from the knowledge base without taking care of any other technical detail. This characteristic grants flexibility of rule-based reasoning, because it enables incremental development of the knowledge base.
- **Provision of explanations:** The ability to provide explanations for the derived conclusions is a straightforward manner. This feature of symbolic rules is a direct consequence of their naturalness and modularity.

2.11 Disadvantage of rule based reasoning:

A Rule based reasoning of prototype knowledge based system has the following limitations [45].

- ✓ **Knowledge acquisition bottleneck:** The standard way of acquiring knowledge through interviews with domain experts is bulky and time-consuming.
- ✓ **Brittleness/fragility of rules:** It is not possible to draw conclusions from rules when there are missing values in the input data.
- ✓ **Inference efficiency problems:** In certain cases the performance of the inference engine is not the desired one especially when the rules are too large.
- ✓ **Difficulty in maintenance of large rules:** The maintenance of rule bases is getting a difficult process as the size of the rules increases.
- ✓ **Interpretation problems:** The general nature of rules may create problems in the interpretation of their scope during reasoning process.

2.12 Related works

According to **Engelmore** and **Feigenbaum** intelligence deals with many cognitive skills, comprising the capability to find solution of problems, learn, and understand language. However, developments up to the present time in AI have been made in the area of problem solving-concepts and methods for constructing program that reason about problems instead of finding the solution [46].

The area of human intellectual endeavor to be captured in a knowledge-based system is called the task domain. Task denotes to certain goal-directed, problem-solving endeavors. Domain denotes to the area within which the task is being performed. Typical tasks are diagnosis, planning, scheduling, configuration and designing [47].

Knowledge base system was evolved from expert systems. It is a computer-based information system that creates knowledge after the process of data or information and can be used for decision making. Hence, the processed data or information is easily understandable by the KBS but not possible by traditional computer-based information systems.

As **Turban** noted, one example of the specialized branches of AI is KBS. The objectives of KBS are listed as follows [48].

- Offers a great level of intelligence
- Supports individuals in finding out and constructing new fields
- provides a huge amount of knowledge in several areas
- Assists in knowledge management that is deposited in the knowledge base
- Finds solution for social problems in a well manner than the traditional computer-based information systems.
- Gains new observations by imitating new circumstances
- Provides important software development productiveness

Tsumoto [49] had proposed a web based medical expert system in which the web server provides an interface between hospital information systems and home doctors. According to them, the recent advances in computer resources have strengthened the performance of decision making process and the implementation of knowledge base. Moreover, the recent advances in web technologies are used in many medical expert systems for providing efficient interface to such systems. Moreover, many such systems are put on the Internet to provide an intelligent decision support in telemedicine and are now being evaluated by regional medical home doctors.

Androuchko [50] proposed an expert system called **Medoctor**, which is a web-based system and has a powerful engine to perform all necessary operations. The system architecture presented by them is highly scalable, modular, and accountable and most importantly enables the incorporation of new features to be economically installed in future versions. The user interface module of that system presents a series of questions in layman's language for knowledge acquisition and also to show the top three possible diseases or conditions. However this system lacks in accuracy in decisions and also it is not following the coding of diseases as per the standards. Hence, there is a need for proposing a system with increased accuracy and standard. Since 1970, **Shortliffe, Feigenbaum** and **Buchanan** [51] had developed the first expert system (MYCEN). It was an expert system for diagnosing blood diseases. It was a precursor to today's expert systems and acts as an ideal case study. MYCIN is a rule based Expert system using backward chaining. MYCIN has two phases in its approach, a ***diagnosis*** and a ***prescription*** phase. In the first phase the nature of the infection and the organism causing the infection are determined. The prescription phase then indicates the drugs for the treatment taking into account any side effects they may have on the patient. MYCIN consists of about 500 rules. It is a backward chaining rule based system using a depth-first search strategy.

According to the above literatures, those works are done on the disease diagnosis, but some of them are the web based diagnosis systems, so in case of Ethiopia it is not be applicable because it consume large amount of money for the network installation, and the usability may be limited. The others develop the systems done using Fuzzy logic. In addition to that those systems are done internationally so it is better to develop such systems in the case of Ethiopian context.

In 2010, Adeli and Neshat [52] have designed a Fuzzy Expert System for Heart Disease Diagnosis. The system has been designed using fuzzy inference system. This system has been designed with follow membership functions, input variables, output variables and rule base. Designed system has been tested with expert-doctor. Designing of this system with fuzzy base in comparison with classic designed improves results. Results have been shown from this system in compression with past time system are logical and more efficient. This system simulates the manner of expert-doctor. This system is designed in way that patient can use it himself. This fuzzy expert system that deals with diagnosis has been implemented. Experimental results showed that this system did quite better than non-expert and about 94% as a well as the expert did [53].

The researchers have also developed a fuzzy expert system for detecting heart disease. The objective of this paper is to detect the heart diseases in the person by using Fuzzy Expert System. The system consists of 6 input fields and two output field. Input fields are chest pain type, cholesterol, maximum heart rate, blood pressure, blood sugar, old peak. The output field detects the presence of heart disease in the patient and precautions accordingly. It is integer valued from 0 (no presence) to 1 (distinguish presence (values 0.1 to 1.0). The Mamdani inference method has been used. The results obtained from designed system are compared with the data in upon database and observed results of designed system are correct in 92%.

This fuzzy expert system that deals with diagnosis has been implemented and the experimental results showed that this system did quite better than non-expert urologist and about 92 % as a well as the expert did.

The designed system aims to achieve the following:

- Detection of heart diseases and risks using fuzzy logic
- The system also defines the precautions according to the risk of the patient.
- System have 6 inputs and 2 outputs
- Each input and output have fuzzy variables
- Each fuzzy Variable is associated with membership function
- The rules strength is calculated based on the membership function of the fuzzy variable.

In the case of Ethiopia, as much as the researchers have tried to review, there is no any research done using fuzzy inference system on triage system. But since the domain is knowledge base system for disease diagnosis, the following works have been conducted before this time on knowledge base system using rule based approach.

Seblewongel [54] has been developed a knowledge based system for anxiety mental disorder diagnosis. The principal objective of this study is to design and develop a prototype knowledge based system for diagnosing patients with anxiety mental disorders with the overall aims of exploring the applicability of knowledge based system technology to the specific area of mental disorder diagnosis. Seblewongel has used Prolog programming language to develop the prototype knowledge based system to achieve the proposed objective. Prolog (programming in logic) is one of the most widely used programming language, especially in the artificial intelligence research, natural language processing, system development, and so on. It is very useful especially on those mentioned areas to specify the situation (rules and facts) and the goal (query).

Finally Seblewongel has been put the following recommendations for future researchers.

- Due to the short time available for the research, the study attempted to develop advisory knowledge based systems for anxiety disorders. However, the scope of the knowledge based system should be expanded to include other mental disorder categories such as mood disorders, psychotic disorders, somatoform disorders, substance induced disorders and adjustment disorder. Therefore, further investigation should be done to integrate an intelligent agent that has the capability to perform mental status examination by including other diseases.
- The scope of the prototype is limited to identifying ‘anxiety disorders and recommending first line treatments and medications, particularly psychotherapy recommendations. For chronic and acute anxiety disorders detail specification of medications are required. Therefore, further investigation should be done on other diseases treatments.
- In rule based systems, the acquired examples are used to construct decision rules. These rules are further used to make decisions regarding new, unknown cases. However, rule based systems are not able to learn from experience and do not operate with cases which have no matching facts in the rule base of the systems. As a result, the development of self-learning system should be considered by using neural networks. Neural networks have the ability to “learn” from the observed data.

Guesh [55] have designed a knowledge base system that can provide a significant help for domain experts involves in the area of blood transfusion such that patients in need of blood transfusion can get the right blood timely.
To promote improvements to the quality of blood transfusion processes such as safe blood transfusion in a way, no adverse reactions or infections occurred, clinically effective, which benefits the patient and efficient in a manner, no unnecessary transfusions take place, and transfusion should administer at the time when the patient needs it. The gaps created among domain experts on the area of blood transfusion can be minimized due to the common understanding obtained from the system.
The necessary knowledge in this study was acquired and elicited using a directive interviews to the medical experts, specifically the physicians in the area of blood transfusion and laboratory technicians. A secondary data from documents such as manuals was also assessed. Furthermore, in this study demonstration and direct observation were considered to acquire the necessary knowledge for designing knowledge base system for blood transfusion.
The elicited knowledge from domain experts was constructed and modeled in a hierarchical tree and decision tree methods. The researcher selected a rule based knowledge representation method to represent the relationship between facts and rules in the form of IF-THEN, which shows condition-action relationships.
This researcher has used a SWI prolog programming language to implement the system. The system is tested and evaluated for its performance by the domain experts in the area of blood transfusion.
Finally the system is found to be applicable for training, education in some courses of hematology. The system registers a promising result after it has been evaluated by domain experts, 82.5% accurate result. The domain experts who involve in the evaluation of this system from Black Lion hospital, Blood Bank section confirms that, the system is applicable for blood transfusion, with valuable comments which helps as an input for further research direction, by incorporating screening of blood and blood transfusion into a single and full-flagged system.
Finally the researcher has been given the recommendation as:
This study is limited to blood transfusion by accepting laboratory outputs and diagnosis output from physicians by using the already represented knowledge. To make the system more useful, the blood screening and transfusion practices should be incorporated; hence it saves costs such as time, man power and increases effectiveness in the treatment.

Tagel [56] conducted research on Knowledge based system for pre-medical triage treatment at Adama university Asella hospital**.**

The main objective of the study to investigate the applicability of rule-based reasoning approach in the development of knowledge based system for hospital triage service so as to improve the quality of decision made by general practitioners, to provide effective and efficient services to

the patients, and to improve shortage of human expert in triage service. The researcher has used rule based system and implemented using Prolog programming language to develop the prototype.
Finally the researcher has given the following recommendations:
Further investigation should be done to integrate an intelligent agent that has a capability to self-learning and update its knowledge base. The knowledge based system can be used self-treatment purposive then the patients are possibly from different local language speakers and patients can express their feeling using their own languages. Therefore, a user interface should be designed to enable the users to communicate using their own language with the knowledge base system.

Solomon [57] conducted research study on application of knowledge based system for settling Tort claims under The Ethiopian Law. This research deals with the development of KBS as an alternative approach for handling tort climates under the Ethiopian law. Common KADS and decision tree modeling techniques are used in the modeling of expertise. Rule-Based reasoning approach is adopted to represent the necessary knowledge base of the system. The knowledge base is developed using SWI prolog which supports backward chaining to make inferences by reading the composed rules in the knowledge base. The testing of the prototype system is done first by using artificial test data and then a sample of thirteen previously decided 35 test cases is taken in law of torts to make comparisons on the decision made by the system and human experts. Therefore, the development of KBS that incorporates predictive capacity to predict judicial decisions by taking precedents (or decided cases) and examining closely the personal attitudes of the presiding judges towards political, cultural, economic, religious, and social factors are demanding to make the system credible in the legal community.

