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Developing Fuzzy Expert System for Diagnosing The Risk Of Physical And Psychological Disorder Related To Khat Addiction

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DEVELOPING FUZZY EXPERT SYSTEM FOR DIAGNOSING THE RISK OF PHYSICAL AND PSYCHOLOGICAL DISORDER RELATED TO KHAT ADDICTION

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By

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February 2020

DECLARATION

I declare that this thesis work was not previously submitted for the award of a degree by this or any other University. To the best of my knowledge, this thesis contains no materials published or written by any other person except the materials where I have acknowledged and refereed in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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To my family

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ABSTRACT

Khat is found in the large shrub, which consists of cathinone. It is the main active ingredient in khat leave responsible for physical and psychological health effects. Khat addiction becomes the growing public health concern in Ethiopia. It is therefore important for individuals to have adequate knowledge of physical and psychological disorder related to khat addiction to avoid the risk. Experts systems are rapidly growing technology and an active area of research in disease diagnosis and treatment. Fuzzy logic is one of the approach used for enhancing personal health care delivery in the health sector. Since there is shortage of experts in the domain area, we develop fuzzy expert system to diagnose the risk of physical and psychological disorder related to khat addicted addiction. A java library (JfuzzyLogic) running on android operating system was used to develop the inference engine and knowledgebase. The source of data to build expert system were collected from literatures, interview with experts and medical data extracted from khat addicted patients with physical and psychological disorder from Felege Hiwote Referral Hospital, Bahir Dar Ethiopia. The designed fuzzy expert system is used for patients and physicians to examine the risk level of the disease. The experimental result showed that the designed expert system performs 95% accuracy. This fuzzy expert system was evaluated and provide effective result for diagnosing physical and psychological disorder related to khat addiction.

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ABBREVIATIONS

API: Application Program Interface

COG: Center of Gravity

DOS: Microsoft Disk Operating System

EDHS: Ethiopian Demographic and Health Survey

FCL: Fuzzy Control Language

FIS: Fuzzy Inference System

FMOH: Federal Minister of Health

GUI: Graphical User Interface

IDE: Integrated Development Environment

IT: Information Technology

LOM: Largest value of maximum

MF: Membership Function

MOM: Mean value Of Maximum

NMHS: National Mental Health Strategy

SC: Soft Computing

SDK: Software Development Kit

WHO: World Health Organization

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CHAPTER ONE

1. Introduction

1.1. Background

Khat (Catha edulis) is evergreen plant to East Africa and Arabian Peninsula which is the most widely used psychoactive herb in the world. Ethiopia is the largest producer of khat. Fresh leaves of khat are used by millions peoples as a recreational drug on daily bases for its euphoric and psycho stimulant effects (Engidawork, 2017). Khat leaves contain psychoactive substance known as Cathinone which have effect on individual's consciousness, behavior, mood and thinking processes (Griffiths et al, 2010). Khat use has been associated with various health problems. Besides damaging health, khat chewing has also impact on socio economic aspects of youth's daily life. Khat chewing has great impact on mental and physical health of chewers. High doses and chronic use of khat can cause more serious adverse on long term khat chewers neurological, psychiatric, cardiovascular, dental, gastrointestinal, and genitourinary effects (Michael & Mustafa, 2017).

The chronic use of khat causing physical and psychological dependence has now become a growing public health problem among society. Ethiopian Demographic and Health Survey (EDHS) 2011 stated the prevalence of khat use in the population of Ethiopia was 27.3% among men and 11.0% among women of 15-49 years (Zekaria, 2011). Similarly other studies show the prevalence of khat use in Ethiopia out school and in school adolescents was 23.0% and 7.5% respectively (Kebede et al, 2005).

Different studies conducted in different part of the country shows that psychological impacts of khat chewing are hazardous to the community. There is a regional variation in the number of peoples affected by khat addiction. There is also significance association psychological khat dependence and frequency of khat use (Dessie et al, 2013). Impaired concentration, insomnia, headache, impaired motor coordination and fine tremors are also central nervous system deficits associated with khat use (El-Setouhy et al, 2016). A study was conducted to assess the effect of khat chewing in Bahir Dar, North west Ethiopia (Birhane & Lebeta, 2014). The result shows, frequently chewing khat have significant effect on health outcome of khat addicted patients. To reduce the risk of addiction for long term chewers, computer based intervention are needed.

The advancement of computer technology is playing important role for diagnosis purpose in medical area. Medical diagnosis in the health area is full of uncertainty and dynamically changed according to the situation. Expert system is one branch of artificial intelligence which was defined first time by prof Feigenbaum who has assumed to be pioneer in this subject as “an intelligent computer systems that uses knowledge of experts and inference procedures to solve tangible world problems that are difficult because of insufficient number of significant human experts” (Feigenbaum, 1982).

Expert system uses data and rules to solve real world problems based on knowledge obtained from one or more human expert in the specific domain area. Expert systems use human knowledge to solve problems that normally would require human expertizes intervention in the domain area. Expert systems play important role in the process of decision support and problem solving. Expert systems also transfer task specific knowledge from human expert to computer like a human consultant gives advice and explains if necessary the logic behind the advice (Meena & Kumar, 2015).

Fuzzy logic has been identified as one of the tool that is used to model human decision making of expert in a computer program such that the program can work like human expert to solve problem (OW et al, 2013). Due to imprecision and uncertainty in medical practice the advantages provided by fuzzy logic for dealing with imprecise and uncertainty situation make it suitable approach for solving complex medical data (Kunhimangalam et al, 2013). Fuzzy expert is a collection of fuzzy rules and membership functions.

1.2. Statement of the Problem

The prevalence of khat use and its physiological, social and psychological problem has been studied in diverse population and different part of Ethiopia (Taye et al, 2017). Khat addiction is currently the main problem that affects people's daily life. There is scarcity of research on knowledge based system in physical and psychological interventions that address khat related health problems. In order to reduce the risk of khat related health problems treatment tools for various severe user groups as well as knowledge base systems are needed (Michael & Mustafa, 2017). Clinicians treat and monitor the health status of khat addicted patients with physical and psychological disorder manually and this leads to wastage of time and resources. Most of the time diagnosis and health monitory services are only provided in hospitals due to critical shortage of man power in the area of mental health.

The effects of khat addiction are sleeping disorder, hallucination; tooth staining, anxiety, loss of appetite, depression, constipation, gastritis, hypertension, psychosis, cardiovascular, respiratory and central nervous system (Zenebe et al, 2015) . Khat also causes immediate increase in blood pressure and heart rate. World Health Organization (WHO) reported that khat use is also related to Cardiovascular, respiratory, reproductive and central nervous system problems. Khat addiction problem is the current issue of our community by affecting their initiation to work, behavioral changes, reducing social life and leads to accidental death. Chewing khat not only affects individuals but also it could have serious socio economic consequences.

A study was conducted in Bahir Dar city administration, Northwest Ethiopia using community based and cross sectional study to determine the prevalence of khat chewing and its associated risky sexual behaviors. The study participants were selected based on sex, age, residence, occupation, education, religion and marital status. Among study participants the life time and prevalence of khat chewers were 25.7% and 19.5% (Abate et al, 2018).

The habit of khat chewing affects large portion of the population especially the productive age group and its negative impact on health was reported by different study findings. Khat chewing practice also reinforces other habits like cigarette smoking, alcohol intake and narcotics. According to Federal minister of health (FMOH) (Admasu, 2012), a National Mental Health Strategy (NMHS) was developed to address the mental health problems. The assessment provided data shows 1.2 mental health professionals per 100,000 people and most of these workers based in the capital city. It indicates how the mental health system in Ethiopia could be improved through

training greater number of mental health workers in areas where they are needed most. Early identification of the disease risk level can help in ensuring relevant interventions are put in place to improve the health status of khat addicted patients (Kunhimangalam et al, 2013).

Developing fuzzy expert system would reduce the burden of human expert and waiting time of patients in hospitals. The developed fuzzy based expert system is used to monitor the health status of addicted patients before it becomes worse. It is also useful to assist human expert by providing appropriate knowledge at the right time for decision making purpose in diagnosing the risk of khat addicted patients with physical and psychological disorder.

Basically, this research addresses the following questions:-

I. What type of knowledge is handled by the proposed model?
II. How to construct a fuzzy expert system to diagnose the risk of physical and psychological disorder related to khat addiction?
III. How the proposed expert system diagnose the risk of physical and psychological disorder related to khat addiction?

1.3. Objective of the Study

1.3.1. General objective

The main objective of this study is to develop fuzzy expert system for diagnosing the risk of physical and psychological disorder related to khat addiction.

1.3.2. Specific objectives

- ✓ To extract the necessary knowledge from domain experts for physical and psychological disorder related to khat addiction
- ✓ To identify the appropriate model for physical and psychological disorder related to khat addiction
- ✓ To develop fuzzy expert system using the acquired knowledge
- ✓ To evaluate and validate the new system

1.4. Methodology

For accomplishing the objective of study experimental research methodology was used. We develop fuzzy logic based expert system. The system was developed with fuzzy set of rules. Fuzzy sets are artificial intelligence techniques that provide appropriate diagnosis to particular problems. Fuzzy logic is based on reasoning. Fuzzy logic provides powerful reasoning technique for handling imprecise and uncertainty in data to diagnose the risk level of physical and psychological disorder related to khat addiction. Fuzzy logic is used when the knowledge in the world is not precise and for drawing inference to conclusion (OW et al, 2013). Fuzziness occurs in physical and psychological disorder since symptoms and risk factors may be exaggerated, removed by patients and sufficient data may not provide by patients for identifying the risk. When the boundary of the information is not clear, fuzziness occurs. In order to process the knowledge in computers, fuzzy rules are generated for knowledge representation. The user input risk factors and symptoms of physical and psychological disorder related to khat addiction. Then the expert system would display the condition of the patient health and provide information about the disease from the facts stored in knowledgebase.

The first step followed for diagnosing the risk level of physical and psychological disorder related to khat addiction using fuzzy expert system were collection of physical and psychological symptoms and risk factors. After collecting the basic symptoms and risk factors, we interact with domain experts for assigning weight to symptoms, construct range of membership functions and

fuzzy rule formation. Finally user interface for the interaction of users were designed and evaluation of the developed fuzzy expert system was performed.

Method of data collection

In order to acquire knowledge for fuzzy expert system, 50 patients data were collected purposely from documented khat addicted patients with physical and psychological disorder from Bahir Dar Felege Hiwote Referral Hospital. Structured and unstructured interview was conducted in order to receive the required knowledge from domain experts (psychotherapist). The acquired knowledge were validated by domain experts. They evaluated based on its significance and frequent occurrence in diagnosing physical and psychological disorder related to khat addiction. The criteria for selecting specialized experts was based on profession, educational background, experience, role and position in diagnosis of khat addicted patients with physical and psychological disorder.

Software tools

Android Studio together with JfuzzyLogic and Wamp Server was used to develop fuzzy expert system. Software development tools are:

- ✓ Android SDK Tools 26.1.1
- ✓ Android API 26
- ✓ Java Development Kit (JDK)
- ✓ Java (JfuzzyLogic) for storing the knowledge of experts
- ✓ MYSQL data base engine used for storing facts about physical and psychological disorder related to khat addiction.

Testing procedure

In order to validate the proposed fuzzy expert system functional testing was used (Leonard , 1991). The symptoms and risk factors of physical and psychological disorder was used as input to the system to test basic functions. Then Fuzzy rules were used to analysis of patient symptoms and the final result was evaluated.

1.5. Scope and Limitation

This study focuses on developing fuzzy expert system for diagnosing the risk level of physical and psychological disorder related to khat addiction to monitor the health status of patients by identifying the risk level of disease based on symptoms to recover from disease in case of Bahir Dar city. The developed fuzzy expert system helps for diagnosing the risk level of physical and psychological disorder related to khat addiction from the stored database based on experts' knowledge in the domain area. The study covers physical and psychological disorder related to khat addiction and doesn't include other kind of diseases.

Some of the major challenges faced during this fuzzy system development was knowledge elicitation and fuzzification of input variables, since symptoms and risk factors are subjective. Expert systems require large data base to process and challenges sometimes exist to work effectively. We limit the scope as suitable relevant to the research.

1.6. Significance of the Study

The significant of the study would be for khat users, researchers, clinicians and for the community as a whole. It supports clinicians to identify the severity of physical and psychological disorder in khat addicted patients. The developed expert system would also help clinicians to improve their skill in diagnosing the risk level of physical and psychological disorder related to khat addiction for providing appropriate diagnosis to their patients. It also allows academicians and researchers to develop new model and tool to diagnosis khat addiction related health problems based on the developed fuzzy expert system. It is also important for self-monitoring of patients with physical and psychological disorder related to khat addiction. The constructed fuzzy expert system is useful for diagnosing the risk level of physical and psychological disorder related to khat addiction.

In the developed expert system, the knowledge of expert were used as evidence based interventions that are feasible, cost effective and scalable to diagnosis the risk level of khat addicted patients with physical and psychological disorder. The finding of the study would fill a clear gap and benefit the society in efforts to diagnosis physical and psychological problems related to khat addiction.

1.7. Ethical Considerations

Confidentiality and privacy related information to patients were considered during the study. The data collected would be used for academic purpose only and would be treated confidentially. Personally identifiable information was not collected. In this study appropriate data was collected from psychiatric diagnosis of patients in Hospitals and interview was used to collect data directly.

CHAPTER TWO

2. Literature Review

2.1. Introduction

Chronic consumption of Khat affects the physical and psychological wellbeing of the chewers and leads to various health disturbances. The use of mobile technologies is new and innovative to improve health and health care delivery. In recent years portable devices like mobile phones and laptops increase the availability of mobile applications to business centers, hospitals and home users. Medical applications change the way humans think and they are accepted by the society. This chapter provides basic information on theoretical background related to this work, it also includes symptoms and risk factors of physical and psychological disorder that was used to design mobile based fuzzy expert system for diagnosing the risk level of khat addicted patients with physical and psychological disorder. Previous and existing research works on this area were reviewed.

2.2. Facts about Khat Addiction

The chewing of khat leaves which is widely chewed in eastern Africa and southern Arabian Peninsula, is a psychoactive substance with ranges of problematic health outcomes. According to Ethiopian Demographic Health Survey (EDHS) 2011 the prevalence of khat chewing in the population of Ethiopia was 27.3% among men and 11.0% among women between the ages of 15-49 years. The reported psychiatric effects of khat addiction are depression, insomnia, feeling anxious and irritability, loose of appetites, nausea and vomiting, difficulty of seeing at night, headache, fast heart rate, depression, difficult with balance and coordination, blurred vision, difficulty in concentration etc. Khat addiction and its relationship with psychophysical symptoms among khat addiction patients was studied. Khat addiction can influence the physical and psychological wellbeing of the community and can cause more serious adverse psychiatric, cardiovascular, dental and gastrointestinal effects.

The data collected from medical history, neurological symptoms and chewing behavior indicates 52.2 % of khat users showed psychological dependency with khat chewing. Long term khat addicted patients (>6) hours were more vulnerable to physical and psychological problems. The effects of khat addiction and its Psychophysical Symptoms was conducted among khat users in

Jazan Region, Kingdom of Saudi Arabia. The finding of the study shows that, physical and psychological symptoms of khat chewing patients are feeling depressed, feeling tired, headache, fast heart rate, loss of appetite, blurred vision and so on. The result of this study shows that physical and psychological symptoms were more associated among khat addicted patients (El-Setouhy et al, 2016).

Khat use and its associated consequence in persons with mental illness were conducted in southwest Ethiopia which indicates that the prevalence of khat use reaches 64.4% (Zenebe et al, 2015). Khat chewing practice and its perceived health effects among communities of Dera Woreda, Amhara Region, Ethiopia shows that khat chewing practice has harmful effect on health and social life of khat user persons and the prevalence of chewing khat was 17% (Asmamaw et al, 2013).
Another study was conducted, about the effects of khat addiction behaviors on health outcomes among male khat chewers in Bahir Dar, North West Ethiopia and the result of the study shows that khat chewing has a huge impact in oral health status and blood pressure of chewers (Birhane & Lebeta, 2014) .
Based on the facts about khat addiction, the need for developing mobile based fuzzy expert system to diagnosis the risk level of khat addicted patients with physical and psychological disorder would be user friendly, cost effective and support decision making in the health sector.

2.3. Physical and Psychological Disorder related to Khat Addiction

Various physical and psychological health problems have been associated with khat use. Khat contains many kinds of compounds that have effect on health including central nervous system and gastro-intestinal system. However the effects of khat use depends on specific khat chewing conditions like high quantity use, daily use, nighttime use and very long use sessions. The use of khat consumption at high rate brings socio-economic, physical and psychological problems among the society. The main psychoactive substances found in khat are cathinone and cathine. Recent studies shows that chronic khat use is associated with physical and psychological health consequences (Michael & Mustafa, 2017).

Since khat addiction related diseases such as physical, mental and psychological problems have different lifecycles, identifying the risk level of physical and psychological disorder helps patients to improve their health status and take appropriate measures to reduce its effect.

2.3.1. Symptoms and Risk Factors for Physical and Psychological Disorder related to Khat Addiction

The potential risk factors for chewing khat are gender of participant, marital status, education status, occupational status, age of starting khat chewing, chewing experience of the patient and frequency of khat use (Taye et al, 2017). Common symptoms of khat addicted patients with physical and psychological disorder are feeling depressed, headache, dizziness, fast heart rate, sleeping disturbance, being absent minded and blurred vision (El-Setouhy et al, 2016). Physical and psychological disorder symptoms were more prevalent among khat dependent chewers. Depression can cause headaches along with other pains in the body and headache causes pain in the head.

2.4. Digital Technology Intervention in the Healthcare Center

The development of intelligent health care systems is active area in monitoring the health status of patients. Currently quality healthcare is an important issue throughout the world since healthcare faces funding crisis due to increase population and occurrence of different diseases. Healthcare systems are a capable of solving those challenges in efficient and cost effective way. In different healthcare applications, the acquisition of medical signals is provided through sensors attached on patients' body and wearable devices. Health care information systems play an important role by allowing Doctors to access patients' medication, past medical history, signs, laboratory data, medical images and it support patients to treat themselves.

In the current state of the art of Digital technologies in the healthcare sector if it is widely implemented, it will reduce the effect of various diseases and addictions that affect peoples' daily life like physical and psychological problems as a result of khat addiction. Those different technologies that exist today also have some challenges. These are:

a. By which method to get acceptance of these new technologies among end users
b. Cost effectiveness
c. Maintenance
d. By Which method to handle large volume of data with the latest technologies

Despite the new technologies today, peoples are still vulnerable to various diseases and addictions. Quality is not assured among healthcare sectors in monitoring patients and provide service. Either

awareness is not created among the society or they are not delivering those new technologies with their premise.

2.4.1. Mobile Computing

It is a combination of Information Technology (IT) products, services, operational strategies and procedures that allow end users to gain access to computational information and related resources through their mobile phones. It supports variety of devices for the users to access data and information from where ever they are and at any time. Its importance is connectivity, social engagement, portability and personalization.

It includes mobile hardware and mobile software.

A. Mobile hardware

It includes mobile devices that deploy services of mobility like tablet pcs, portable laptops and personal digital assistant. Considerations for components of hardware are screen type and size, battery life span, primary and secondary storage, microprocessor, stability of the device and communication efficiency.

B. Mobile software

It is the actual program that run on the device hardware. It is responsible for the operation of the device. Some of commonly used system software and operating system on mobile computers include Windows 10 (NT 10.0 (2015)), Microsoft Disk Operating System (DOS), Android and UNIX.

2.4.2. Benefit of Mobile Applications for Personal Health Monitoring

The advantage provided by mobile devices and applications by individuals and health professionals supports individuals for monitoring their health status, improve quality of health and allows health professionals for decision making purpose. Patients can easily diagnosis and treat a disease at home with their mobile devices. It helps peoples to manage their health and wellness, promote healthy living and gain access useful information at any time.

2.5. Soft Computing

(Kumar et al, 2013) States that, soft computing (SC) is an important approach to incorporate human knowledge effectively, deal with uncertainty, imprecision and learn to adapt to unknown or changing environment for solving real world problems. It is new multi-disciplinary field for constructing a new branch of artificial intelligence which is computational intelligence. Soft computing perform different computing operations such as neural network, fuzzy logic, approximate reasoning and genetic algorithms. Fuzzy logic which is based on knowledge driven reasoning was used in this research work.

2.6. Applications of Fuzzy Logic

Fuzzy logic is one approach of soft computing that used for modeling knowledge of human experts and applied to real world problems. The motivation of selecting fuzzy logic in this research work is because of fuzzy logic delivers effective results on unclear verbal information like human reasoning. Since there is no enough domain experts in diagnosing the risk level of physical and psychological disorder related to khat addiction, fuzzy logic plays important role in representing the knowledge of experts and works as human expert. It gives the processing capability of linguistic variables for physical and psychological disorder related to khat addiction symptoms and risk factors. This variables are symbolically replace numeric values and assign the calculated representative foundation using fuzzy logic concepts. Human beings solve real world problems by creating linguistic rules such as “if <event realized> is this, the <result> is that”. Fuzzy logic systems use linguistic terms and variables together with linguistic rules. This linguistic terms and variables are represented in fuzzy system using membership degrees and functions. Symbolic expressions are transferred to computers by fuzzy logic mathematical model.

2.6.1. Fuzzy Logic Theory

Fuzzy logic studies human knowledge modeling system that allows new logical variables to be evaluated as functions of certain existing variables. Classical logic theory works with conclusions or decisions made that are either true or false. It contains variables with different combination that represent preposition. The variables are combination of a truth value (either true or false) but it can’t be between the two values or not true and false at the same time. The basic assumption in classical logic theory is every preposition is either true or false and it has only two alternatives. But now this principle is accepted as by different prepositions as both partially true and partially false.

The first publication of Fuzzy set theory by (Zadeh, 1965) generalize the classical notion of set and preposition (statement) to accommodate fuzziness. Fuzzy logic uses rule based IF X AND Y THEN Z approach to solve problem rather than modeling mathematically. In fuzzy system truth values or membership values are indicated in the range [0, 1], with 0 representing absolute falseness and 1 representing absolute truth. It provides a clear procedure to reach conclusion based on ambiguous, imprecise and missing information.

2.6.2. Fuzzy Sets

Fuzzy sets contain values with degree of membership which belongs to set and not belongs to set. It doesn't have crisp, clearly defined boundary, and the fuzzy boundary is described with membership degree of the elements in the range from 0 to 1. Fuzzy inference systems are based on approaches of fuzzy set theory, fuzzy reasoning and if-then rules. FIS works by mapping a specific input to output based on experts' knowledge. The knowledge is programmed as sets of clear rules, which can be easily understood without basic knowledge of individuals (Osawaru, Olaleru, & Olauluwa, 2018). Fuzzy facts are used in knowledge which is inexact, vague and indefinite. It is especially used in medical fields to represent member sets with some degree of association. Characteristic functions are used to represent U of set D.

$\mu D(u) = 1$, if u is an element of the set D, and

$\mu D(u) = 0$, if u is not an element of the set D,

An object can either belongs to a given set of elements or does not belong to a set. In fuzzy sets an object can belongs to a given set partially. The degree of membership for elements of a set is expressed through a generalized characteristic function known as membership function:

$\mu D(u): U \rightarrow [0,1]$

Where U is universe of a given set, and D is a fuzzy subset of U.

Membership function is a curve which defines how each point in the input space is mapped to the corresponding degree of membership as a real number in the interval [0, 1]. Membership function selection for fuzzy sets is specified by domain experts or based speed and efficiency (Youssefi, Nahaei, & Nematian, 2011). The result of this membership functions are real numbers in the range

[0, 1], where 0 indicates the input value is not a member of a set and 1 indicates the input value belongs to the set. The values are known as membership degree.

Fuzzy set theory can be considered as extension of ordinary set theory. Ordinary sets (crisp values) are type of fuzzy sets, when two membership degrees 0 and 1 are used. Crisp borders are defined between sets. The formulation of a fuzzy set depends on selecting variables used for universe of discourse and specification of suitable membership function.

Let Z be universe of discourse and the elements are represented as variable x. In classical set theory, crisp values of set A in Z is represented as function $f_A(x)$, as shown in equation 2.1 below.

$f_A(x)$: $Z \rightarrow \{0, 1\}$, where (2.1)

$$f_A(x) = \begin{cases} 1, \text{if } x \in A \\ 0, \text{if } x \notin A \end{cases}$$

The above set maps Z to a set of two variables. For any element x of universe Z, characteristic function $f_A(x)$ is equal to 1, if x is an element of set A, and is equal to 0, if x is not a elements of A.

For any element x of universe Z, if x is element of set C, membership function of μC(x) is equal to the degree to which x belongs to the set as stated below. If x is not an element of set C in the function, then the membership function μC (x) is equal to zero (Zadeh, 1965).

The membership function of fuzzy set C (μC(x)) for element x is defined as follows:

μC(x) where, 1, if x is completely element in C (2.2)

0, if x is not element of C

$0 < \mu C(x) < 1$, if x is partially element of C

If C and D are two fuzzy elements in a set defined as universe of discourse Z to the interval [0, 1]. Fuzzy set of C is expressed by its membership function μ (C) and fuzzy set of D is defined by its membership function μ (D) over Z.

There are three basic operations in fuzzy sets, these are complement, intersection and union. The most widely used logical operations on fuzzy sets are AND, OR and NOT. Logical AND operator was used in this research work in formulating fuzzy rules. In fuzzy logical operations, logical AND operator is defined by function min, and the variables C AND D is equal to min (C, D). Logical Operator OR is described by function max. Therefore, C OR D is equivalent to max (C, D), where operand C and D are degree of membership values in the interval [0, 1].

2.6.3. Linguistic Variables

Linguistic variables describe linguistic expressions rather than numeric values whose values are words or sentences in artificial language. Example height is linguistic variable in which the value is expressed as i.e., Very short, short, tall, very tall, etc. (Huynh, HO, & Nakamori, 2002). Let y be a linguistic variable labelled 'height' and its set of values (term set) T can be expressed T (height) = {very short, short, tall, very tall}.

Multiple antecedents in fuzzy rule formation are connected with conjunction (AND), union (OR) and complement (NOT) fuzzy operators. To form several fuzzy rules, fuzzy sets are connected using if-the statements. Linguistic variables are expressed by their name and value, which is fuzzy value. These fuzzy values has a membership function which assign membership degree μ Label (x) to a crisp element x that belong to a specified range of values called universe of discourse (UOD). Example, "age is old" shows the linguistic variable 'age' accepts 'old' which is linguistic value.

Example, Rule: 1 IF speed is fast THEN stopping_distance is long

In the above rule, the linguistic variable speed has values in the range (the universe of discourse) between 0 and 200 km/h, but this range includes fuzzy sets, such as slow, medium and fast. The input values for linguistic variable stopping_distance can be between 0 and 200 m and may include such fuzzy sets as short, medium and long.

2.6.4. Membership Function

Membership function maps each and every value in the input space to a membership degree between [0, 1] Membership functions are represented in curves to define features of fuzzy set for each element by assigning each element a membership value. The assignment of membership value to fuzzy variables is the main task of fuzzification. Commonly used types of membership

functions in fuzzy expert systems are singleton membership function, triangular membership function, trapezoidal membership function and Gaussian membership function. Figure 2.1 shows plot of triangular membership function (Zadeh, 1965).

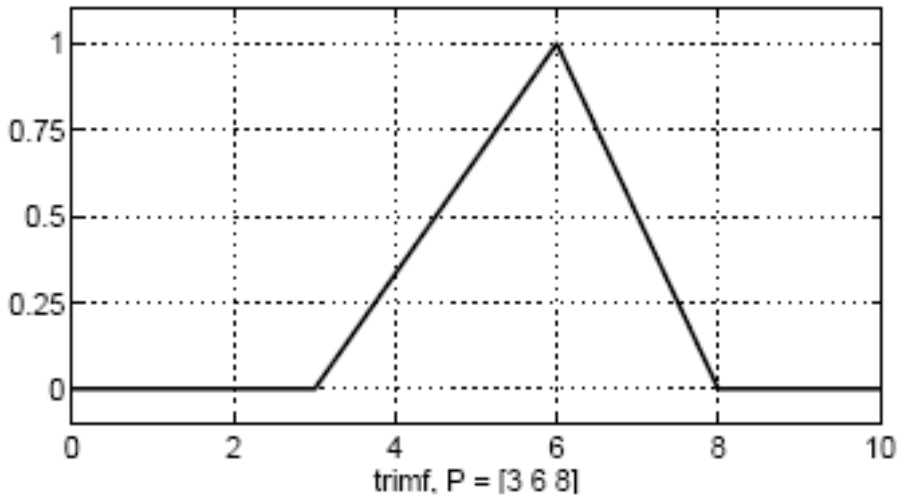

Figure 2.1 Triangular membership function

The x- axis in the above membership function curve indicates universe of discourse and the y-axis represents membership value in [0, 1] range. The horizontal axis represents input element x and the vertical axis defines the corresponding degree of membership μ(x) for the input element x.