Dejene [58] conducted research on the Application of Knowledge Based System for Woody Plant Species Identification. This study attempts to design prototype KBS for woody plant species identification. The knowledge based system uses rule based approach for the proposed system. The system is modeled in decision laddering; domain knowledge is represented using production rules in prolog to construct the knowledge base. The prolog built in backward inferring mechanism is used for the identification of the species. Finally, the system is tested and evaluated by the users. The result shows that, the system identifies the woody plant species correctly and can be applicable in woody plant species identification. As compared to existing way of identification we come up with new knowledge/rules with minimum features that registers comparable performance.
Therefore, as it is possible to understand from the above research works, each of the researchers have worked on the specific area and all of them have been recommended as the system can have efficient result if the fully implemented system can developed. Because of that the current study is invited to design and develop a knowledge base system for Triage using fuzzy logic inference system on some of the selected diseases, and for the future it is possible to improve the system and develop a better system which is able to include all the necessary diseases and finally in

other works it is also possible to make itself learning system by using neural network, because in fuzzy inference system it is easy to implement the concept of neural network since it is integrated with Matlab tool. So the researcher has been decided to do on fuzzy logic system by including some of the selected diseases which are currently dangerous and killer as recommended by the domain experts in Menelik II hospital.

CHAPTER THREE
KNOWLEDGE ACQUISITION AND CONCPTUAL MODELLIING

3.1 KNOWLEDGE ACQUISITION

Knowledge acquisition (KA) is the process of acquiring relevant knowledge from domain experts and other sources of information such as books, databases, guidelines, manuals, journal articles, computer files, etc. [59].

KA is the process of eliciting, structuring and representing (formalizing) domain knowledge acquired from different sources. The knowledge acquisition component allows the expert to enter their knowledge or expertise into the expert system, and to refine it later as and when required. Historically, the knowledge engineer played a major role in this process, but automated systems that allow the expert to interact directly with the system are becoming increasingly common. The term knowledge acquisition and knowledge elicitation have been used interchangeably in the field of artificial intelligence (AI) literature. The acquired knowledge can be specific to the problem domain, it can be general or it is meta-knowledge (knowledge about knowledge). Knowledge acquisition is the first step and time consuming task in the development of knowledge based system.

There are certain important steps that the knowledge engineer needs to carry out during knowledge acquisition process [60].

These are:

1. Eliciting data and information from the domain experts.
2. Interpreting the acquired information to understand human expert reasoning processes.
3. Constructing model to represent the expert's knowledge.
4. Repeating step I-III as the knowledge base system involves into a functional system.

3.2 Triage Knowledge Acquisition

Before the actual knowledge acquisition process, the researcher has tried to conduct informal discussion with the domain experts to understand the dimension of the problems. In addition to that, secondary sources of knowledge are reviewed on the proposed diseases.

Based on the informal discussion, the researcher constructed unstructured interview questions in a way that help show to acquire the required knowledge from the domain experts and conducted with the medical director. Therefore, the researcher tried to interact with domain experts in order to collect, gather and analyze the required knowledge. The knowledge content covers issues such as how general practitioner diagnosis of patient based on their pillar symptoms and how they have identified (triage) the patients for further diagnosis and treatment.

3.2.1 Knowledge Acquisition from domain experts

Primary sources of knowledge are collected from human experts by interviewing them in the domain area at Minelik hospital. Interview is one of the knowledge elicitation techniques which involve asking the domain expert on how they perform their tasks in the patient identification by observing their symptoms and further ways of identifications and measurements that the triage nurses have used. Interview can be structured, semi structured and unstructured [61].

In this study to acquire knowledge unstructured interview technique is used. Unstructured interview is an interview with open-ended questions. It is more flexible than structured one because the interviewer has the chance to change the order of questions according to the context of response. Unstructured interview is a kind of interview that is not pre-determined. It depends on the interaction of the researcher and domain expert. Since one of the main focuses of this research is eliciting relevant tacit knowledge from the domain experts, domain experts were selected from each case teams as per the recommendation of the medical director of the hospital by applying purposive sampling technique. So the necessary information on the triage cases is collected by interviewing with the experts.

During the interview phase, the main challenge is willingness of the experts to share their expertise and experience, which is important to acquire the relevant knowledge. To solve problem the researcher have tried to make some discussion with the domain experts on the advantage of the research for the triage system and on which data that the researcher want to collect. The domains of interview with expert covered issues such as what are the tasks that are performed in patient identification using symptoms, how the experts interact with patient and identify the disease, what are techniques used to identify the pillar symptoms of the patient, what are the major identified symptoms of selected diseases, how to identify the degree of the symptoms that have been identified on the diseases and compare them, what are the advantages and disadvantages of the expert system on the health centers. In this discussion the experts tried to reflect on the questions prepared for them and the researcher tried to acquire the relevant tacit knowledge which is significant to represent the symptoms of the diseases as an input for the fuzzy logic. During face to face communication, the acquired knowledge from domain experts has been recorded manually by using pen and paper sheet. Experts tried to express the advantages and disadvantages of expert systems for disease diagnosis in the health centers.

They have listed advantages as:

- The developed systems is easy for manipulation,
- Better for the recorded symptoms,
- Minimizing time and energy lost, and
- Increasing data confidentiality.

On the other hand they also discussed on disadvantages as follows:

- There is updating problem because if the new cases are added, so the system cannot add those cases automatically because of that in some instants it may loss the correct patient identification.
- The system needs computer skilled human power, and in such a case there may be the scarcity of human power because it is difficult to get experts skilled both in health care and computer knowledge,
- It may restrict the decision given by human being during diagnosis, but here we have made some discussions and agreed as since the system is be used by the experts as a supportive agent the expert can give their own decision in addition to the result given by the system.

No	Educational level	Specialization	Area interviewed	Role
1	MD	Medicine	Medical Category	TB specialist
2	Nurse	Nurse	TB cases	TB nurse
3	Nurse	Nurse	Triage system	Triage nurse
4	MD	Medicine	Medical category	Medical Director

Table 3.1: Profile of experts interviewed

3.3 Knowledge Modeling

After the knowledge is acquired from knowledge sources, the next step was organizing and structuring of knowledge. Knowledge modeling is the representation of information in the form of logic for the purpose of processing knowledge to simulate intelligence. In this research the Knowledge acquired using different knowledge acquisition technique is modeled using hierarchical tree structure. The hierarchical tree diagram provides the analyst with an effective visual condensation of the clustering results. The hierarchical tree diagram is one of the most commonly used methods of determining the number of clusters in this case number of selected diseases. It is also useful in spotting outliers; as these are appear as one member clusters that are joined later in the clustering process. The numbers at the top and bottom of the hierarchical tree diagram represent equally spaced values of the criterion function. It gives a pictorial representation of the criterion function information. For this study, hierarchical tree structure was used to represent knowledge modeling. Hierarchical tree structure can easily model concepts and clearly explains the concepts in the problem area. The hierarchical knowledge seems like the following figure 3.1.

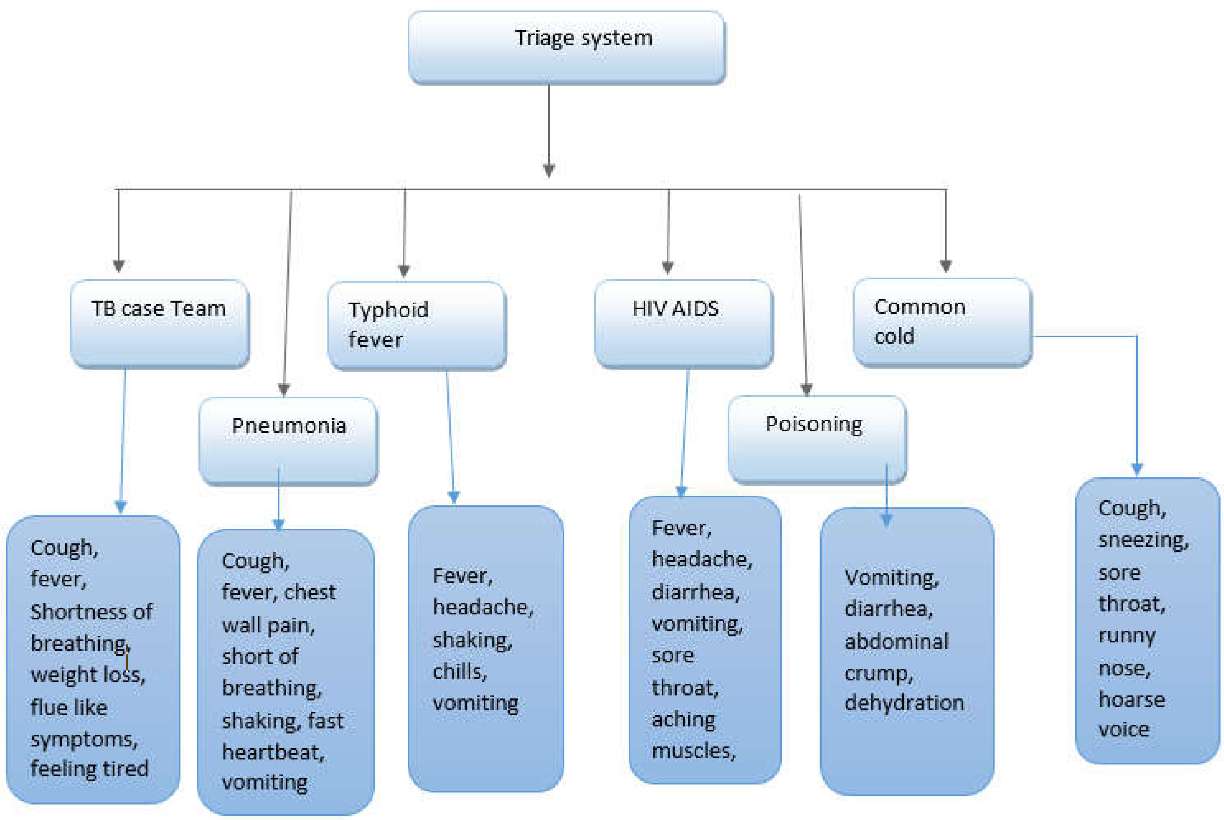


Fig 3.1 Hierarchical knowledge modeling

3.4 Hierarchical structure of triage system

Triage system may have four categories namely, medical, surgical, gynecology and psychiatric, even though the human health problems can be categorized into numbers of divisions. When a new category is identified during the diagnosing process, the human experts re-assign the case into the specific category. The following Figure 3.2 shows the general structure of triage system of Menelik II hospital.