2.7. Knowledge base Techniques

Knowledge base contains basic knowledge about domain area that is required for understanding, formulating and solving real world problems. Knowledge can acquire from domain expert, documents, books and others (Mishra et al, 2011). Knowledge based systems are more useful than traditional computer systems when there is shortage of experts, expertize is to be multiplied and stored for future use and intelligent assistant is required for decision making. Knowledge base systems increase productivity when there is shortage of knowledge for future use (Abbod et al, 2001). Knowledge base systems are capable of solving specific problems in a given domain at a level comparable to human expert in the field. A knowledge base system contains knowledge base for storing domain-specific knowledge and inference engine contains algorithms for executing the knowledge stored in the knowledge base. There are five major steps in the development of knowledge base systems (Russell & Norvig, 1995).

1. **Identification of the problem**

In this step, the expert and knowledge engineer interact for identifying the characteristics of the problem. The scope and amount of resources needed are considered. Overall specifications are made for the problem that needs much trouble and a solution for the problem.

2. **Decision about mode of development**

Once the problem is identified, the next step is deciding the way of development. The knowledge engineer can develop the system using the appropriate programming language. In this step various tools are identified and analyzed to fit the characteristics of the problem. In case of this research, fuzzy inference using JfuzzyLogic is identified and used together with android studio.

3. **Development of prototype**

For developing the prototype, the knowledge engineer (researcher) and domain expert interact to extract knowledge in the specific domain area. After extracting knowledge, the knowledge engineer select method of representation. Then the prototype is constructed and tested for various problems.

4. **Planning for full-scale system**

After the success of prototype construction, the full-scale system can be implemented.

5. **Final implementation, maintenance and evaluation**

This is the final step of expert system. In this phase, basic resource requirements and testing techniques are adopted. The knowledge base has to be maintained for minor modification. Finally human experts are used for evaluation of the system

2.8. Fuzzy Inference System

Fuzzy inference system is a process of mapping a given input to output using fuzzy logic. This helps to make decision based on patterns. It has been applied in various areas such as medicine, data classification, expert system, robotics, and pattern recognition.

The mapping is done by a number of if-then fuzzy rules formulated by the help of experts. The antecedent of a rule defines a fuzzy input variable in the input space, while the consequent specifies the output variable in the fuzzy output region. This process requires model input variables and determination of fuzzy model type based on experts' knowledge. The main process performed in Fuzzy Inference systems are:

a. The fuzzification component of fuzzy system transform crisp input variables into membership grade based on membership function
b. The inference engine control fuzzy operators in order to get fuzzy sets.
c. Defuzzifier converts fuzzy result in to crisp output using defuzzification technique.

Basically, there are two types of fuzzy inference approaches that are commonly used. (Negnevitsky, 2016), Define mamdani and sugeno fuzzy inference techniques. Mamdani inference is most commonly used method for complex systems and decision processes. The basic difference between Mamdani and Sugeno fuzzy inference is Sugeno output membership functions are either linear or constant (Sugeno & Kang, 1998) . Mamdani fuzzy inference approach was used for this research work, because of the output of the system is not constant or linear. The output varies depending on the type of input. It includes four main steps. These are fuzzification (selection of fuzzy rules), knowledge base (membership functions used in fuzzy rules), inference engine (decision making mechanism) and defuzzification (it provides appropriate output based on given facts and rules).

1. Fuzzification

In the fuzzification process, the system reads the input data, scale and fuzzify to appropriate linguistic variables which can be handled as fuzzy sets. For completing fuzzification process, membership functions should be constructed by gathering knowledge from domain experts. Before the rules are evaluated, inputs should be fuzzified for each linguistic sets. Direct rating approach was used for describing fuzziness that arises from individual subjective vagueness. The same

question is asked again and again, then membership function is constructed with assumption of probabilistic errors by estimating parameters.

2. Knowledge base

Knowledge base includes membership functions constructed as database and a set of fuzzy rules formulated as a rule base. The rules defined contain the relationship between input and output variables.

Fuzzy rules has a form of:

IF **antecedent (condition)** THEN **consequent (action)**

The condition is a fuzzy expression connected by fuzzy operators (and, or) and the action part is an expression that assign fuzzy value to output variables. Both the rule base and database are collectively called knowledge base. The rule base contains IF-THEN fuzzy rules and the database includes membership functions of fuzzy sets which are used in fuzzy rules.

3. Inference Engine

The basic steps performed by FIS in fuzzy reasoning are input variables are compared with membership functions to the antecedent part for obtaining membership values of linguistic label, combine membership values to the antecedent part, generate qualified consequents and aggregate consequents to get crisp output. Aggregation represents a single fuzzy set for the output of each rules. The output of aggregation is one fuzzy set for each output variable.

4. Defuzzification

In this stage fuzzy output is interpreted into crisp value. The input to defuzzification is a fuzzy set and the output is a single number. There are different methods used for defuzzification such as centroid of area or gravity (COG), bisector, mean value of maximum (MOM) and largest value of maximum (LOM). From those methods the most popular defuzzification method is centroid, which commonly applied for determining a point in a fuzzy set which indicate center of gravity.

2.9. Fuzzy Logic in Physical and Psychological Disorder related to Khat Addiction

Fuzzy logic allows membership values between 0 and 1, which provides more realistic representation of data that was inherently noisy and imprecise. Khat related diseases like physical and psychological disorder includes several levels of uncertainty depending on the patient and surrounding environment. Fuzzy logic is used to design medical knowledge to support health status of individuals. Medical cases which are ambiguous are defined using fuzzy sets. The foundation of vagueness in physical and psychological disorder related to khat addiction can be classified as given below.

a. Errors exists in sample experimental results and diagnose
b. Patient symptoms might be faked or exaggerated
c. Patient symptoms might be rejected by patients themselves or medical experts
d. Sufficient data about the patient is may not provided
e. Physicians when they examine khat addicted patients, there is no clear boundary between physical and psychological problems and cases are not clearly known.

2.10. Related Works

Diagnosing the risk of physical and psychological disorder related to khat addiction includes several layers of ambiguity and imprecision that makes traditional methods unsuitable. Fuzzy logic which is one of soft computing methodology has been widely used in the health sector to model the knowledge of domain experts in the area of specialization. Since diagnosing the risk pf physical and psychological disorder related to khat addiction has not been done in the previous researchers, related works that use fuzzy logic to diagnosis the risk level of different diseases was reviewed.

The authors of this article used fuzzy tsukamoto method to diagnosis the risk level of cattle reproductive diseases based on six clinical symptoms. The result showed that the system performs as human expert in diagnosing cattle with endometritis and performs 100% accuracy. It was observed that detection and treatment of endometritis in cattle using mobile application was more efficient and comfortable (Suharjito et al, 2017). However, the authors use only 12 samples to test the accuracy of the system.

In this paper the authors use fuzzy inference approach to formulate membership functions. Mamdani approach was used for the system design. The suggested fuzzy expert system was implemented in MATLAB software. The system accommodate imprecision, tolerance and uncertainty to achieve tolerance and low cost. The result of the study indicates that the developed fuzzy expert system recorded higher accuracy and the system was capable of detecting early Gastric Cancer risk levels (Safdari et al, 2018). Strong rules were not constructed in this paper for inferencing knowledge of experts.

(Owoseni & Ogundahusni, 2016), design a mobile based fuzzy expert system for diagnosing malaria. According to this study the crisp inputs by the system was carried by inter valued and triangular membership functions while the defuzzification the inference engine was done by weighted average method. The development of the system was done with the help of Java 2 micro edition of Java. The system was a capable of executing mobile device of patients. This fuzzy expert system was effective in diagnosis the risk level of malaria.

(Angbera et al, 2016), Developed a fuzzy based expert system for tuberculosis diagnosis and treatment. The authors used java (JFuzzy logic), membership functions, input variables, output variables and rule base for designing the expert system. They used the symptom of the patients as

input for determining the risk level of the disease and the system was efficient in diagnosing patients with tuberculosis with in short period of time.

Mobile based expert system for febrile disease diagnosis was developed (Alu et al, 2017). The system was implemented using android SDK programming language and SQLite as database which contains experts' knowledge. The system was faster and less prone to error in diagnosis the disease of patients. The result of this research indicates that using expert system for diagnosis and treatment of fevers helps medical professional, patients and those who want to know brief information about various types of fevers, their treatment, prevention and advice.

A fuzzy expert system for diagnosis of cystic Fibrosis was designed and developed using MATLAB environment. It was designed based experts knowledge and previous literature. For eliminating uncertainty in the disease fuzzy logic approach was used for making decision based on patients' risk factor and symptoms. The system was capable of storing the knowledge of experts in the area and used as training tool for new physicians. The system was used as diagnostic assist to the specialists for providing patients with suitable treatment. The result shows that the system was efficient in diagnosing cystic fibrosis disease with 93.02% precision, 89.29% specificity, 95.24% sensitivity and 92.86% accuracy (Maryam et al, 2017).

The authors of this paper develop a Medical Expert System as knowledge sharing tool for the diagnosis and treatment Hypertension in Pregnancy to be used in the Reproductive Health Division at Moi Teaching and Referral Hospital in Eldoret, Kenya (Gudu et al, 2012). The authors finding indicates that an expert system is important to assist users in getting the correct diagnosis of the health problem of video game addictions that range from (Musculoskeletal issues, Vision problems and Obesity) (Abu et al, 2016). A fuzzy inference approach was implemented for the diagnosis of sleep disorders with symptoms by classifying the symptoms of patients into groups using three membership functions. This system was able to diagnose four (4) forms of sleep disorders namely, sleep apnea, insomnia, parasomnia, and snoring. However, the developed system was not mobile system (Garg & Bansal, 2015).

Mobile based fuzzy expert system was developed for diagnosis of viral infections by accepting symptoms from users and provides the appropriate diagnosis (Patel & Virparia, 2012) .

Another study conducted using fuzzy expert system to classify multi-fever symptoms indicates that the developed expert system was effective and accurate in the diagnosis of multi-fever by

accepting symptoms of the disease. The fuzzy rules were accurate in identifying the type of fever and level of infection as mild or sever (IghoyotaBen et al, 2017).

According to this study (Jasmin et al, 2018) a mobile based fuzzy expert system to provide information about venereal and sexually transmitted diseases was developed. The system was capable of diagnosing patients' different signs and symptoms that arise in their body. The source of data to build the expert system was collected from various literatures and interview with experts. The system was supportive to patients for identifying signs and symptoms about sexually transmitted diseases and develop their knowledge about related infectious diseases. A fuzzy logic algorithm was used to filter different signs and symptoms and it was accurate in diagnosing the disease. The system was evaluated by domain experts and provide a better result in terms of functionality, efficiency and portability.

In the reviewed literature, most of the studies focus on the effects of khat addiction using community based and cross sectional studies. The gaps identified in related works are small number samples were used to test the performance of the system and strong rules were not constructed. Some of the studies develop the system using web based and they don't consider basic symptoms and risk factors in diagnosing the disease. Therefore, based on the gaps identified in the literature, we develop mobile based fuzzy expert to diagnose the risk of physical and psychological disorder related to khat addiction.

2.11. Summary

The current state of the art on khat addiction shows that khat chewing is rapidly increasing. Most of the studies shows that khat addiction is frequently associated with physical and psychological disorder with khat dependent chewers compared to none chewers.

Uncertainty and ambiguity issues are associated with diagnosis of khat addicted patients with physical and psychological disorder. The evidence in the body of the reviewed literature used several community based cross-sectional studies and risk factors to assess the effects of khat addiction. Most of the studies focus on the physical, psychological, economic and social impacts of khat addiction. There wasn't a model designed and developed for diagnosing the risk levels of khat addicted patients with physical and psychological disorder at different stage. Some of the research works conducted reported that computer based interventions are needed to reduce the risk level of physical and psychological disorder among khat addicted patients.

Different studies shows that the prevalence and effects of khat addiction is high. The previous studies was focusing on the risk factors and health consequences of khat chewing. Therefore to reduce the risk level of khat addicted patients with physical and psychological disorder, this research work was considering in the following way:

- ✓ Basic symptoms and risk factors of physical and psychological disorder related to khat addiction was used in the system.
- ✓ Symptoms and Risk factors were used to formulate rules for expert system.
- ✓ Rules were used to build the knowledge base.
- ✓ This fuzzy expert system could be widely used among the society
- ✓ The expert system is personally used

CHAPTER THREE

3. Methodology

3.1. Introduction

This chapter describes the details of the methodology used to design fuzzy expert system for diagnosing the risk of physical and psychological disorder related to khat addiction to determine the risk level at different stages.

Research methodology includes planning the general approach to the research process according to research questions and objectives. This chapter presents a detail description of the methodology that was used to design fuzzy expert system for khat addicted patients with physical and psychological disorder as well as data collection methods used in designing the system. The range of values for formulation of membership functions was used in the design of fuzzy expert system.

3.2. Design of the Proposed Fuzzy Expert System

In order to diagnose the risk level of physical and psychological disorder related to khat addiction, mobile based fuzzy expert system was developed. Fuzzy expert systems are knowledge based systems using Fuzzy IF-THEN rules and membership functions. The architecture of the proposed mobile based fuzzy expert system is presented in Figure 3.1. The mobile users can access the knowledge of the expert stored in the database to identify the risk level of physical and psychological disorder related to khat addiction by filling symptoms and risk factors.

The information provided by the system would support users in monitoring their health status by providing the risk level of the disease and can improve their knowledge regarding to physical and psychological disorder related to khat addiction.