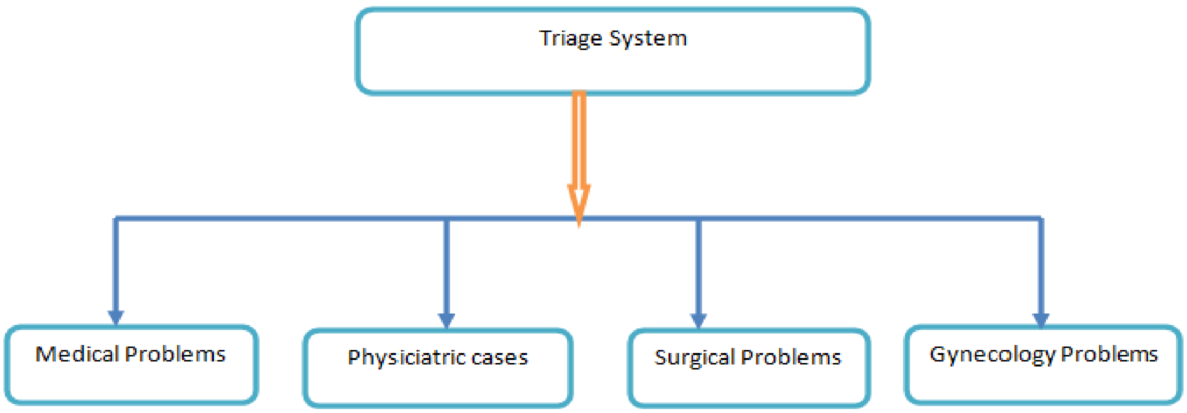


Fig 3.2 General Structure of triage system

In addition to the above general structure, it is possible to represent the types of diseases that are identified in the triage system as follows in figure 3.3.

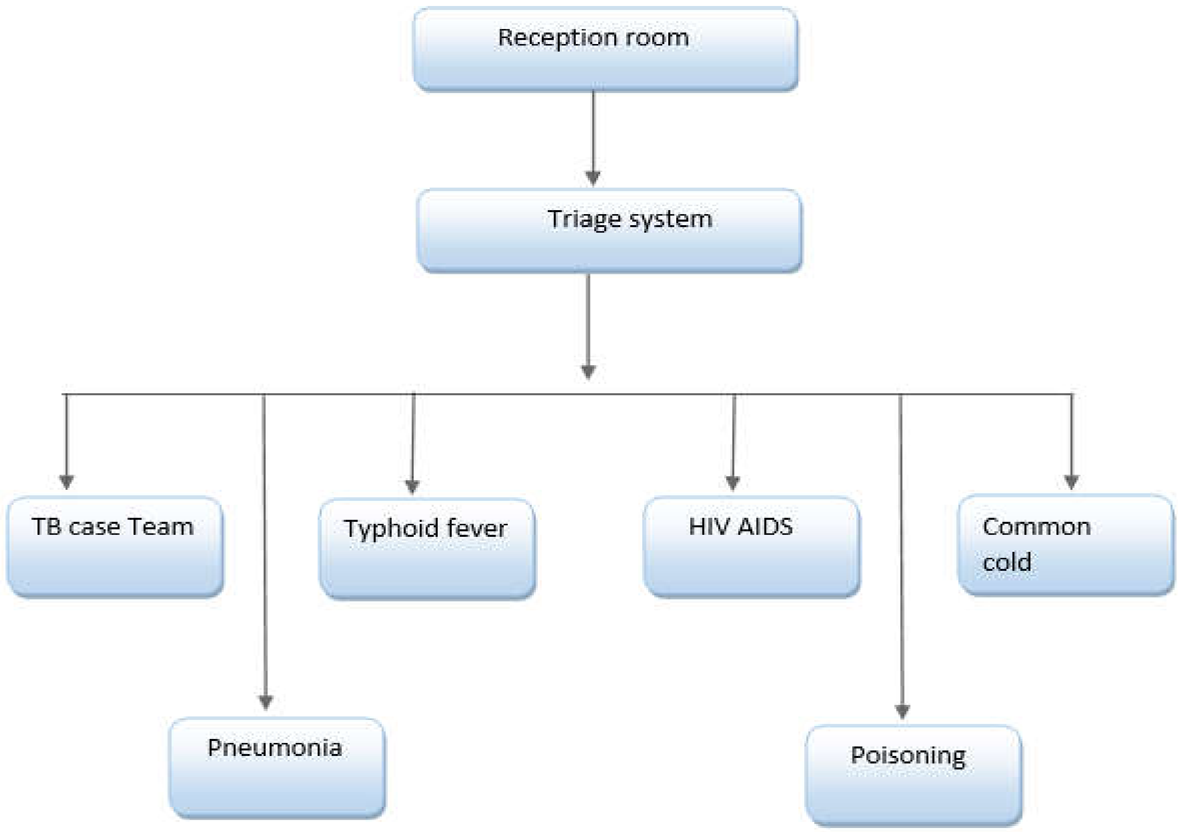


Fig. 3.3 structure of the triage system with identified diseases

The main inputs of the inference system are the information (data) gained from the domain experts such as symptoms of the disease and related health status which are provided for the system. Finally, the output is the recommendations for the experts or for the triage that enables them to make decision easily in patient identification or triage process.

As described by the experts of the hospital, after patients have completed the triage system, they can be assigned for further diagnosis for either of the disease case teams listed in the architecture. The identification is made based on the symptoms shown on the patient. Based on the symptoms, the patient may be assigned to diagnosis in TB case team, typhoid fever, HIV AIDS, common cold, pneumonia, poisoning, or for other concerned diseases. In this case since the system does not include all types of diseases, the user interference is useful for further identification of diseases, since the system is used as a support for the triages. As the experts said, in Ethiopia there are some diseases which are dangerous for the death of the people. In the case of Menelik II hospital the following diseases are currently selected as dangerous and death full diseases as recommended by the domain experts. These selected diseases are described as follows:

- **Tuberculosis (TB):**

Tuberculosis (TB) is a disease caused by bacteria that are spread through the air from person to person. If not treated properly, TB disease can be fatal. People infected with TB bacteria who are not sick may still need treatment to prevent TB disease from developing in the future. Learn to recognize the symptoms of TB disease and find out if you are at risk.

TB bacteria can live in the body without making the patient sick. This is called latent TB infection. In most people who breathe in TB bacteria and become infected, the body is able to fight the bacteria to stop them from growing. People with latent TB infection do not feel sick, do not have any symptoms, and cannot spread TB bacteria to others.

If TB bacteria become active in the body and multiply, the person go from having latent TB infection to being sick with **TB disease**.

The domain experts have identified the following symptoms which are shown on people who are living with TB bacteria.

- ✓ Fever
- ✓ Persistent cough more than two weeks
- ✓ Chest pain
- ✓ Shortness of breathing
- ✓ Weight loss

- **Typhoid Fever:**

Typhoid fever is an acute illness associated with fever caused by salmonella typhi bacteria. The bacteria are deposited in water of food by human carrier and are spread to other people in the area.

Typhoid fever is contracted by drinking or eating the bacteria in the contaminated food or water. People with acute illness can contaminate the surrounding water supply through stool, which contains a high concentration of the bacteria. Contamination of water supply can in turn, taint the food supply. The bacteria can survive for weeks in water or dried sewage.

After the ingestion of contaminated food or water the bacteria invade the small intestine and enter the bloodstream temporarily.

The patient with typhoid fever develops the symptoms like:

- ✓ Fever
- ✓ Headache
- ✓ Shaking

- ✓ Chills
- ✓ Vomiting

- **HIV AIDS:**

HIV is the infection that causes AIDS. HIV may have a few or even no symptoms for up to 10 or more years before the symptoms of AIDS are developed. HIV/AIDS does not have any cure but treatments are available. HIV can spread during sexual intercourse and in any other means of blood contact with the one living with the Virus.

Generally a patient with HIV AIDS may develop the following symptoms as the domain experts have been suggested.

- ✓ Fever
- ✓ Headache
- ✓ Diarrhea
- ✓ Rapid weight loss
- ✓ Sore throat

A patient with these symptoms have a high probability to be infected by HIV AIDS, so it is better to get HIV testing and check the health condition.

- **Common Cold:**

Common cold is a viral infection of upper respiratory tract, nose and throat. Common cold is usually harmless, although it may not fell that way at the time. More than 100 viruses can cause a common cold, to some extent signs and symptoms may vary. But in general, the following symptoms are reflected on the patient with common cold.

- ✓ Cough
- ✓ Sneezing
- ✓ Sore throat
- ✓ Runny nose
- ✓ Hoarse voice

- **Pneumonia:**

Pneumonia is a severe acute lower respiratory infection that specifically affects the lungs. Push and fluid fill the alveoli, which is the smallest air spaces in the lungs and make it difficult to absorb oxygen.

Bacteria are more likely to result in severe pneumonia, because bacteria are the causes of pneumonia. Pneumonia can also be caused by viruses, such as influenza and fungi which is the cause of pneumonia in persons with AIDS. Environmental factors such as overcrowding in homes, exposure to tobacco smoke and indoor air pollution increase the risk of acquiring pneumonia.

People who have developed pneumonia have the following symptoms:

- ✓ Cough(mostly productive cough)
- ✓ Fever
- ✓ Chest wall pain
- ✓ Short breathing
- ✓ Shaking
- ✓ Fast breathing
- ✓ Vomiting