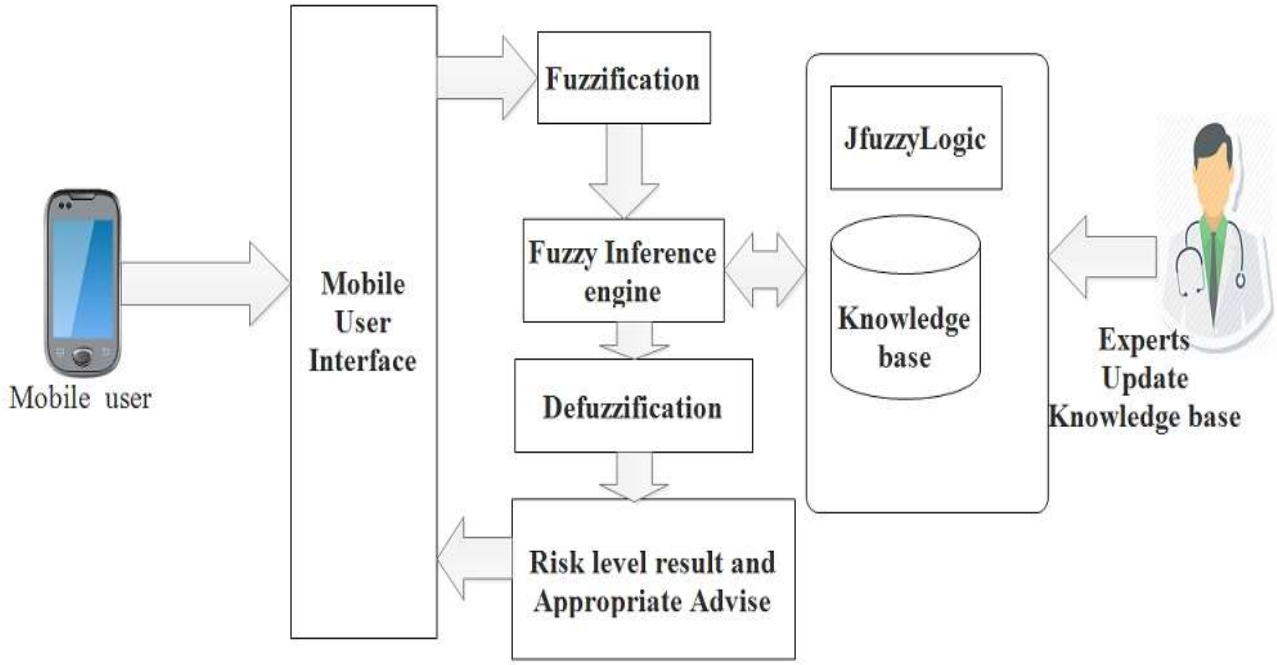

Figure 3.1 Architecture of the Proposed Fuzzy Expert System

3.2.1. Knowledge Representation using JfuzzyLogic

(Cingolani & a-Fdez, 2013) Developed JfuzzyLogic which is an open source Fuzzy logic library implementing industry standards to simplify fuzzy system developments. It allows us to design fuzzy logic controllers. This library is written in java. It supports the development of rule based expert system applications which can be tightly coupled to code written in portable, powerful and platform independent java language. For developing android applications, android studio is a popular development environment to write and build applications. It is preferred integrated development environment (IDE) for java and android development. The knowledge formulated in the rule base and database is stored in .FCL (fuzzy control language) file extension. The interaction between java and knowledge base is by exchange object instances for membership function and rules using fuzzy inference engine. The android application sends information about the user and the expert system evaluate and generate the risk level value for individual object. All the rules, facts and functions are coded in JfuzzyLogic. The template for the fact must be defined before facts are used. In the rule base the if-part is interpreted as facts and then-part is interpreted as function calls. Fuzzy rule based design using JfuzzyLogic was an important rule engine for java

platform in this research work. The problem specific information in the rule was written in JfuzzyLogic and the inference engine displays the solution automatically.

3.2.2. Process of the Designed Fuzzy Expert System

In the first step we gather information about physical and psychological disorder symptoms and risk factors related to khat addiction from three (3) doctors, patient records and literature studies. After gathering information, the risk factors and symptoms of physical and psychological disorder related to khat addiction collected from literature studies was presented to domain experts.

The input and output variables of the proposed model was obtained from experts opinion by considering their degree of significance. Eight (8) symptoms and risk factors were selected as influencing factors that leads to physical and psychological disorder. These symptoms and risk factors were considered as input variables of fuzzy expert system with single output that reflect the risk status, which further divided into “very low risk”, “low risk”, “medium risk”, “high risk” and “very high risk”. Then prepare a range of values and fuzzify them using membership function for each symptoms and risk factors. After preparing range of values construct fuzzy rule with the help of experts, generate fuzzy inference and apply defuzzification. Finally design user interface for interaction and the output is the risk of physical and psychological disorder related to khat addiction.

For designing mobile based fuzzy expert system to diagnose khat addicted patients with physical and psychological disorder, Mamdani fuzzy inference system procedure was followed. This fuzzy inference system is suitable for human input and it supports multiple input multiple output as compared with other type of inference system (Ature et al, 2016). Fuzzy inference system (FIS) consists of four steps. These are fuzzification, rule evaluation, aggregation and Defuzzification. The five components used for designing mobile based fuzzy expert system to diagnosis the risk level of physical and psychological disorder for khat addicted patients are: user interface, fuzzification, inference engine, knowledge base and defuzzification. The input variables are symptoms and risk factors of the patient such as headache, depression, Being Absent minded, blurred vision, sleep disturbance, fast heart rate. The output variable is risk level of khat addiction patients with physical and psychological disorder as very low, low, medium, high and very high.

Step 1-User Interface

It is the way of communication for the user. The fuzzy expert system to diagnosis physical and psychological disorder related to khat addiction utilizes the knowledge of experts to understand patients' symptoms and provide accurate decision according to fuzzy rules constructed. Reports of the diagnosis are displayed to the user using graphical user interface (GUI). This technique uses graphic components such as List view, spinner, buttons and text view.

Step 2 –Fuzzification

It is a process that determines the degree of membership to the fuzzy set based on membership function. In this research each symptoms and risk factors of physical and psychological disorder related to khat addiction are considered as universe of discourse. In this step crisp inputs are taken and assign the degree to which this inputs belong to the fuzzy sets. The degree of membership for each input is calculated using appropriate membership function. The range of values for universe of discourse is assigned by human experts. Methods used for fuzzification are Singleton, Triangular, Trapezoidal and Gaussian. The method used for fuzzification in this research work is Triangular fuzzification approach. This type of membership function works well in terms of simplicity, efficiency and speed in taking computational time (Barua et al, 2013). Triangular membership function is specified by three parameters. These parameters are a1, a2 and a3 where a1 and a3 are triangular end points. The equation for triangular membership function is represented by equation 3.1. In this membership function the three variables a1, a2 ,a3 are in the x-axis where a1 and a3 are known as 'feet values' which has membership degree zero and a2 is known as 'peak' value with membership degree one.

$$\mu(x) = \begin{cases} 0 & if\ x < a1 \\ x - a1 / a2 - a1 & if\ a1 <= x < a2 \\ a3 - x / a3 - a2 & if a2 <= x < a3 \\ 0 & if\ x >= a3 \end{cases} \quad 3.1$$

Fuzzy logic input variables and their acronym used to generate fuzzy logic model to diagnosis khat addicted patients with physical and psychological disorder are:

1. Feeling depressed (DP), (low, moderate, severe)
2. Dizziness (DZ), (low, moderate, severe)
3. Headache (HD), (low, moderate, severe)
4. Being absent minded (BAM), (low, moderate, severe)
5. Fast heart rate (FHR), (low, moderate, severe)
6. Blurred vision (BV), (low, Moderate, severe)
7. Sleep disturbance (SD) (low, moderate, severe)
8. Chewing frequency (CF) (low, moderate, severe)

The output parameter of physical and psychological disorder related to khat addiction are risk level of the disease such as very low, low, medium, high and very high. The membership function for each risk factors and symptoms of khat addicted patients with physical and psychological problems was calculated (Appendix I).

Step 3 Knowledge Base

Knowledge base contains rule base and database. The rule base part includes if then-rules and the database consists of membership function of fuzzy sets used in the rule base. Knowledge base is the combination of knowledge of human experts. The rules use input membership values to determine their influence on fuzzy output for final conclusion.

Fuzzy Rules create association between input and output values. The designed fuzzy expert system includes rules which were extracted from knowledge of three specialized experts with physical and psychological disorder related to khat addiction. Six thousand five hundred eighty seven (6587) fuzzy rules were constructed. However, in order to increase efficiency and reduce complications, only relevant rules were considered based on experts' opinion. Sample fuzzy rules used for fuzzy system were presented (appendix II). The knowledge stored in the knowledge base would be updated by domain experts. Domain experts are experts who has a capable of solving problems in the domain area. They have special knowledge, judgement, experience and method to give advice and solving problems.

In this research work fuzzified inputs were applied to antecedent of fuzzy rules using rule evaluation. AND operator was used to get a single value from multiple antecedents. Then the obtained value is applied to the consequent membership function (risk level of khat addicted patients with physical and psychological disorder) as determined by the help of experts.

Step 4 Fuzzy Inference Engine

Fuzzy inference engine is guided by fuzzy rules. It checks all the user inputs and all corresponding rules in knowledge base. It shows how an expert system applies the rules to reach conclusion. The rules has IF (condition) and THEN (action) structure. When the IF part of the rule is satisfied, the rule is fired and its action part is executed. The designed fuzzy expert system inference engine links the rules given in the rule base to the facts stored in the database. The problem specific information which is called database are collection of facts used to match IF (condition) part of the rules stored in the knowledge base. The designed model of this fuzzy expert system used standard MAX-MIN (mamdani) fuzzy inference algorithm, since it is the most popular algorithm used in fuzzy inference strategy. It tests the magnitude of all applicable rules and select the highest one. The facts related to the rules are stored in the working memory. The inference engine matches the facts stored in the database with rules in knowledge base. When the IF (condition) is matches a fact, the rule is fired and THEN (action) part is executed. When the rule is fired a new fact is added to the database. The inference cycle indicates how an expert system applies the rules to reach a conclusion.

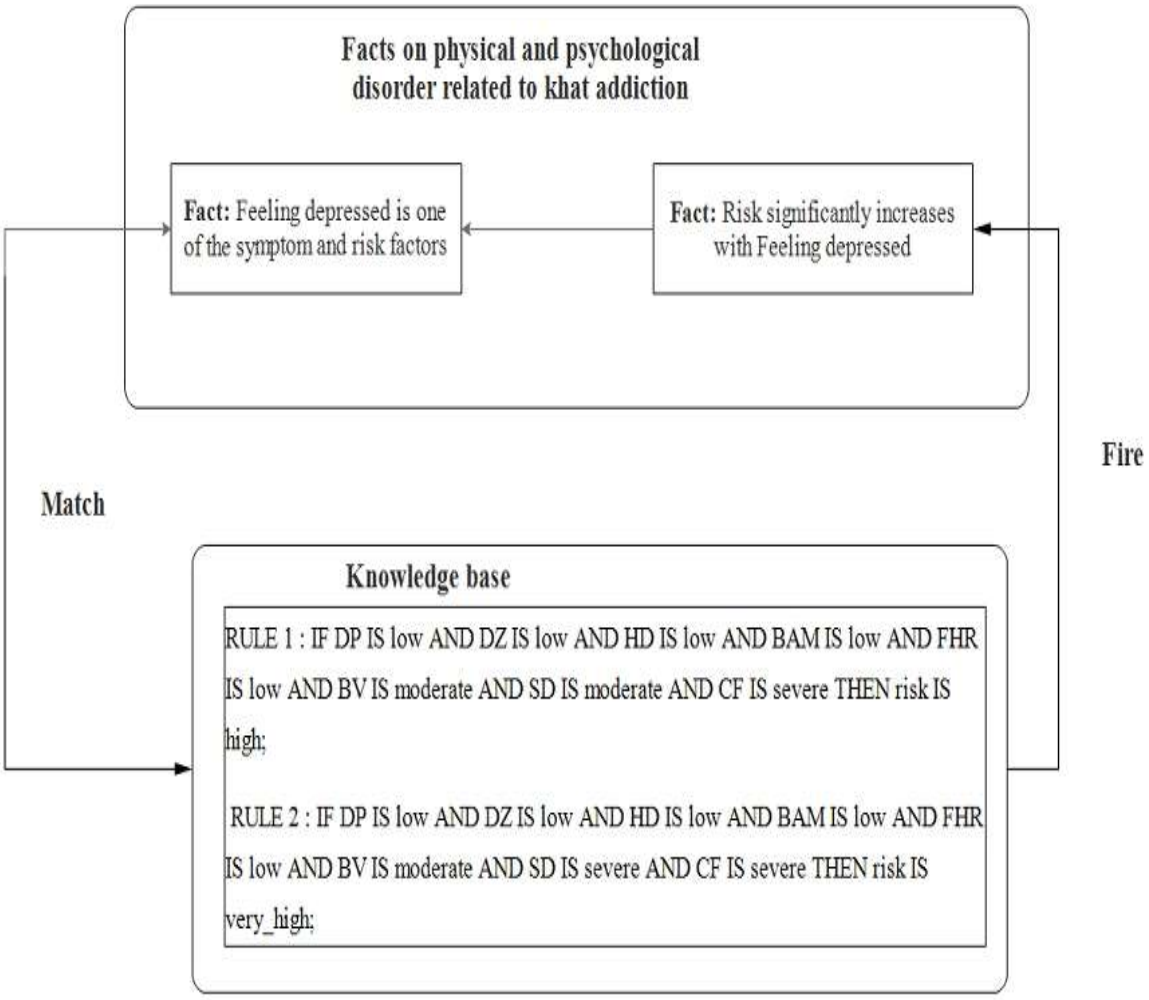

Figure 3.2 Adopted inference engine showing match-fire procedure

Aggregation of the outputs rule

The input of aggregation process is a list of consequent membership functions and the output is a single fuzzy set for individual risk of physical and psychological disorder. It unifies the output of all fuzzy rules. The membership function of each symptoms and a set of functions for every rule were obtained. These rules were used to get the final output. The aggregation operator was used for aggregating all rules together to form a single value.