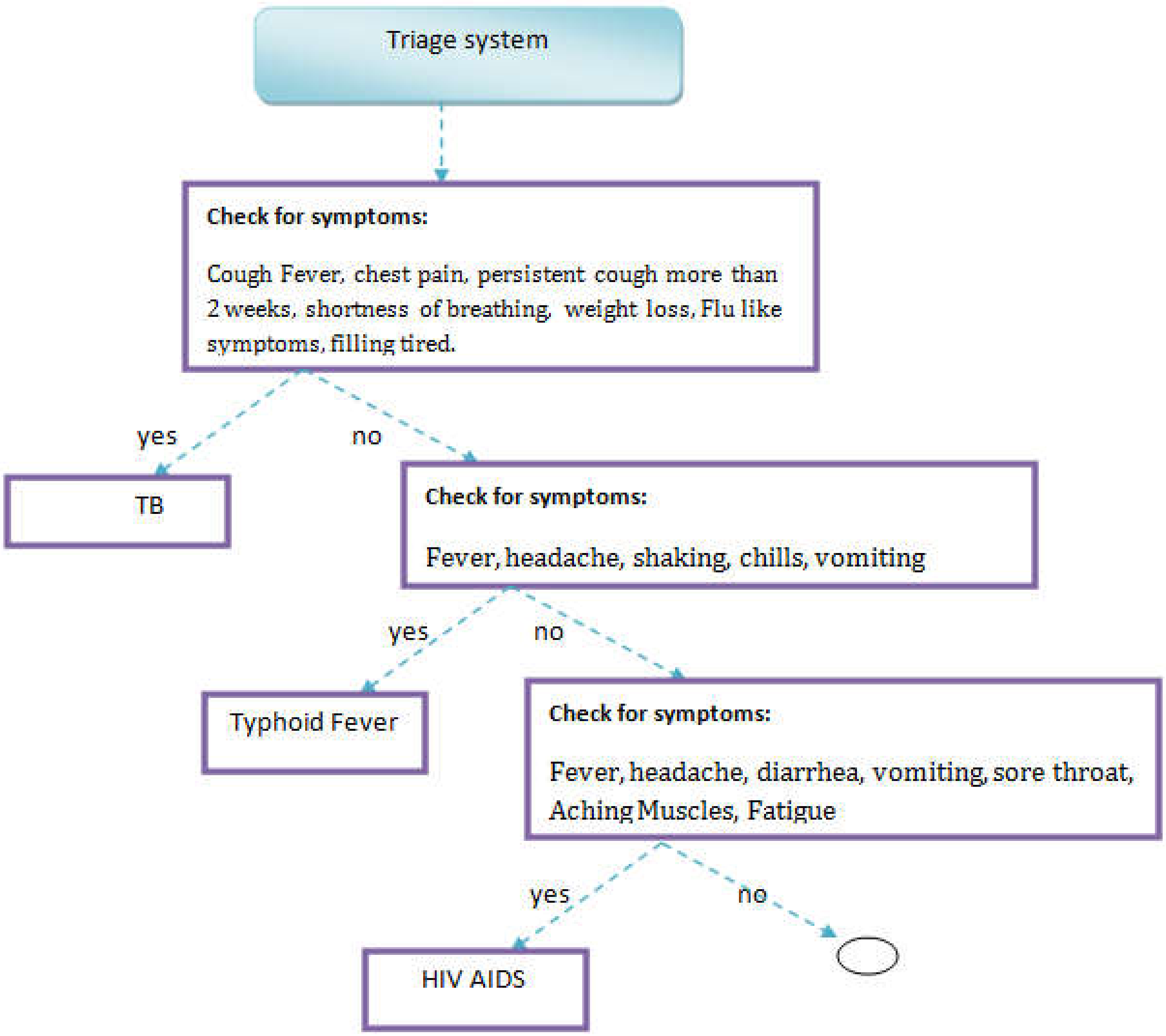
- **Poisoning:**

Poisoning occurs when individuals drink, eat breath, inject or touching the chemicals. A poison is any substance that is harmful to the body when eaten, breathed, injected or absorbed through the skin. Any substance can be poisonous if enough is taken. The dangers of poisoning ranges from short-term illness to brain damage, coma and death. Some poisons in very small amounts can cause illness or injury. Some poisons cause immediate injury, such as battery acid or house hold cleaner. Other poisons may take years of exposure to create a health problem, such as heavy metals (lead, arsenic, mercury).

The following symptoms are some of the identified symptoms of poisoning.

- ✓ Vomiting
- ✓ Diarrhea
- ✓ Abdominal cramp
- ✓ Dehydration
- ✓ Weakness

Those diseases with some description with their symptoms are graphically represented as follow and further described next:



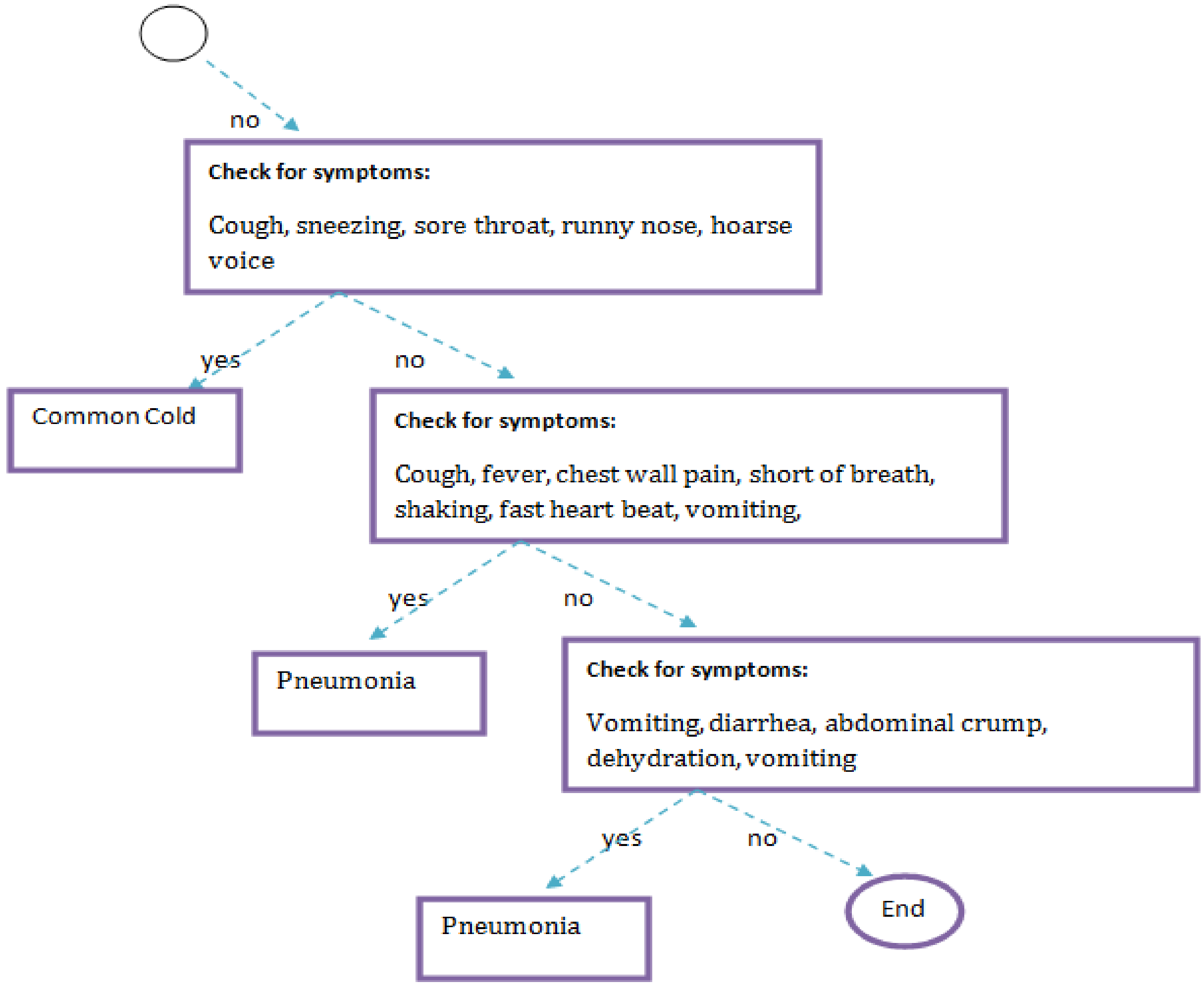


Fig. 3.4 Structure of triage system patient identification

The symptoms that are listed above can be summarized in the form of table as follows:

No	Major diseases	Identified symptoms
1	TB(Tuberculosis)	Cough, Fever, chest pain, persistent cough more than 2 weeks, shortness of breathing, weight loss, Flu like symptoms, filling tired
2	Typhoid Fever	Fever, headache, shaking, chills, vomiting
3	HIV AIDS	Fever, headache, diarrhea, vomiting, sore throat, Aching Muscles, Fatigue
4	Common cold	Cough, sneezing, sore throat, runny nose, hoarse voice
5	Pneumonia	Cough, fever, chest wall pain, short of breath, shaking, fast heartbeat, vomiting,
6	Poising	Vomiting, diarrhea, abdominal crump, dehydration, vomiting

Table3.2: identified symptoms of selected diseases

By using those symptoms, experts ask the symptoms from the patients and insert into the fuzzy logic and the system assists them to identify the patient.

CHAPTER FOUR

KNOWLEDGE BASED SYSTEM IMPLEMENTATION AND EVALUATION

After knowledge has been elicited from the source i.e. the tacit knowledge from experts, it is modeled and knowledge representation is done using in the previous chapter.

In this chapter architecture design (facts and rules), explanation facility, inference mechanism, the knowledge base editor, user interface and the prototype development is done using fuzzy inference tool.

4.1 Knowledge Base

A **knowledge base** (**KB**) is a technology used to store complex structured and unstructured information used by a computer system. The initial use of the term was in connection with expert systems which were the first knowledge-based systems. The original use of the term knowledge-base was to describe one of the two sub-systems of a knowledge-based system. The knowledge base stores all relevant knowledge, fact, rules, and relationships used by the knowledge based system which was acquired from the domain experts. The knowledge base of the fuzzy logic system contains the domain knowledge which used to identify the types of disease bases on the symptoms. Based on this, the knowledge base is constructed by using Matlab fuzzy inference rule based tools in the forms of ‘if then’ rule. The rules that are constructed for this triage system which are stored as a knowledge base.

4.2 The inference engine

The inference engine simulates the domain expert reasoning process. It matches the goal by searching through knowledge base to find rules whose premises match with the given facts in knowledge base. The searching process continues until the inference engine unable to match any premise with the facts in the working memory. As the researcher discussed before, the system have used forward chaining reasoning mechanism. Forward chaining is one of the two main methods of reasoning when using an inference engine and can be described logically as repeated application of modus ponens. Forward chaining is a popular implementation strategy for knowledge base systems. Forward chaining starts with the available symptoms and uses inference rules to extract more data (from an end user) until a goal of the diagnosis result is reached. An inference engine using forward chaining searches the inference rules until it finds one where the symptoms are known to be true. When such a rule is found, the engine can conclude, or infer, the diagnosis result, resulting in the addition of new information to its symptoms.

4.3 User Interface

User interface means it is the means by which the user and a computer system interact, in particular the use of input devices and software. The acceptability of a knowledge based system depends on the quality of the user interface. The user interface is used as the means of interaction between a user and the knowledge based system. In this study the user can interact with the system, the triage nurse observe the symptoms of the patients, then enter to the system on an input space, then the system compare the symptoms with the rules that are stored in the knowledge base and displays the result of the diagnosis in the ranking order. Since the result is displayed in percentage, the user can select the largest percentage and can make further diagnosis by sending the information for diagnosis department. For this fuzzy logic system to open the user interface, first we open the Matlab tools and write a command 'fuzzy' then press enter. The interface opens as follows:

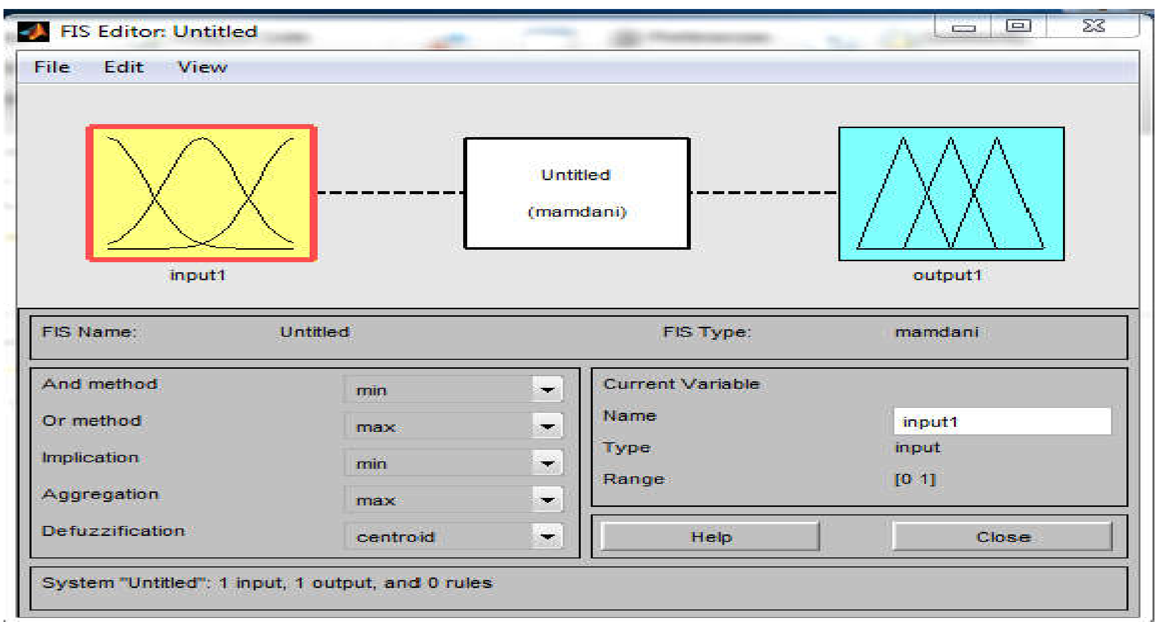


Fig. 4.1 GUI of fuzzy logic inference system

The default inference type if Mamdani, to display the type of inference system and the significance field, like the methods, inputs and outputs we can type:

readfis('file name.fis').

It is possible to save the fuzzy file to any file name. To know the inference type that the fuzzy runs, the methods and inputs type the above command as follows:

readfis('TRIAGE RESULT.fis') then press **enter** give the following;

```
>> readfis('TRIAGE RESULT.fis')

ans =

            name: 'TRIAGE RESULT'
            type: 'mamdani'
       andMethod: 'min'
        orMethod: 'max'
    defuzzMethod: 'centroid'
       impMethod: 'min'
       aggMethod: 'max'
           input: [1x15 struct]
          output: [1x6 struct]
            rule: [1x25 struct]
```

Fig. 4.2The platform of the fuzzy inference system

From the above result it is possible to see that the file name is **TRIAGE RESULT**, the fuzzy inference type is **Mamdani**, and the methods that are used in the inference are **andMethod, orMethod, defuzzMethod, impMethod, aggMethod,** and **input, outputs** and **rules.**

4.4 Variables:

In fuzzy inference there are two variables: input variable and output variable.

4.4.1 Input variables

By default the system gives one input variable and one output variable. To add any more inputs and output variables, **click on edit > Add variable > input** and for out puts **click on edit > Add variable > output.**

For instance let us see how to add variables using one variable from the system used in this research.

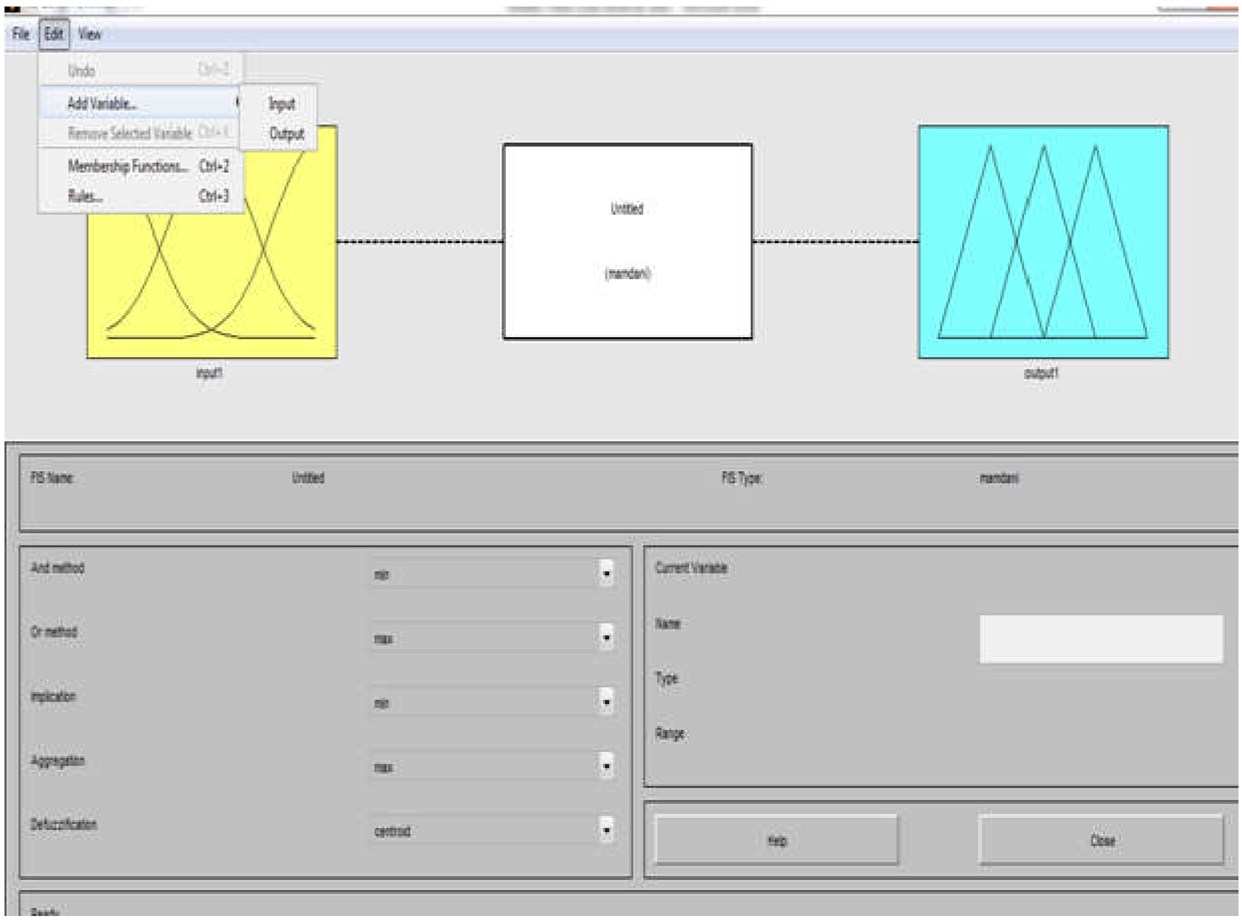


Fig. 4.3 adding variables (input and outputs)

Then double click on the variable that is added then renames it and adjust the available membership functions for the variable.

Let rename the variable as **fever** and the membership functions for fever in the case of this research are **high, normal** and **low.**

To add membership functions click on **edit > add MFs, then** click on each graph and rename it and adjust the values based on the scale of **high fever, normal fever** and **low fever.**

When we click on **edit > add MFs** it displays the following window, which enables to adjust the **types** and **numbers** of membership functions then by adjusting these two things click ok.

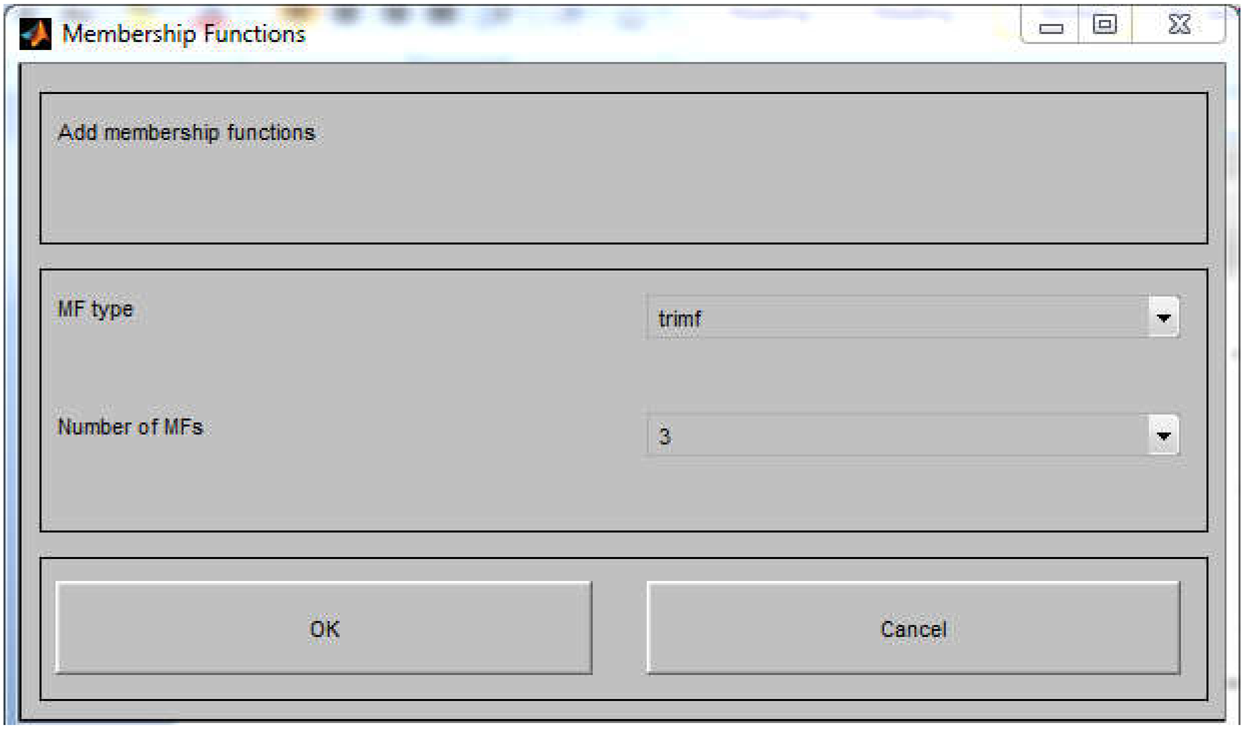


Fig. 4.4 Adding Membership functions

In the case of **fever** three membership functions are considered and the membership type is **trapezoid** because these membership functions have their own distinction which is clearly identified to say high, low and normal**.**

Then click on each membership functions and adjust their respective values.