Step 5 Defuzzification

It is one component of fuzzy expert system which used to obtain one single value that shows the best output of aggregate fuzzy set result. It involves converting a fuzzy set in to crisp output. The input to the defuzzification process is a single fuzzy set (aggregated output fuzzy set) and the output is a single value. The commonly used approaches in defuzzification process are mean of maximum (MOM), smallest of maximum (SOM), largest of maximum (LOM) and center of gravity (COA) or weighted average method. In this research center of gravity (COA) method was used for defuzzifying results of inference engine because of its prevalence and advantage over other methods. The center of gravity is the most widely used method because the defuzzified values move smoothly around the output fuzzy region, thus giving more accurate representation of the output fuzzy set for any shape. The mathematical equation for this method is represented below (3.2).

$$\text{COG}=\frac{\sum_{X=a}^{b}\mu A(X)/X}{\sum_{X=a}^{n}\mu A(X)} \qquad 3.2$$

Where $\mu A(X)$=membership value in the membership function and X is center of membership function.

Center of gravity (COG) method takes the centroid of total area represented by membership function curve in the aggregate final result of membership function.

3.3. Data Collection

Symptoms and risk factors of physical and psychological disorder related to khat addiction were collected from literature studies and interview with domain experts. Questionnaires, structured and unstructured interview were conducted to gather knowledge from experts. They evaluated the acquired knowledge based on its significance and frequent occurrence in diagnosing physical and psychological disorder related to khat addiction. The criteria for selecting specialized experts was based on profession, educational background, experience, role and position in diagnosis of khat addicted patients with physical and psychological disorder. For constructing membership functions, the response of three medical experts was aggregated to determine the range of final MF formulation and fuzzy rules. The lowest and highest value were considered to formulate

membership function for each symptom and risk factors. For collecting data about symptoms and their risk level, Fifty (50) patients' data were collected purposely from their psychiatric diagnosis in Felege Hiwote Referral Hospital (Bahir Dar, Ethiopia). The data was presented to medical specialists and asked them to rate the range of each symptoms based on the risk level of the disease. In this research work data is also obtained from twenty (20) khat addicted individuals with physical and psychological disorder based on their experience of using khat and other personal characteristics using interview. The data was collected from those already diagnosed in the disease. During interview from khat addicted individuals, it was similar with symptoms collected from hospitals and severe symptoms related to physical and psychological disorder were identified with the help of experts.

CHAPTER FOUR

4. Data Analysis, Results and Discussion of Findings

4.1. Introduction

Fuzzy expert system for diagnosing the risk level of khat addicted patients with physical and psychological disorder has been developed. The developed fuzzy expert system supports khat addicted patients with physical and psychological disorder to improve their health status and helps clinicians to diagnosis their patients. Since khat addiction is currently the main problem of our society, this fuzzy expert system is used to diagnosis the risk level of physical and psychological disorder for patients.

4.2. System Requirements

The hardware and software requirements for the designed fuzzy expert system to diagnosis physical and psychological disorder of khat addicted patients are:

1. Software requirements

The software requirement for this fuzzy expert system is any android operating system (OS) based tablets, phones, etc.

2. Hardware requirements

Android devices with the following configuration are required for this fuzzy expert system to function efficiently.

- ✓ Memory: A minimum of 1 GB RAM and above
- ✓ Processor: A minimum of 800 MHZ or 1.5 GHZ and above
- ✓ Hard disk(HDD): 5GB and above android devices

4.3. Design of Fuzzy Expert System Specification

Software tool that used for developing the expert system was Android version 3.0 with Android SDK tools and JfuzzyLogic. Android is widely used platform due to its computing power and performance. Android version 3.0 is used to develop this fuzzy expert system. The minimum requirement for the expert system to run in android device is the android version 4.4 KitKat and it is capable of running 95% of the devices.

This fuzzy expert system software would be installed in android devices. The system can easily integrated and portable to all mobile phones which run on android platform.

4.4. Physical and Psychological Disorder Risk Factors and Symptoms Specification related to Khat Addiction

In real world, physicians take the risk factors and symptoms of a patient based on their experience as input for providing the appropriate diagnosis to the patients. So this research work is based on reality. Physical and psychological disorder related to khat addiction is associated with risk factors such as frequency of khat chewing and symptoms like feeling depressed, headache, dizziness, absentminded, fast heart rate, blurred vision and sleep disturbance.

A list of different symptoms and risk factors was found in literature studies and physical examination of patients' data. Questionnaires were organized for domain experts based on their experience to assign suitable weight between 1(non-significant) and 5 (very significant) to the symptoms based on their significance of diagnosing physical and psychological disorder related to khat addiction. According to the completed questionnaires highest weight were selected. This research consists of the following eight (8) input variables for designing fuzzy expert system to diagnosis the risk of physical and psychological disorder related to khat addiction according to interviewed medical experts and literature. These are:

1. Feeling depressed
2. Dizziness
3. Headache
4. Being absent minded
5. Fast heart rate
6. Blurred vision
7. Sleep disturbance
8. Chewing frequency

The above parameters are identified with the help of domain experts (psychotherapy specialists) and literature studies. This parameters were used to include all possible range values for a given membership function selection. The model classifies the symptoms and risk factors of khat addicted patients with physical and psychological disorder into five categories. These are very low, low, medium, high and very high. The expert system would recommend the patients for further

physical examination if the risk is very high. If risk is medium proper treatment would be provided in order to reduce the risk level of physical and psychological disorder related to khat addiction.

Table 4.4.1 Description of input variables and their range based on experts rating

Type	NO	Variable Name	Linguistic set	Actual range of variables
Input	1	Feeling depressed (age of symptom in days)	Low	<3
			Moderate	2-6
			Severe	5-10
	2	Dizziness (age of symptom in days)	Low	<8
			Moderate	7-14
			Severe	13-20
	3	Headache (age of symptom in days)	Low	<4
			Moderate	3-6
			Severe	5-10
	4	Being absent minded (age of symptom in days)	Low	<4
			Moderate	3-6
			Severe	5-10
	5	Fast heart rate (age of symptom in days)	Low	<4
			Moderate	2-6
			Severe	5-10
	6	Blurred vision (age of symptom in days)	Low	<5
			Moderate	4-10
			Severe	7-15
	7	Sleep disturbance (age of symptom in days)	Low	<6
			Medium	5-12
			High	11-20
	8	Chewing frequency (in days)	Low	<5
			Medium	4-10
			High	8-15

4.4.1. Description of Input Variables

Detail description of input variables for constructing fuzzy expert system to diagnosis physical and psychological disorder related to khat addiction based on experts knowledge are:

1. Feeling depressed (DP)

Feeling depressed is one of the symptom of khat addicted patients with physical and psychological disorder which have high health effect among long term khat chewers. The input variables for feeling depressed are classified in to three (3) fuzzy sets as below

Age of the symptom in days

<3	low
2-6	moderate
5-10	severe

2. Dizziness (DZ)

Dizziness symptom leads to high risk level among khat addicted patients with physical and psychological disorder when they use it in their daily life. The input variable for Dizziness are classified in to three (3) fuzzy sets as described below

Age of the symptom in days

<=8	low
7-14	moderate
13-20	severe

3. Headache (HD)

It is common symptoms of khat addicted patients which increase the risk level of physical and psychological disorder when used frequently for a long session. The input variable for headache are classified in to three (3) fuzzy sets as described below

Age of the symptom in days

<4	low
3-6	moderate

5-10 severe

4. Being absent minded (BAM)

These symptom is frequently seen in patients with physical and psychological disorder related to khat addiction which have high effect on khat dependent chewers. The input variable for being absent minded are classified in to three (3) fuzzy sets as described below

Age of the symptom in days

<4 low
3-6 moderate
5-10 severe

5. Fast heart rate (FHR)

Those who frequently use khat as daily base are affected by fast heart rate as a result of using khat for a long period of time. The input variable for Fast heart rate are classified in to three (3) fuzzy sets as described below

Age of the symptom in days

<4 low
2-6 moderate
5-10 severe

6. Blurred vision (BV)

Regular khat chewing has a huge factor for increasing the risk level of physical and psychological disorder related to khat addiction. The input variable for blurred vision are classified in to three (3) fuzzy sets as described below

Age of the symptom in days

<5 low
4-10 moderate
7-15 severe

7. Sleeping disturbance:

Sleeping disturbance is one of the factor which increases the risk of physical and psychological problems among khat addicted patients. The clinical finding of chewing sides of addicted patients varied according to the duration of khat chewing habit. The input variables for sleeping disturbance are classified into three (3) fuzzy sets.

Sleeping disturbance duration in days

<6	low
5-12	moderate
11-20	severe

8. Chewing frequency

The frequency of khat chewing is the risk factor of khat addicted patients with physical and psychological disorder. Khat dependent patients which use khat frequently are more vulnerable to physical and psychological disorder. The input variables for chewing frequency are classified into three (3) fuzzy sets.

Chewing frequency in days

<5	low
4-10	moderate
8-15	severe

Table 4.4.2 Linguistic terms and output variable classification for physical and psychological problems of khat addicted patients

Fuzzy set	Interval
Very low symptoms	[0-3]
Low symptoms	[2-5]
medium symptoms	[4-8]
high symptoms	[7-11]
Very high symptoms	[10-20]

4.4.2. Membership Function Plot for Input and Output Variables

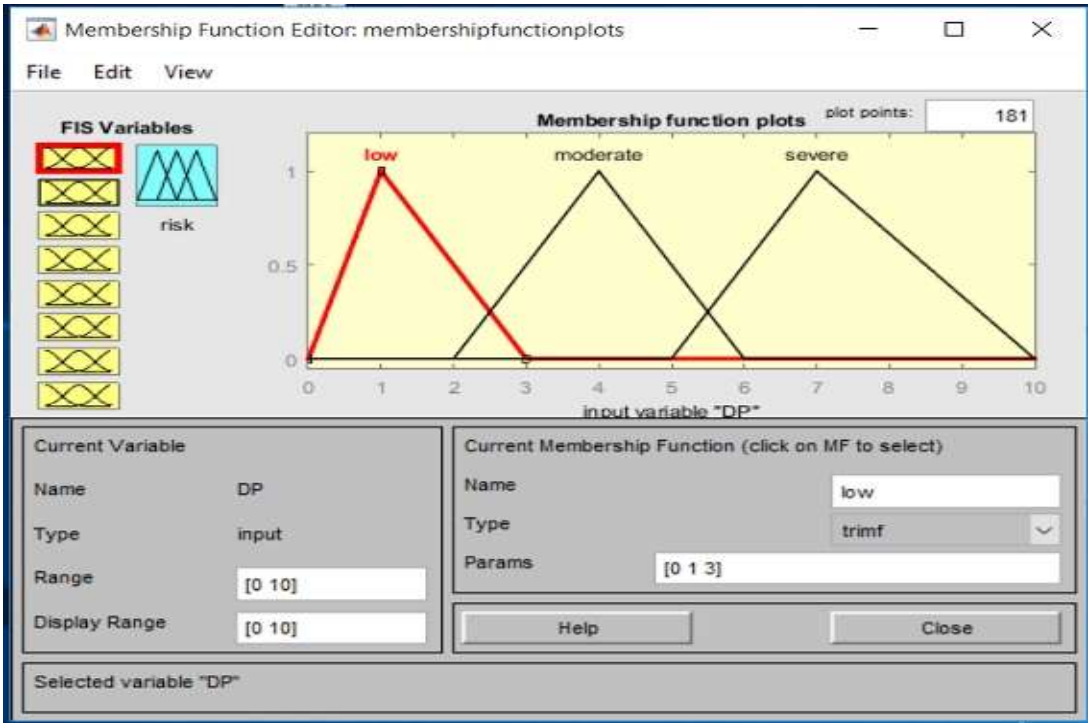

Figure 4.1 Membership function plot for input variable feeling depressed

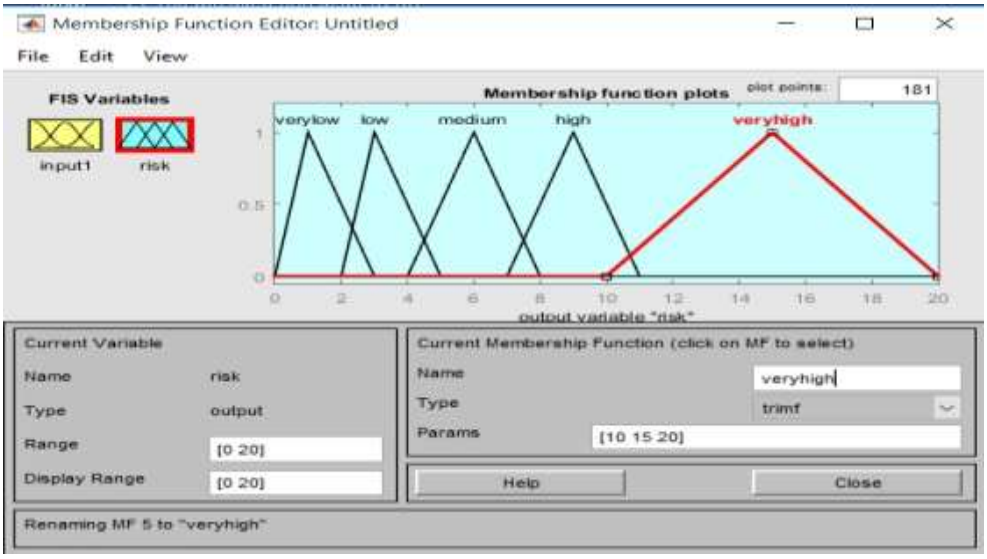

Figure 4.2 Membership function plot for output variable risk

4.5. System Implementation

The designed fuzzy expert system has user friendly user interface that allow users to easily use it. The system begins by asking users to fill user name and password in order to create unique record of the user before analyzing the input data. Symptoms and risk factors from individual patients is takes as input data for the system. After filling the symptoms and risk factors of physical and psychological disorder related to khat addiction, the expert system displays the risk level and provides advice to take appropriate measures for improving the health status of patients.

4.5.1. Screen Shots of Fuzzy Expert System

The user interface includes main user interface and diagnosis physical and psychological disorder interface. The designed fuzzy expert system includes human concerns such as interactivity and reliability. In order to get the diagnosis result, the user should select the age of the symptom in days for each symptoms as mentioned below in Figure 4.3 and the output is displayed in the text box as shown in Figure 4.4 and 4.5. The input symptoms and risk factors for physical and psychological disorder diagnosis expert system are feeling depressed, dizziness, headache, absent minded, fast heart rate, blurred vision, sleeping disturbance and chewing frequency. The final output of the designed fuzzy expert system is determined by aggregation of the result from all symptoms and risk factors. The system display the diagnosis result as very low, low, medium, high and very high with appropriate advice. The values inside the spinner shows the age of the symptom in days and the user should select those values based on the symptoms. After selecting the

symptoms age in days, the user should click submit button to get the diagnosis result. Finally the risk level of physical and psychological disorder would be displayed with relevant feedback. If the risk level is high, it is advised to take psychotherapy, appropriate medication and physical examination (Figure 4.5). If the risk is very high, the patient is advised to take urgent medical attention (Figure 4.4).

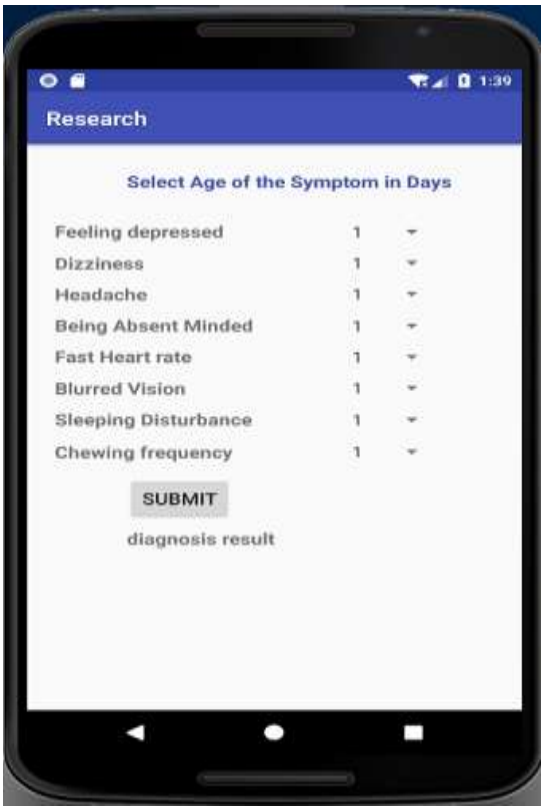

Figure 4.3 Input Symptom user Interface

Figure 4.4 Sample one output Section of fuzzy Expert System

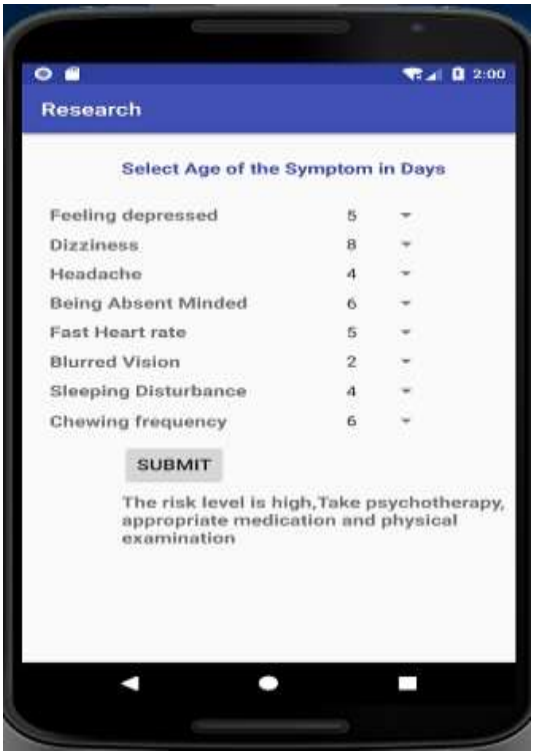

Figure 4.5 Sample two output Section of fuzzy expert system

4.6. Experimental Result

As the design model is accomplished, fuzzy expert system software to diagnosis the risk level of khat addicted patients with physical and psychological disorder was developed. The users select the age of symptoms in days and click Submit Button. After clicking Submit button, membership degrees for all inputs are calculated with the designed fuzzy expert system and all fuzzy rules formulated were checked. As a result, the risk level of khat addicted patients with physical and psychological disorder is displayed in interface as low, medium, high and very high with recommended advisory message to take measures.

For testing the performance of the system in diagnosing physical and psychological disorder related to khat addiction, data was collected and processed using the designed fuzzy expert system. The dataset is divided into training and testing sets. Thirty (30) samples were used to derive membership functions and fuzzy rules. Twenty (20) samples were used for testing fuzzy model. The designed fuzzy expert system is tested by matching the system output and experts analysis. The input symptoms and risk factors feeling depressed, dizziness, headache, absent minded, fast heart rate, blurred vision, sleeping disturbance and chewing frequency are filled and the result shows, better performance of the system in diagnosing khat addicted patients with physical and psychological disorder. Table 4.3 shows, the result of testing dataset after filling the age of symptoms in days, the system output was compared with expert output to test the performance of the system.

Table 4.3 Sample test results of the designed fuzzy expert system

No	Input age symptom in days								Output by the System	Output by the expert	Result
	Feeling depressed	Dizziness	Headache	Absent Minded	Fast Heart Rate	Blurred Vision	Sleeping Disturbance	Chewing Frequency			
1	7	5	4	5	7	6	6	8	veryhigh	veryhigh	True
2	5	8	4	6	5	2	4	6	High	High	True
3	2	3	5	7	6	5	5	4	veryhigh	veryhigh	True
4	3	2	2	2	3	4	3	6	medium	medium	True
5	2	4	3	4	7	5	8	7	High	High	True
6	4	3	3	2	3	2	2	4	Low	Low	True
7	3	2	7	5	3	7	5	8	High	High	True
8	6	3	4	2	9	5	5	6	veryhigh	veryhigh	True

9	4	3	2	2	2	3	3	4	verylow	verylow	True
10	7	5	4	4	3	6	2	7	High	High	True
11	4	2	2	3	4	8	5	8	medium	medium	True
12	3	7	2	6	3	8	8	7	veryhigh	veryhigh	True
13	7	5	4	3	7	3	5	6	veryhigh	veryhigh	True
14	6	2	5	4	7	7	3	6	veryhigh	veryhigh	True
15	1	3	2	4	2	4	3	5	Low	Low	True
16	5	7	5	9	4	5	9	13	veryhigh	veryhigh	True
17	1	2	4	4	3	2	6	4	medium	low	False
18	1	2	1	2	4	3	3	6	medium	medium	True
19	2	7	5	8	4	3	3	6	High	High	True
20	1	7	3	5	4	3	3	7	Medium	medium	True

Based on analyzed data (Table 4.3), the designed fuzzy expert system was evaluated using performance measures such as accuracy, precision and sensitivity have been used.

Table 4.4 Confusion matrix used to calculate the accuracy of the designed system

N=20	Incorrectly Diagnosed	Correctly Diagnosed	
Actually Incorrect	TN=1	FP=1	2
Actually correct	FN=0	TP=18	18
	1	19	

Where, True Negative (TN) - In this case, we have predicated no risk of physical and psychological disorder.

False Positive (FP) – In this case, we have predicated physical and psychological disorder and they have no disease.

True positive (TP) – In this case, we have predicated physical and psychological disorder according to the data and it was actual.

False Negative (FN) – In this case, we have predicated no risk of physical and psychological disorder and they have physical and psychological disorder.

FP+TP=1+18=19 indicates the actual instances classified. TN+FN=1+0=1shows the incorrect instances classified.

$$Accuracy\ value = \frac{TP+TN}{TOTAL} = \frac{18+1}{20} = 0.95\text{=}95\%$$

$$Precision = \frac{TP}{Correctly\ diagnosed} = \frac{18}{19} = 0.94 = 94\%$$

$$Sensitivity = \frac{TP}{TP + FN} = \frac{18}{18} = 1 = 100\%$$

The confusion matrix of the expert system in Table 4.4 shows twenty (20) samples of data used to test the system.

It is observed that the developed system performance was effective in all performance metrics for diagnosing khat addicted patients with physical and psychological disorder with accuracy of 95%, precision 94% and sensitivity of 100%. Accuracy indicates agreement of the system and approved diagnosis by expert physicians, which showed the proposed system was 95% equal to medical experts' diagnosis. Precision metric 94% shows the developed system is consistent when repeatedly tested. Sensitivity value calculated shows the correctness of the proposed system to predicate the percentage of the patients with disease having positive test. Higher sensitivity (100%) indicates the system can respond to even smallest input.

Triangular membership function was employed to evaluate the degree of participation of each symptoms and risk factors to diagnose khat addicted patients with physical and psychological disorder. The designed fuzzy expert system provide relevant feedback for the users to take appropriate measure according to the risk level of physical and psychological disorder. Figure 4.6, 4.7 and 4.8 shows symptoms degree of participation in diagnosing the risk level of khat addicted patients with physical and psychological disorder. The degree of membership shows the degree of truth in diagnosing the risk level of the disease.

Degree of Membership

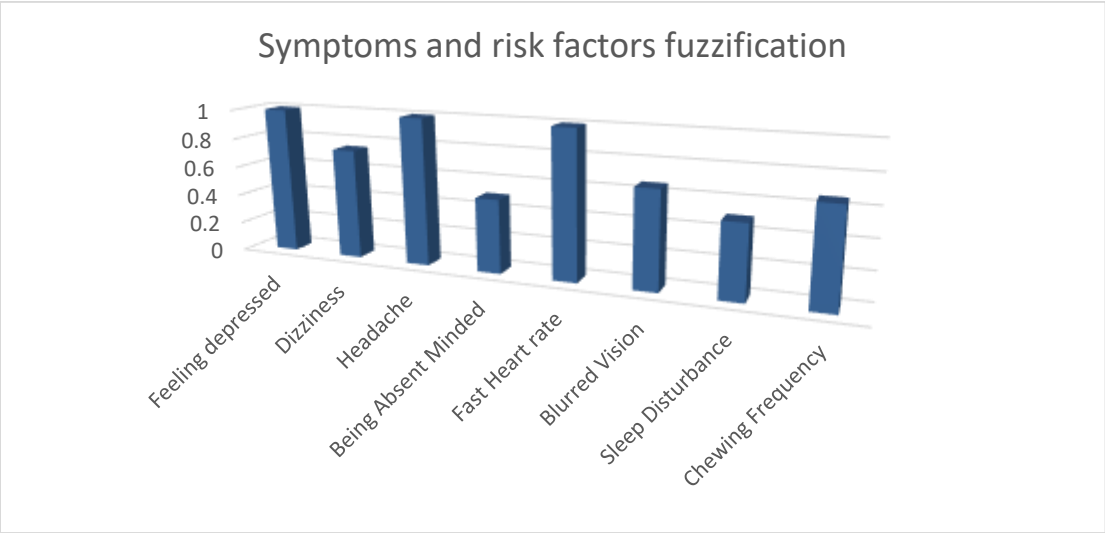

Figure 4.6 Symptoms and risk factor fuzzification showing each level of membership degree (first data in Table 4.3)

Degree of Membership

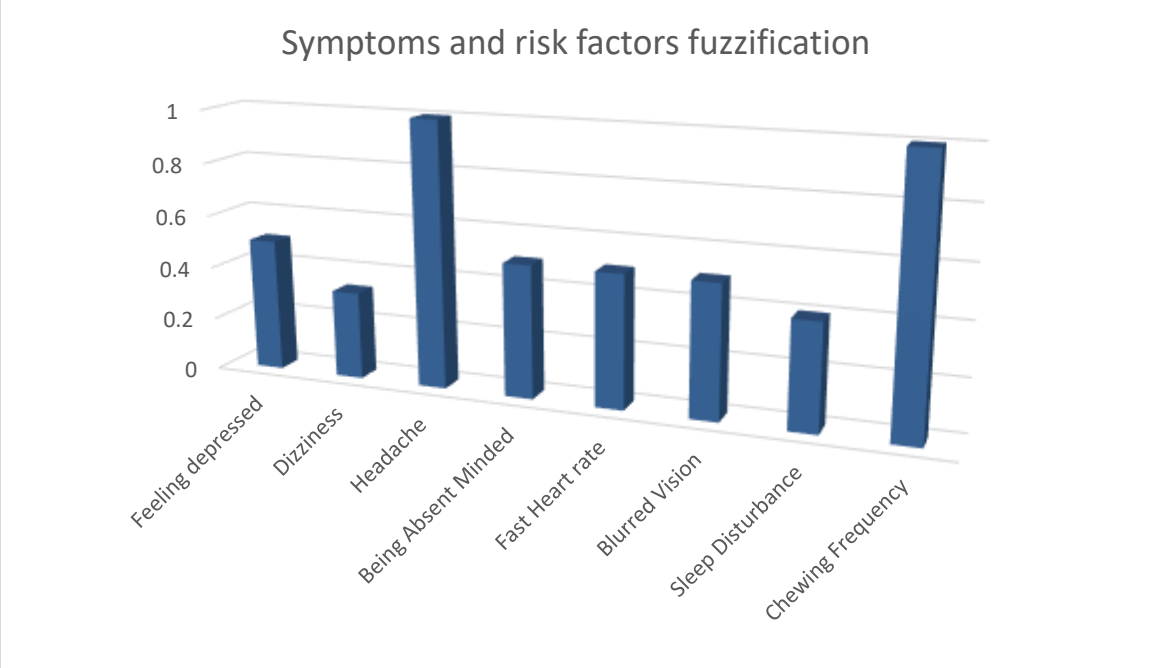

Figure 4.7 Symptoms and risk factor fuzzification showing each level of membership degree (Second data in Table 4.3)