The range of fever is considered from 35°C to 42°C, then low fever has the value [35, 36], normal fever has the value [37, 38] and high fever has values [39, 42]. Each membership functions also have parameters.

Membership functions for fever seems like the following figure 4.5:

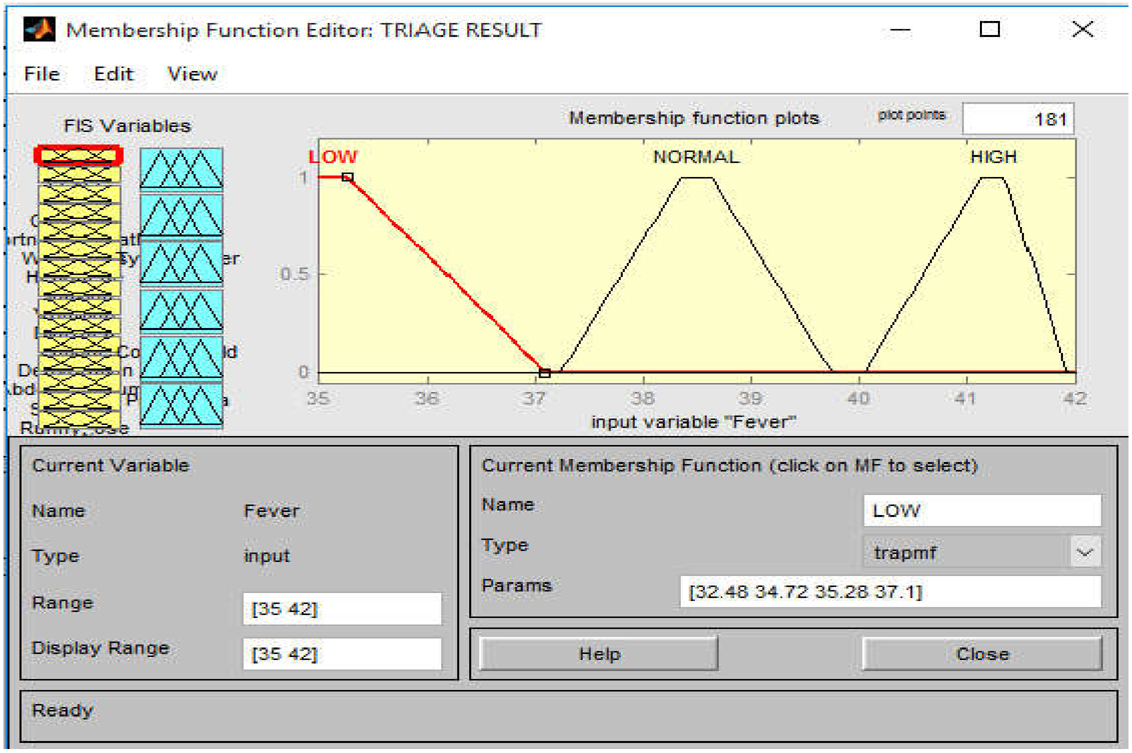


Fig 4.5 Membership functions for fever

In the same way, for all variables and membership functions similar processes have been done. Finally the result for all membership functions seems like this:

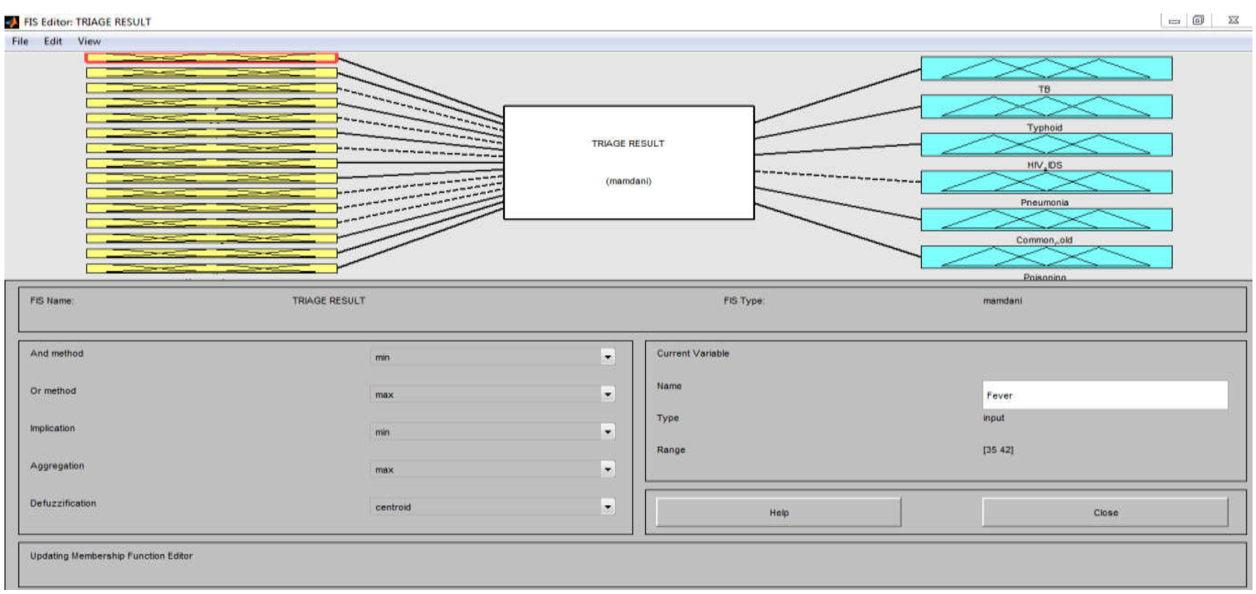


Fig 4.6 Overall lookup of the inputs and outputs of the system

The following table 4.1 shows the scales of each variable with each respective membership functions.

Symptoms (Variables)	Range	Membership Function	Parameters
Fever	35-42 ^{o}c	Low	35-36
		Normal	37-38
		High	39-42
Cough	1-4 weeks	Acute	1-2
		Sub-acute	2-3
		Chronic	3-4
Chest pain	1-5 days	Low	1-2
		High	3-5
Shortness of breathing	10-25 breath/minute	Low	10-12
		Normal	12-20
		High	20-25
Weight loss	2-7 %	Low	2-4
		High	4-7
Headache	1-7 days	Low	1-2
		High	3-7
Shaking	1-3 days	Low	1-1.5
		High	1.5-3
Vomiting	1-3 times	Low	1-1.5
		High	1.5-3
Diarrhea	3-7 times	Low	3-5
		High	5-7
Fatigue	1-7 days	Low	1-4
		High	4-7
Dehydration	1-7 days	Low	1-4
		High	5-7
Abdominal Crump	2-7 days	Low	2-4
		High	5-7
Sneezing	0- 1 days	No	0 -0.5
		Have	0.5 - 1
Runny nose	0 -1 days	No	0 -0.5
		Have	0.5 - 1
Hoarse Voice	0- 1 days	No	0 -0.5
		Have	0.5 – 1

Table4.1: Membership functions and their parameters

4.4.2 Output Variables:

There are six output variables with their respective membership functions.

The identified six diseases are used as a membership function for the system. So the range have been given as [0, 6], but for the parameters there is no distinct values given for each membership functions, because the result of the system is fully depends on the values that is gained from the inputs. So for the sake of representation each membership functions are represented starting from 0 to 6. Each membership functions (types of diseases) which have similar symptoms have been overlapped each other. Each membership functions (diseases) have been given equal values.

The output looks like this:

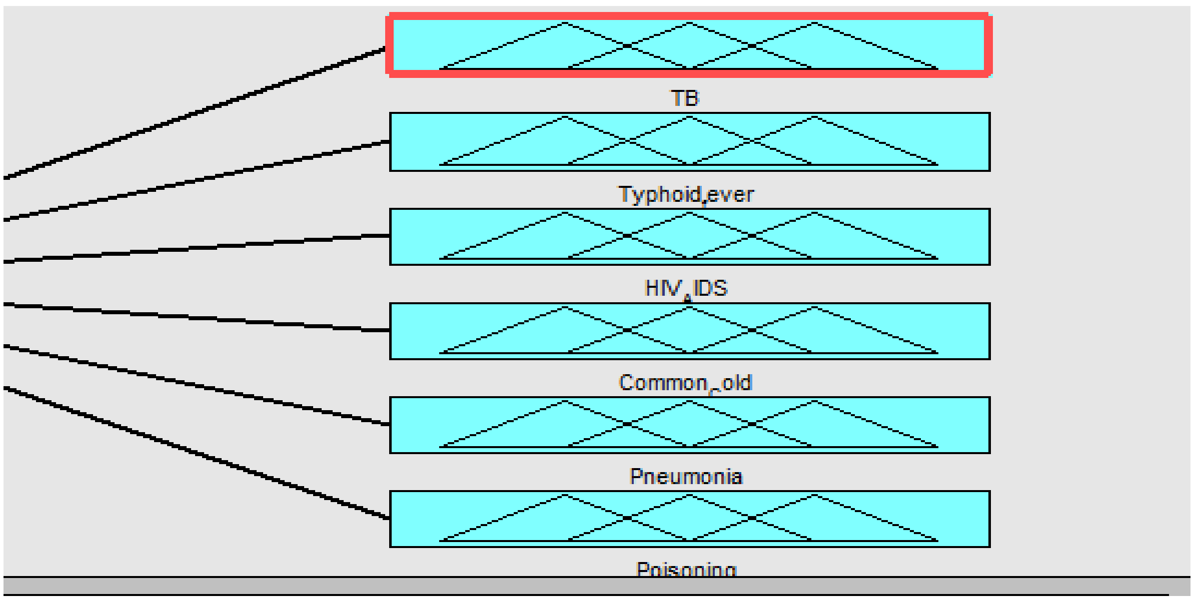


Fig.4.7 Outputs of the triage system

4.5 Rules

The next step is constructing the rules that produce the output. In order to set up the rules double click on the connector that is named as **TRIAGE RESULT.**

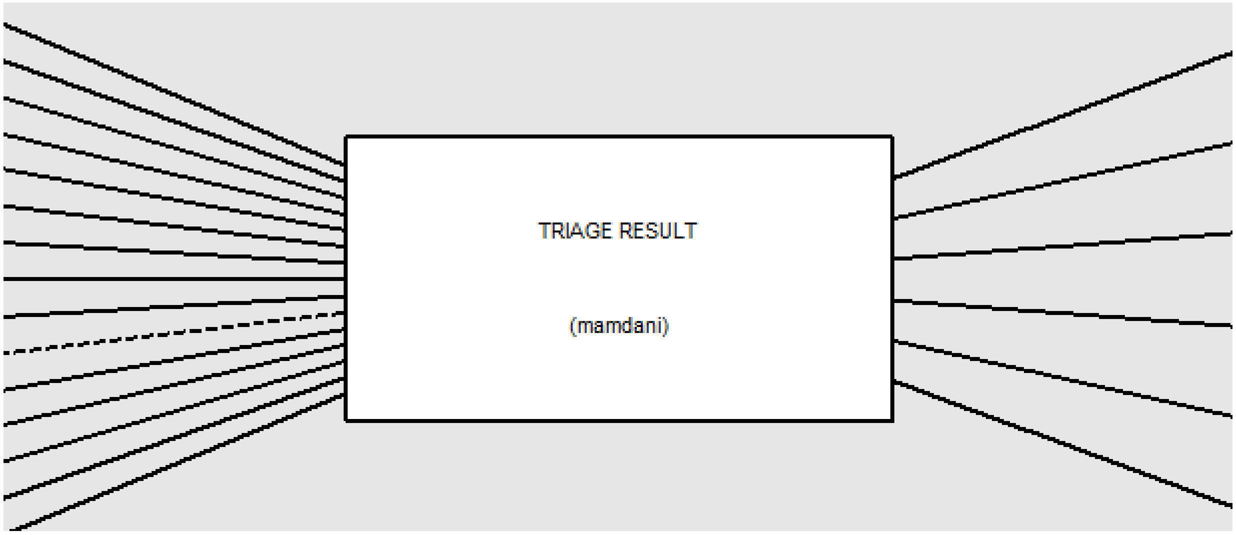


Fig. 4.8 inputs and output connector

After Double clicking on this, the rule editor window displayed. Then it is possible to add as much as rules as possible.