Degree of Membership

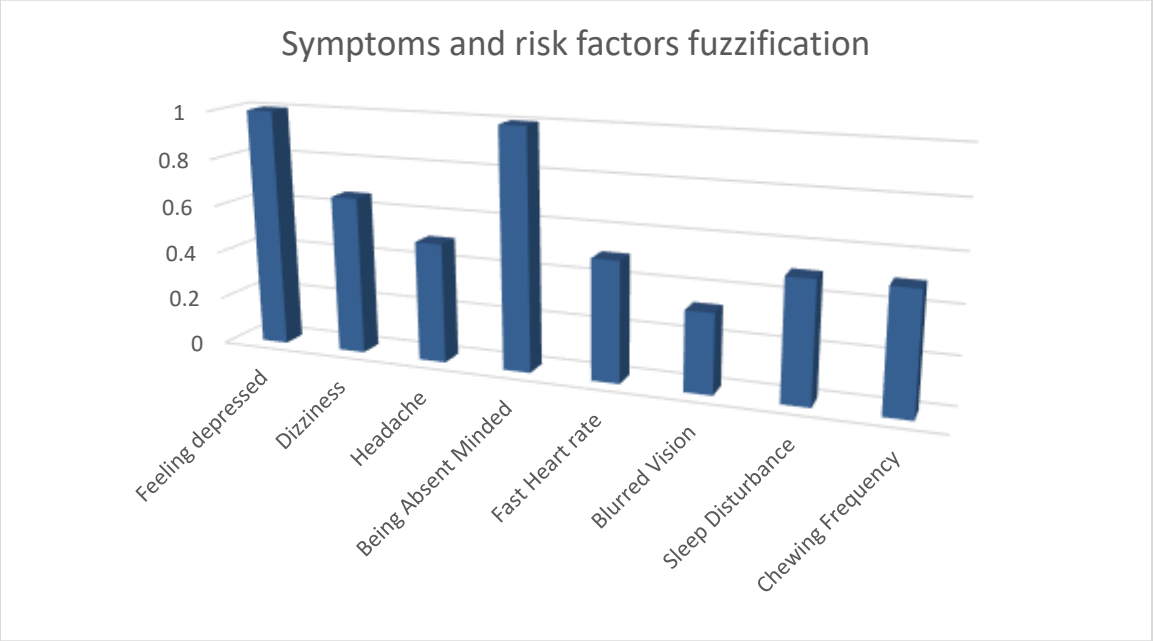

Figure 4.8 Symptoms and risk factor fuzzification showing each level of membership degree (Third data in Table 4.3)

4.7. Discussion

In this research work, a fuzzy expert system was designed and implemented to diagnose the risk level of individuals with physical and psychological disorder related to khat addiction. The system contains eight (8) input variables: feeling depressed, dizziness, headache, absentminded, fast heart rate, blurred vision, sleep disturbance and chewing frequency. It uses five output parameter values: very low, low, medium, high and very high. Triangular fuzzifier was used for membership function evaluation. The fuzzified data were used to infer diagnosis with the knowledge stored in the knowledge base. The rule base was designed based on knowledge of domain experts. The system has 6587 fuzzy rules building strong rule base, since quality of the results in fuzzy system depends on rule base of the system. The designed fuzzy expert system uses rules to diagnosis the risk level of khat addicted patients with physical and psychological disorder based on symptoms and risk factors. Center of gravity method was used for defuzzification of the output variable. Defuzzification was used to produce crisp value on arbitrary scale of fuzzy out variable as risk of physical and psychological disorder. The efficiency of the designed expert system was tested with

data of khat addicted patients with physical and psychological disorder. The test result indicates that the symptoms and risk factors used in designing the model were responsible physical and psychological disorder related to khat addiction. The designed system has recorded 95% accuracy.

Appropriate advice is provided to minimize the risk level of khat addicted patients with physical and psychological disorder by the designed fuzzy expert system. Mobile based fuzzy expert system model for diagnosing the risk level of khat addicted patients with physical and psychological disorder as a new approach was used.

The motivation for the choice of fuzzy expert system model was because of real and near accurate drawing of inference from the system, based on the nature of the disease (physical and psychological disorder). We used fuzzy logic approach for removing uncertainty, ambiguity and vagueness in physical and psychological disorder related to khat addiction. It was perceived that best result were gotten by testing mobile based fuzzy expert system using real data of individuals.

4.8. User Acceptance Testing

Testing was used to identify whether the developed system achieve the goal or not. Two methods are used for expert system evaluation. These are functional testing and structural testing (Leonard , 1991). Functional testing approach was used in this research work for testing the basic functions of the system such as the risk level of physical and psychological disorder related to khat addiction. Real data and expert reported cases were used for testing the functionality of the designed expert system. The performance Metrix used to test the designed fuzzy expert system are efficiency, functionality, and portability following ISO 9126 software quality characteristics standard. Ten (10) respondents were selected randomly for evaluation of the designed system. Among ten individuals two of them were medical experts and eight of them are khat addicted patients. They were asked to determine portability, functionality and efficiency and the result is presented below. The functionality of the proposed system was measured based on correctness suitability of functions in determining the risk level of the disease. The portability of the proposed system is measured in terms of efforts required to install the device in different environment. The efficiency is evaluated based on system response for input symptoms and risk factors of diagnosing the risk level.

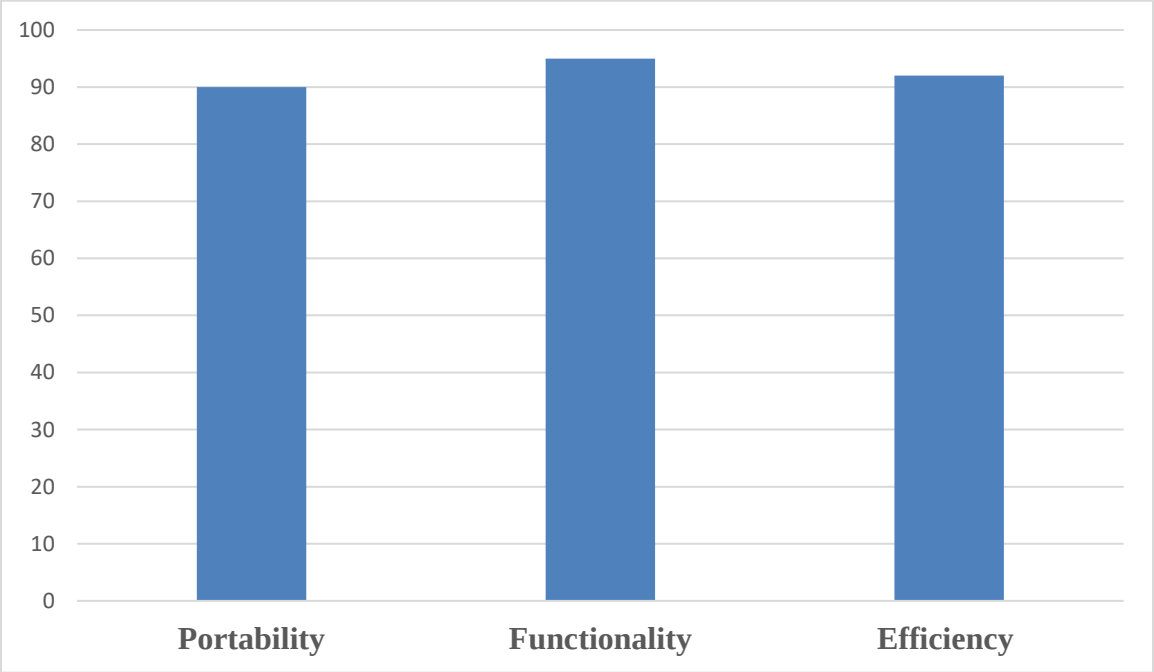

Figure 4.9 Chart result for Evaluation of the Designed System

For evaluating the designed fuzzy expert system, we include users (patients and physicians) feedback based on a set of criteria. The data collected was analyzed to recognize the usefulness of the designed fuzzy expert system for patients and physicians to improve their knowledge about physical and psychological disorder related to khat addiction. The users evaluated the designed fuzzy expert system in terms of functionality, efficiency and portability. The developed fuzzy expert system was evaluated by taking respondents answer by asking serious of questions using Likert scale (Appendix II). The users give score five (Strongly Agree) as highest value and 1 as lowest value (Strongly Disagree). We summarized the evaluation result of two (2) experts and Eight (8) khat addicted patients in table 4.5 below.

Table 4.5 Result of Evaluation

Criteria	User 1	User 2	Average	Interpretation
functionality	4.8	4.7	4.75	Agree
Efficiency	4.6	4.5	4.55	Agree
portability	4.6	4.4	4.5	Agree
Mean Average			4.6	Agree

Where User1- Experts in physical and psychological disorder

User2- khat addicted patients with physical and psychological disorder

The above table 4.5 shows the result of evaluation conducted by users (khat addicted patients and physicians) and its interpretation. The Evaluation result (4.6) indicates that most of the respondents agreed which is equivalent to 92 % result of the system evaluation.

CHAPTER FIVE

5. Conclusion and Recommendation

5.1. Conclusion

Fuzzy expert system for diagnosing the risk level of physical and psychological disorder related to khat addiction which runs on android operating system was successfully designed and implemented using symptoms and risk factors of khat addicted patients with physical and psychological disorder. The developed fuzzy system would be used by khat addicted patients with physical and psychological disorder for monitoring their health status.

The nature of physical and psychological disorder related to khat addiction created a big problem in health care centers. In developing countries like Ethiopia where insufficient specialists are in the area, the disease spreads from time to time. The use of fuzzy logic has been found important technology to model uncertainty in medical area. The designed fuzzy expert system can provide decision support platform for assisting khat addicted patients with physical and psychological disorder, researchers, clinicians and health care workers to diagnosis the risk level of physical and psychological disorder caused by khat addiction.

The fuzzy expert for diagnosing the risk level of khat addicted patients with physical and psychological disorder was implemented using data of those already diagnosed with physical and psychological disorder. This approach supports users of the developed expert system for monitoring their health status and reduce the risk level of khat addiction.

The fuzzy logic model used in this research work achieved the overall result by using symptoms and risk factors of physical and psychological disorder related to khat addiction. This model delivers effective solution and provide more accurate diagnose result to a problem. The designed fuzzy expert system performs 95% success. The symptoms and risk factors used in the designed fuzzy expert system was confirmed as contributing factors for increasing the risk of physical and psychological disorder related to khat addiction. Therefore, the output of fuzzy expert system provides advice which enables individuals to take the necessary measures in reducing the risk level of physical and psychological disorder related to khat addiction.

5.2. Contribution

This study has the following contributions:

1. The study would contribute to the innovation of mobile health systems by developing fuzzy expert system which provides effective result for diagnosing the risk of physical and psychological disorder related to khat addiction.
2. This study would contribute on diagnosing the risk of physical and psychological disorder related to khat addiction by using knowledge of experts, since most studies focus on the effects of khat addiction using community based and cross sectional studies.
3. This fuzzy expert system minimizes uncertainty and risk level of physical and psychological disorder related to khat addiction. It helps to reduce the problem before it becomes worse.
4. Since the result of fuzzy system depends on the rule base, strong rules were constructed to get quality result. Basic symptoms and risk factors were also considered during the design of the system using the support of domain experts, literature studies and already diagnosed data of patients.

5.3. Recommendation

For future research direction, this research can be extended on khat addiction related health problems using different approaches. The symptoms and risk factors of physical and psychological disorder may continuously change based on different factors like health status of the patient. So future works can be done on integrating intelligent systems that has capability of self-learning using neural network adaptive systems. A major challenge is specialized experts are expensive and are not likely to sit down and write large number of rules. Wide consultation of psychiatrists is required to improve the accuracy of the system.

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APPENDIX

Appendix I: Equations to calculate membership function of each symptoms and risk factors

Feeling Depressed μ *low* (DP)=0, if DP<1

DP-1, if 1<=DP<2

3-DP, if 2<=DP<3

0, if DP>3

μ *moderate* (DP)= 0, if DP<2

(DP-2)/2, if 2<=DP<4

(6-DP)/2, if 4<=DP<6

0, if DP>6

μ *severe*(DP)= 0, if DP<5

(DP-5)/2, if 5<=DP<7

(10-DP)/3, if 7<=DP<=10

0, if DP>10

Dizziness μ *low* (DZ)= 0, if DZ<1

(DZ-1)/3, if 1<=DZ<4

(8-DZ)/4, if 4<=DZ<=8

0, if DZ>8

μ *moderate* (DZ)= 0, if DZ<7

(DZ-7)/3, if 7<=DZ<10

(14-DZ)/4, if 10<=DZ<=14

0, if DZ>14

μ *severe*(DZ)= 0, if DZ<13

(DZ-13)/3, if 13<=DZ<16

(20-DZ)/4, if 16<=DZ<=20

0, if DZ>20

Headache μ *low* (HD)= 0, if HD<1

HD-1, if 1<=HD<2

(4-HD)/2, if 2<=HD<4

0, if HD>4

μ *moderate* (HD)= 0, if HD<3

HD-3, if 3<=HD<4

(6-HD)/2, if 4<=HD<=6

0, if HD>6

μ *severe*(HD)= 0, if HD<5

(HD-5)/2, if 5<=HD<7

(10-HD)/3, if 7<=HD<=10

0, if HD>10

Being absent minded μ *low* (BAM)= 0, if BAM<1

BAM-1, if 1<=BAM<2

(4-BAM)/2, if 2<=BAM<4

0, if BAM>4

μ *moderate* (BAM)= 0, if BAM<3

BAM-1, if 3<=BAM<4

(6-BAM)/2, if 4<=BAM<=6

0, if BAM>6

μ *severe*(BAM)= 0, if BAM<5

(BAM-5)/2, if 5<=BAM<7

(10-BAM)/3, if 7<=BAM<=10

0, if BAM>10

Fast heart rate μ *low* (FHR)= 0, if FHR<1

FHR-1, if 1<=FHR<2

(4-FHR)/2, if 2<=FHR<=4

0, if FHR>4

μ *moderate* (FHR)= 0, if FHR<2

(FHR-3)/2, if 2<=FHR<4

(6-FHR)/2, if 4<=FHR<=6

0, if FHR>6

μ *severe*(FHR)= 0, if FHR<5

(FHR-5)/2, if 5<=FHR<7

(10-FHR)/3, if 7<=FHR<=10

0, if FHR>10

Blurred vision μ *low* (BV)= 0, if BV<1

(BV-1)/2, if 1<=BV<3

(5-BV)/2, if 3<=BV<=5

0, if BV>5

μ *moderate* (BV)= 0, if BV<4

(BV-4)/3, if 4<=BV<7

(10-BV)/3, if 7<=BV<=10

0, if BV>10

μ *severe*(BV)= 0, if BV<7

(BV-7)/4, if 7<=BV<11

(15-BV)/4, if 11<=BV<=15

0, if BV>15

Sleeping disturbance μ *low* (SD)= 0, if SD<1

(SD-1)/2, if 1<=SD<3

(6-SD)/3, if 3<=SD<6

0, if SD>6

μ *moderate* (SD)= 0, if SD<5

(SD-5)/2, if 5<=SD<7

(12-SD)/5, if 7<=SD<=12

0, if SD>12

μ *severe* (SD)= 0, if SD<11

(SD-11)/4, if 11<=SD<15

(20-SD)/5, if 15<=SD<=20

0, if SD>20

Chewing frequency μ *low* (CF)= 0, if CF<1

(CF-1)/2, if 1<=CF<3

(5-CF)/2, if 3<=CF<=5

0, if CF>5

μ *moderate* (CF)= 0, if CF<4

(CF-3)/3, if 4<=CF<7

(10-CF)/3, if 7<=CF<=10

0, if CF>10

μ *severe* (CF)= 0, if CF<8

(CF-8)/3, if 8<=CF<11

(15-CF)/4, if 11<=CF<=15

0, if CF>15

Appendix II: Sample rules for physical and psychological disorder diagnosis related to khat addiction