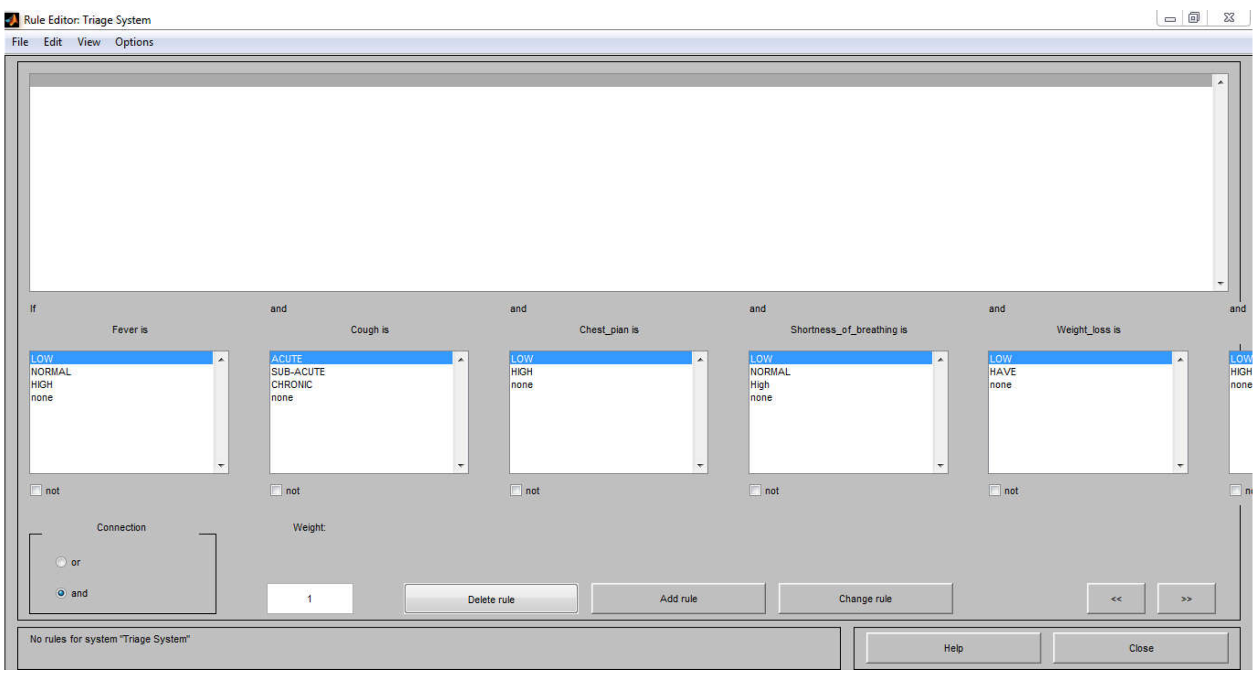


Fig. 4.9 Rule editor window

Then it is possible to generate rules using inputs and outputs from the above window. As discussed before the rules are generated using in-then rule, and it uses the connectors **AND or OR** based on the nature of the symptoms on the diseases.

Some examples of rules that have been generated are shown like this.

1. If (Fever is HIGH) or (Cough is CHRONIC) or (Chest_pian is HIGH) or (Shortness_of_breathing is High) or (Weight_loss is HAVE) then (TB is HIGH) (1)
2. If (Fever is NORMAL) or (Cough is CHRONIC) or (Chest_pian is HIGH) or (Shortness_of_breathing is High) or (Weight_loss is HAVE) then (TB is HIGH) (0.5)
3. If (Fever is HIGH) or (Cough is CHRONIC) or (Shortness_of_breathing is High) or (Weight_loss is HAVE) then (TB is HIGH) (0.5)
4. If (Fever is HIGH) or (Cough is CHRONIC) or (Shortness_of_breathing is High) then (TB is HIGH) (0.5)
5. If (Fever is HIGH) or (Cough is CHRONIC) or (Weight_loss is HAVE) then (TB is HIGH) (0.5)
6. If (Fever is HIGH) or (Headache is HIGH) or (Shaking is HIGH) or (Vomiting is HIGH) then (Typhoid_fever is HIGH) (1)
7. If (Fever is HIGH) or (Cough is ACUTE) or (Shortness_of_breathing is High) or (Headache is HIGH) or (Shaking is HIGH) then (Typhoid_fever is HIGH) (1)
8. If (Fever is HIGH) or (Cough is ACUTE) or (Shortness_of_breathing is High) or (Headache is HIGH) then (Typhoid_fever is HIGH) (0.5)
9. If (Fever is HIGH) or (Weight_loss is HAVE) or (Headache is HIGH) or (Vomiting is HIGH) or (Diarrhea is HIGH) then (HIV_AIDS is HIGH) (1)
10. If (Fever is LOW) or (Weight_loss is HAVE) or (Headache is HIGH) or (Vomiting is HIGH) or (Diarrhea is HIGH) then (HIV_AIDS is HIGH) (0.5)
11. If (Fever is LOW) or (Weight_loss is HAVE) or (Headache is LOW) or (Vomiting is HIGH) or (Diarrhea is HIGH) then (HIV_AIDS is HIGH) (0.5)
12. If (Weight_loss is HAVE) or (Vomiting is HIGH) or (Diarrhea is HIGH) then (HIV_AIDS is HIGH) (0.5)
13. If (Fever is HIGH) or (Cough is ACUTE) or (Weight_loss is HAVE) or (Headache is HIGH) or (Diarrhea is HIGH) then (HIV_AIDS is HIGH) (0.5)
14. If (Fever is HIGH) or (Cough is ACUTE) or (Headache is HIGH) or (Sneezing is HAVE) or (Runny_Nose is HAVE) or (Horse_Voice is Have) then (Common_Cold is HIGH) (1)
15. If (Fever is HIGH) or (Cough is ACUTE) or (Sneezing is HAVE) or (Runny_Nose is HAVE) or (Horse_Voice is Have) then (Common_Cold is HIGH) (0.5)
16. If (Fever is HIGH) or (Cough is ACUTE) or (Sneezing is HAVE) or (Horse_Voice is Have) then (Common_Cold is HIGH) (0.5)
17. If (Headache is HIGH) or (Sneezing is HAVE) or (Runny_Nose is HAVE) then (Common_Cold is HIGH) (0.5)

Fig 4.10 Sample rules of inference system

4.6 Rule Viewer

Rule viewer and surface viewers are used to view the result of the rules and which able to give decision based on the inputs.

Rule Viewer is used to view the fuzzy inference diagram. Use this viewer as a diagnostic to see, for example, which rules are active, or how individual membership function shapes influence the results. In the rule viewer when we change the inputs, the outputs have shown the result. On the input part of the system we can adjust values that are given for each respective symptom, or it is also possible to adjust by simply dragging the graph from the input part. When we adjust the inputs, the result displayed both graphically and also it shows the result in percentage, which means how much percent that the result is approached for each output. So the triage can be given priority for the diseases based on the percentage that is shown on the result.

Surface Viewer is used to view the dependency of one of the outputs on any one or two of the inputs that is, it generates and plots an output surface map for the system.
The surface viewer is used to show the graphical representation between the inputs (symptoms) and the output (the triage result). Here also we select the inputs and outputs and we can see the relations graphically.

To see rule viewer click on **view > Rules**

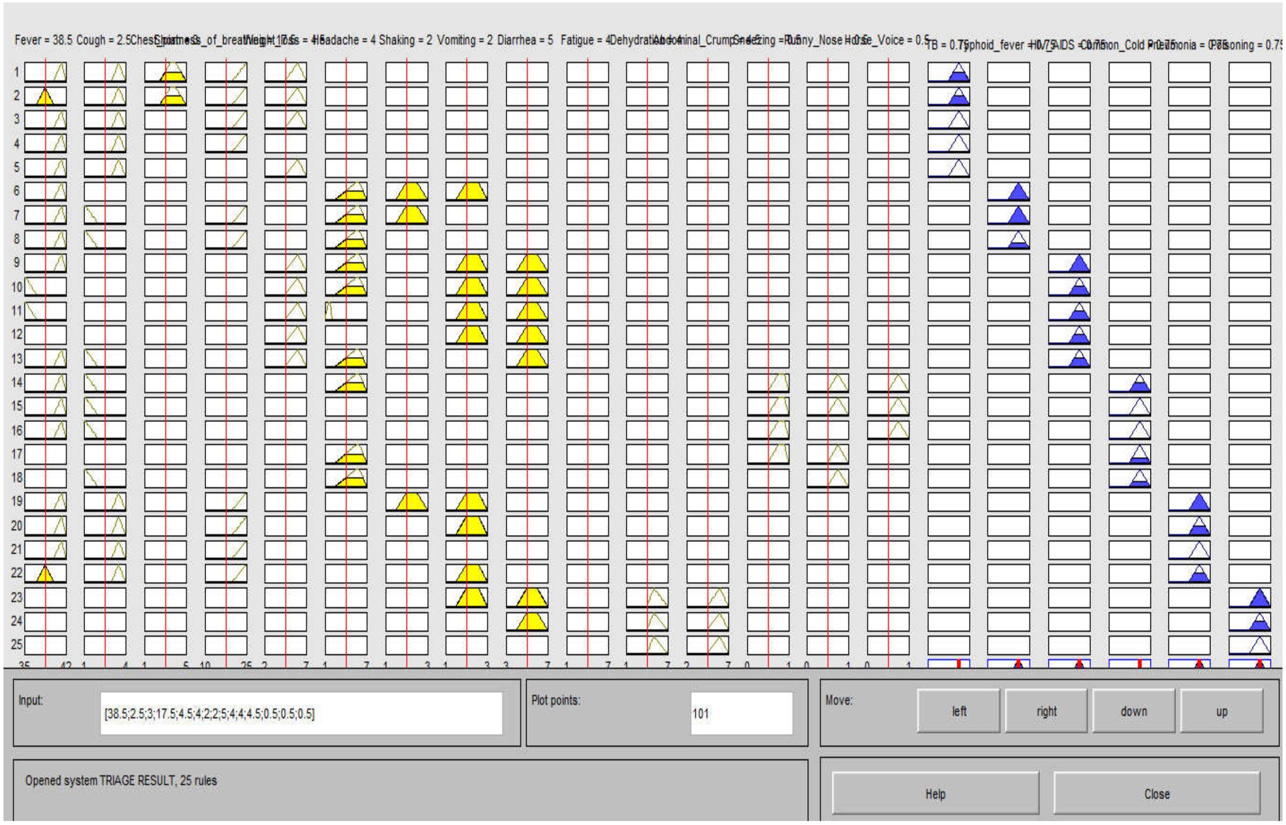


Fig.4.11 Rule viewer for triage system

4.7 Surface Viewer

In surface viewer it is possible to see each of the dependencies for every input and outputs by changing X (input), Y (input) and Z (output).