RULE 1 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS low AND CF IS low THEN risk IS very_low;

RULE 2 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS low AND CF IS moderate THEN risk IS very_low;

RULE 3 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS low AND CF IS severe THEN risk IS medium;

RULE 4 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS moderate AND CF IS low THEN risk IS very_low;

RULE 5 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS moderate AND CF IS moderate THEN risk IS low;

RULE 6 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS moderate AND CF IS severe THEN risk IS medium;

RULE 7 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS severe AND CF IS low THEN risk IS medium;

RULE 8 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS severe AND CF IS moderate THEN risk IS high;

RULE 9 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS low AND SD IS severe AND CF IS severe THEN risk IS very_high;

RULE 10 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS low AND CF IS low THEN risk IS very_low;

RULE 11 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS low AND CF IS moderate THEN risk IS low;

RULE 12 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS low AND CF IS severe THEN risk IS medium;

RULE 13 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS moderate AND CF IS low THEN risk IS low;

RULE 14 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS moderate AND CF IS moderate THEN risk IS medium;

RULE 15 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS moderate AND CF IS severe THEN risk IS high;

RULE 16 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS severe AND CF IS low THEN risk IS medium;

RULE 17 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS severe AND CF IS moderate THEN risk IS high;

RULE 18 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS moderate AND SD IS severe AND CF IS severe THEN risk IS very_high;

RULE 19 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS low AND CF IS low THEN risk IS medium;

RULE 20 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS low AND CF IS moderate THEN risk IS medium;

RULE 21 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS low AND CF IS severe THEN risk IS high;

RULE 22 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS moderate AND CF IS low THEN risk IS medium;

RULE 23 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS moderate AND CF IS moderate THEN risk IS medium;

RULE 24 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS moderate AND CF IS severe THEN risk IS high;

RULE 25 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS severe AND CF IS low THEN risk IS very_high;

RULE 26 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS severe AND CF IS moderate THEN risk IS very_high;

RULE 27 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS low AND BV IS severe AND SD IS severe AND CF IS severe THEN risk IS very_high;

RULE 28 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS low AND CF IS low THEN risk IS very_low;

RULE 29 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS low AND CF IS moderate THEN risk IS low;

RULE 30 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS low AND CF IS severe THEN risk IS medium;

RULE 31 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS moderate AND CF IS low THEN risk IS low;

RULE 32 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS moderate AND CF IS moderate THEN risk IS medium;

RULE 33 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS moderate AND CF IS severe THEN risk IS high;

RULE 34 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS severe AND CF IS low THEN risk IS medium;

RULE 35 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS severe AND CF IS moderate THEN risk IS medium;

RULE 36 : IF DP IS low AND DZ IS low AND HD IS low AND BAM IS low AND FHR IS moderate AND BV IS low AND SD IS severe AND CF IS severe THEN risk IS very_high;

Appendix III: Sample codes for the designed Fuzzy Expert System

```
package com.example.selam.research;

import android.annotation.SuppressLint;
import android.app.AlertDialog;
import android.app.ProgressDialog;
import android.content.DialogInterface;
import android.os.AsyncTask;
import android.support.v7.app.AppCompatActivity;
import android.os.Bundle;
import android.util.Log;
import android.view.Menu;
import android.view.View;
import android.widget.Button;
import android.widget.Spinner;
import android.widget.TextView;
import android.widget.Toast;

import net.sourceforge.jFuzzyLogic.FIS;
import net.sourceforge.jFuzzyLogic.rule.Rule;
import net.sourceforge.jFuzzyLogic.rule.Variable;

import org.apache.http.NameValuePair;
import org.apache.http.message.BasicNameValuePair;
import org.json.JSONObject;

import java.io.IOException;
import java.io.InputStream;
import java.util.ArrayList;
import java.util.List;

public class MainApp extends AppCompatActivity implements View.OnClickListener{

    Spinner x1, x2, x3, x4, x5,
            x6, x7, x8;
    String
feelingdepressed,dizziness,headache,absentminded,fastheartrate,blurredvision,sleepDist
urbance,chewingfrequency,risklevel;
    Button btnsubmit,btnf;
    TextView risklevelresult, txt,fuzzyvalue;
    double rsk;
    double waitingtime;
    private AlertDialog alert;



    private ProgressDialog pDialog;
    private static final String TAG_SUCCESS = "success";
    private static final String TAG_MESSAGE="message";
    private static final String url = "http://10.0.2.2/member/facts.php";
    String error_message;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main_app);
        x1 = findViewById(R.id.spinner1);
        x2 = findViewById(R.id.spinner2);
        x3 = findViewById(R.id.spinner3);
        x4 = findViewById(R.id.spinner5);
        x5 = findViewById(R.id.spinner7);
        x6 = findViewById(R.id.spinner8);
```

```
        x7 = findViewById(R.id.spinner12);
        x8 = findViewById(R.id.spinner13);
        risklevelresult = findViewById(R.id.textView15);
       // fuzzyvalue = findViewById(R.id.textView11);
        txt = findViewById(R.id.risklevel);
        btnsubmit = findViewById(R.id.button);
       // btnf=findViewById(R.id.button2);
       // Button btn=findViewById(R.id.button4);
        btnsubmit.setOnClickListener(this);
    }

    @SuppressLint("SetTextI18n")
    public void onClick(View v) {
        feelingdepressed = x1.getSelectedItem().toString();
        Integer X1 = Integer.parseInt(feelingdepressed);
        dizziness = x2.getSelectedItem().toString();
        Integer X2 = Integer.parseInt(dizziness);
        headache = x3.getSelectedItem().toString();
        Integer X3 = Integer.parseInt(headache);
        absentminded = x4.getSelectedItem().toString();
        Integer X4 = Integer.parseInt(absentminded);
        fastheartrate = x5.getSelectedItem().toString();
        Integer X5 = Integer.parseInt(fastheartrate);
        blurredvision = x6.getSelectedItem().toString();
        Integer X6 = Integer.parseInt(blurredvision);
        sleepDisturbance = x7.getSelectedItem().toString();
        Integer X7 = Integer.parseInt(sleepDisturbance);
        chewingfrequency = x8.getSelectedItem().toString();
        Integer X8 = Integer.parseInt(chewingfrequency);
        try {

            double risk = fuzzyProcess(X1, X2, X3, X4, X5, X6, X7, X8);
            if(risk>=0 && risk<2){
                risklevelresult.setText("The risk level is very low,advised to
maintain this level");
            }
           else if(risk>=2 && risk<4) {
                risklevelresult.setText("The risk level is low, Take psychoeducation
to reduce effect of khat addiction");}
            else  if (risk >= 4 && risk < 7){
                risklevelresult.setText("The risk level is medium, Take the
appropriate psychotherapy like Family and Group therapy,Behavioral therapy");}
            else if(risk>=7&& risk<10){
                risklevelresult.setText("The risk level is high,Take psychotherapy,
appropriate medication and physical examination");}
            else if(risk>=10 && risk<=20) {
                risklevelresult.setText("The risk level is very high, seek urgent
medical attention");
            }
            else {
                risklevelresult.setText("No match found");
               // fuzzyvalue.setText(String.valueOf(risk));

                // generateRuleBlock();
            }
            risklevel=risklevelresult.getText().toString();
        }catch (Exception e){
            e.printStackTrace();
            infoalert();
        }
new mainapp().execute();

    }
```

```
    public void infoalert(){
        AlertDialog.Builder builder = new AlertDialog.Builder(this);
        builder.setTitle("Alert");
        builder.setMessage("fill all the appropriate data correctly.");
        builder.setNeutralButton("Ok", new DialogInterface.OnClickListener() {
            public void onClick(DialogInterface arg0, int arg1) {
                alert.dismiss();
            }
        });
        alert = builder.create();
        alert.show();
    }
    @SuppressLint({"DefaultLocale", "SetTextI18n"})
    public double fuzzyProcess(Integer ADP, Integer BDZ, Integer CHD,Integer
EBAM,Integer GFHR, Integer HBV, Integer LSD, Integer MCF) throws InterruptedException
{
        //load from FCL file
        InputStream inputStream = null;
        try {
            inputStream =
getApplicationContext().getAssets().open("khataddiction.fcl");
        } catch (IOException e) {
            e.printStackTrace();
        }

        boolean first = true;
        FIS fis = FIS.load(inputStream, true);
         //error while loading
        String error = "can't load fis";
        if (fis == null) {
            txt.setText(error);
        }
          //set inputs
        assert fis != null;
        fis.setVariable("DP", ADP);
        fis.setVariable("DZ", BDZ);
        fis.setVariable("HD", CHD);
        fis.setVariable("BAM", EBAM);
        fis.setVariable("FHR", GFHR);
        fis.setVariable("BV", HBV);
        fis.setVariable("SD", LSD);
        fis.setVariable("CF", MCF);
        // Show each rule (and degree of support)
        for (Rule r :
fis.getFunctionBlock("khataddiction").getFuzzyRuleBlock("No1").getRules()) {
           if (first)
                       first = false;
        }

        fis.evaluate();

        Variable rsk = fis.getFunctionBlock("khataddiction").getVariable("risk");
        double risk = rsk.defuzzify();
        Thread.sleep(100);

        setWaitingTime(fis.getVariable("risk").getLatestDefuzzifiedValue());
        // String x= String.valueOf(risk.getLinguisticTerm(risk.getName()));
        //fuzzyvalue.setText(risk);
        return risk;
    }
```

```
    class mainapp extends AsyncTask<String, String, String> {


        @Override
        protected void onPreExecute() {
            super.onPreExecute();
        }

        /**
         * Registering Client
         * */
        protected String doInBackground(String... args) {
            // Building Parameters
            List<NameValuePair> params = new ArrayList<NameValuePair>();
            //params.add(new BasicNameValuePair("userid", user_id));
            params.add(new BasicNameValuePair("feelingdepressed",feelingdepressed ));
            params.add(new BasicNameValuePair("dizziness",dizziness ));
            params.add(new BasicNameValuePair("headache", headache));
            params.add(new BasicNameValuePair("absentminded", absentminded));
            params.add(new BasicNameValuePair("fastheartrate",fastheartrate ));
            params.add(new BasicNameValuePair("blurredvision",blurredvision ));
            params.add(new BasicNameValuePair("sleepDisturbance", sleepDisturbance));
            params.add(new BasicNameValuePair("chewingfrequency", chewingfrequency));
            params.add(new BasicNameValuePair("risklevel", risklevel));

            JSONParser jsonParser =new JSONParser();
            // getting JSON Object
            // Note that create product url accepts POST method
            JSONObject json = jsonParser .makeHttpRequest(url,"POST", params);

            // check log cat fro response
            Log.d("Create Response", json.toString());

            // check for success tag

            return null;
        }
        protected void onPostExecute(String file_url) {
            super.onPostExecute(file_url);
            // dismiss the dialog once done
        }}

    public  void setWaitingTime(double time){
        waitingtime=time;
    }
    public  double getWaitingtime(){
        return waitingtime;
    }

    @Override
    public void onPointerCaptureChanged(boolean hasCapture) {

    }
    public boolean onCreateOptionsMenu(Menu menu) {
        // Inflate the menu; this adds items to the action bar if it is present.
        getMenuInflater().inflate(R.menu.main, menu);
        return true;
    }

}
```

Appendix IV: Evaluation of the designed fuzzy expert system survey

1. I would like to use this system frequently

Strongly Disagree	1	2	3	4	5	Strongly Agree

2. I found this system complex

Strongly Disagree	1	2	3	4	5	Strongly Agree

3. I thought the system is easy to use

Strongly Disagree	1	2	3	4	5	Strongly Agree

4. I need support of technical person to use this system

Strongly Disagree	1	2	3	4	5	Strongly Agree

5. I thought there is too much inconsistency in this system

Strongly Disagree	1	2	3	4	5	Strongly Agree

6. I imagine most people would learn to use this system quickly

Strongly Disagree	1	2	3	4	5	Strongly Agree

7. I feel confident in using this system

Strongly Disagree	1	2	3	4	5	Strongly Agree

8. I need to learn new concepts before using the system

Strongly Disagree	1	2	3	4	5	Strongly Agree

9. Does the system fulfill the intended function to diagnosis the risk level of physical and psychological disorder related to khat addiction(YES/NO)
10. General_comments_____
_____
_____
_____

Appendix V: Questionnaires used for gathering knowledge from experts

1. What are the common type of diseases frequently associated with khat addiction?
2. What are the physical and psychological symptoms and risk factors of khat addiction?
3. What kind of treatment is given to khat addicted patients with physical and psychological disorder?
4. Which symptoms and risk factors have very high risk, high risk, medium risk, low risk and very low risk?
5. What is the physical and psychological effects of long term khat addicted patients?
6. How to diagnose the physical and psychological disorder related to khat addiction?
7. When the physical and psychological disorder related to khat addiction becomes very high, high, medium, low and very low?
8. How to recover or withdraw from khat addiction to reduce its effect?
9. Does frequency of khat chewing increase the risk of physical and psychological disorder?