The following figure shows the dependency between fever and cough with TB.

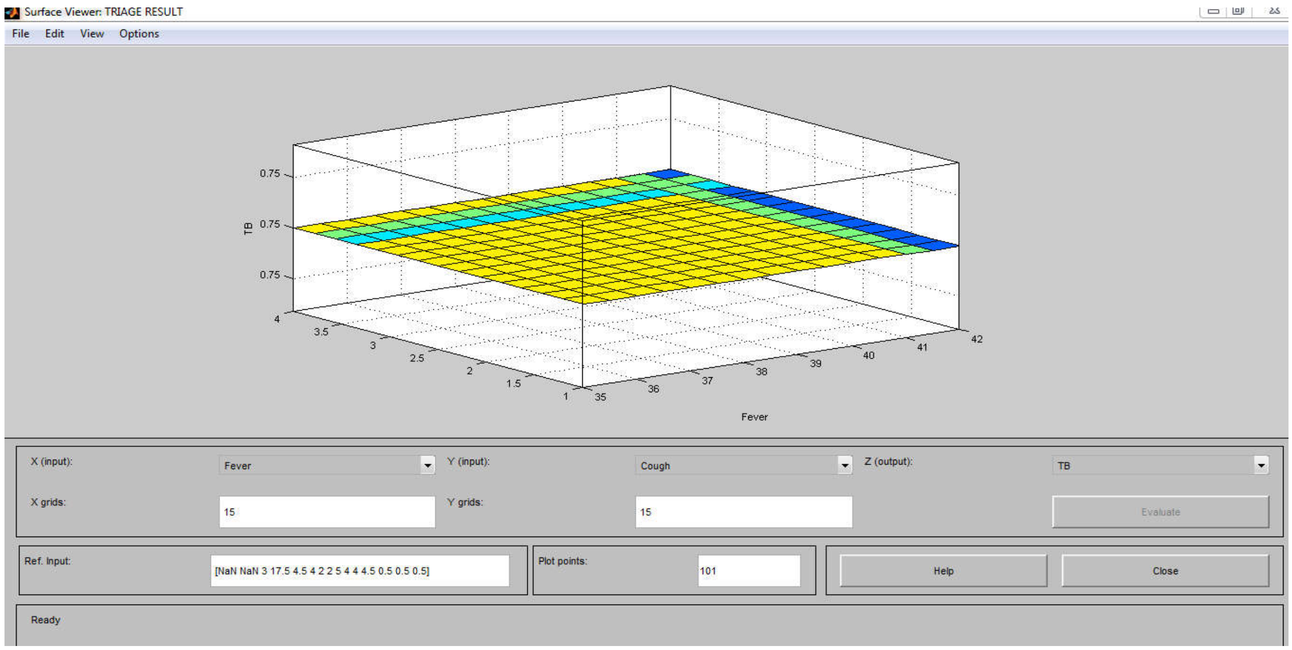


Fig. 4.12 Surface viewer for TB with (fever and cough)

4.8 User Acceptance Testing

Testing is used to identify whether the developed system is achieve its minimal goal or not, because one of the objective of this research is to test the user acceptance and the performance of the system. The system testing is made on its accuracy for making triage identification, so it is measured by the domain experts in the field of domain area. So the researcher has developed some questions that are answered by the domain experts during interacting with the system. For evaluation purpose 4 domain experts have been selected purposively from Menelik II hospital, and they have tried to evaluate the system by discussing with themselves and have given their recommendation on the system. Totally questions have been prepared and there are five levels for the evaluation; these are **poor, fair, good, very good, and excellent,** and have **1, 2, 3, 4** and **5** respective values. In terms of percentage, 5 is given 100%, 4 is equal to 80%, 3 is equal to 60%, 2 is equal to 40% and 1 is equal to 20%. These values have given by the domain experts, during interaction with the system.

The following are questions that are prepared for evaluation.

No	Questions	Poor (1)	Fair (2)	Good (3)	Very Good (4)	Excellent (5)	Percentage (100%)
1	Is the system is easy to understand and use?			X			60%
2	Is the user interface is attractive for use?			X			60%
3	Is it accurate in prioritizing the patients based on their symptoms?				X		80%
4	Does the system is important for the domain experts?				X		80%
5	Does the system have significance contribution for the domain area?					X	100%
6	What is the level of applicability of the system?				X		80%
7	How do you get the system will be useful as a training tool?			X			60%
8	**Average Result**						**74.28 %**

Table 4.2: User acceptance evaluation

As the domain experts have evaluated the system on their point of view, they have rated **74.28 %** effective and efficient. Finally they have given their own recommendation both on the further improvement of the system and on the strength of the system. According to the system evaluators the following are some of the basic limitations of the knowledge based system:

- The system cannot make intelligent decision as human expert by considering the current status of the patient, rather it decided by considering only the symptoms that have fed to it.
- The Fuzzification of the symptoms is difficult because there is no universal agreement on Fuzzification and this affects membership function assignments.
- The system lacks flexibility; because the users of the system are interact with the given symptoms only.

In addition to the limitations, the domain experts have given their own positive feedback on the developed system.

- The system helps the domain experts in identifying the symptoms easily in short time with minimized cost.
- The system has reduced the required manpower in the triage department, reduce the time lost by the patient and minimize the crowdedness of patients.
- Consistent decision have been given by the system for similar symptoms, it does not give different decision for the same case.

- Encourages other researchers on development of related systems which will improve the development of expert systems in the domain area for future researchers.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1CONCLUSION

This research has tried to solve some problems that have been seen on the triage system in hospitals. As the researcher has discussed on the statement of the problem, triage system, there are different triage problems that have been observed in the hospitals because it was possible to prioritize the patients based on symptoms observed on them. The triage has got some problems which are resulted from the triage nurses. Some of the problems are lack of experience of the triage nurses in the triage patient identification, biasedness, frustration during some injured or very sick patients, tiredness and carelessness of the triage nurses. So this research has tried to solve these and related problems discussed above and make the prioritization somehow simple. By using this system the triage nurses can be able to do better prioritization. The system can improve quality of health care, shortage of skilled manpower in triage identification, minimize the overcrowded number of patient and minimize patient's time to spend on triage. So this system aimed to help the triage nurses in the processes of triage patient categorization and making proper decisions.

To conduct this research the researcher has been used design science research methodology, and the necessary knowledge have been collected from domain experts in Menelik II Hospital. The proposed knowledge based system is conceptually modeled using hierarchical structure with logical relationships between the identified symptoms and the respective disease of the patient. The system have been developed using Fuzzy inference system in Matlab tool. The developed system can be able to identify the diseases based on the query given. It can be able to provide suggestions on the basis of symptoms what will be the recommended disease and to where further diagnosis will be made by putting the recommended disease type in ranking order.

5.2 RECOMMENDATION

The study achieved the main objectives by developing the rule based system in pre medical triage service. Based on the developed system and challenges to the system the following recommendations have been forwarded for future works.

- The fuzzy inference system can handle patient identification if perfect data have been fed. But in this research fuzzifying the symptoms of the patient was a very difficult task, because there is no universal agreement on Fuzzification of the symptoms. In this study the Fuzzification is made by taking the average values that are given by the domain experts based on their agreement. Most of the symptoms of the diseases are subjective, so it is difficult to change into numerical representation (Fuzzification). When the researcher has tried to fuzzify the inputs, there was a variation between different domain experts, which have negatively affected the system development. So to solve this problem isolated research can be conducted in the future on only identifying the major symptoms of each diseases and formulate Fuzzification on each of the symptoms.

- The scope of the knowledge based system should be extended to include others diseases categories of triage system since this system is limited to only 6 major diseases which are dangerous today.
- The symptoms of the diseases may continuously change based on different factors like environmental factors and the ability of the patient that able to immune the diseases. So this makes the triage treatment complex and subjective. Therefore, the future works can be done on integrating an intelligent agent that has a capability of self-learning and update its knowledge base automatically by using neural network adaptive system.
- Since such types of systems developed in English language, the applicability of the system is limited, so the researcher recommended that the system will have more applicability if it can be developed in local languages, because the users can able to conduct with the system in their mother tongue language.

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Appendix

Interview questions

Addis Ababa University School of information science for the fulfillment of MSC program Interview questions prepared for Menelik Hospital TB case Team.
First of all thank you for your attention and help.

1. What are the tasks that are performed in the disease diagnosis?
2. Do you think that expert systems are useful in health organizations for diagnosis and treatment?
3. What are the advantages and disadvantages of expert systems for disease diagnosis in the health centers?
4. What are the major identified diseases which are difficult for the society?
5. How do you identify and diagnosis disease?
6. What are the major identified symptoms of the selected disease in our country?
7. What are the treatments do you have taken after you have got the disease?
8. What steps do you follow to diagnosis them?
9. Is there any advice that is given for patients in order to protect them from the diseases?
10. What are the recommended actions do you use to prevent the disease before the occurrence?

Thank you for your help

Declaration

I, the undersigned declare that this thesis is my original work and has not presented as a partial degree requirement for degree in any other university and that all sources used for the thesis have been duly acknowledged.

……………………………………..

Mulatu Dagnachew

January 2016

As an advisor I, the undersigned declare that this thesis is the original work of Mulatu Dagnachew and has not presented as a partial degree requirement for degree in any other university and that all sources used for the thesis have been duly acknowledged.

……………………………

Solomon Teferra (PhD)

January 2016