IZMIR KATIP CELEBİ UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

EXPERT SYSTEM DESIGN BY USING ARTIFICIAL INTELLIGENCE TECHNIQUES FOR THE DIAGNOSIS OF LIVER DISORDERS

M.Sc. THESIS

Naciye MÜLAYİM

Department of Biomedical Technologies

Thesis Advisor: Assoc. Prof. Dr. Ayşegül Alaybeyoğlu Yılmaz

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İZMİR KATİP ÇELEBİ ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

KARACİĞER HASTALIĞININ TANISI İÇİN YAPAY ZEKA TEKNİKLERİ İLE UZMAN SİSTEM TASARIMI

YÜKSEK LİSANS TEZİ

Naciye MÜLAYİM
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MAYIS 2016

Naciye Mülayim, a **M.Sc.** student of **IKCU Institute of Biomedical Technologies** student ID Y130101006, successfully defended the **thesis** entitled "**EXPERT SYSTEM DESIGN BY USING ARTIFICIAL INTELLIGENCE TECHNIQUES FOR THE DIAGNOSIS OF LIVER DISORDERS**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Assoc. Prof. Dr. Ayşegül ALAYBEYOĞLU YILMAZ**
İzmir Katip Çelebi University .....

Jury Members : **Assistant Prof. Dr. Fatih Cemal CAN** .....
Izmir Katip Çelebi University

Assistant Prof. Dr. İlker KILIÇ .....
Celal Bayar University

Date of Submission : 27 May 2016
Date of Defense : 27 May 2016

To my spouse and son,

FOREWORD

Primarily, I would like to express my thanks to my advisor, Assoc. Prof. Dr. Ayşegül Alaybeyoğlu Yılmaz, for her guidance, supports and helping with farsighted thoughts and ideas throughout the research.

I would like to thank to my husband, Oğuz Mülayim, for his advices, motivations, moral and material supports. I also thank my friends for their encouragement.

May 2016 Naciye Mülayim

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ABBREVIATIONS

ES **:** Expert System
AI **:** Artificial Intelligence
FA **:** Firefly Algorithm
SVM **:** Support Vector Machine
GA **:** Genetic Algorithm
ANN **:** Artificial Neural Network
AWAIS **:** Artificial Immune System
GA-AWAIS **:** Genetic Algorithm Artificial Immune System
AIA **:** Artificial Immune Algorithm
DE **:** Differential Evolution
PSO **:** Particle Swarm Optimization
K-FA **:** K-Means Firefly Algorithm
BRCFF : Binary Real Coded Firefly
MCET **:** Minimum Cross Entropy Thresholding
LBG **:** Linde-Buzo-Gray
QPSO **:** Quantum Particle Swarm Optimization
ED **:** Economic Dispatch
ABC **:** Artificial Bee Colony
ILPD **:** Indian Liver Patient Dataset
GPS **:** General Problem Solver
U.K. **:** United Kingdom
U.S. **:** United State
IBM **:** International Business Machines Corporation
ALT **:** Alanine Aminotransferase
SGPT **:** Alanine Aminotransferase
ALS **:** Aspartate Aminotransferase
SGOT **:** Aspartate Aminotransferase
ALP **:** Alkaline Phosphatase

A/G Ratio **:** Albumin- Globulin Ratio

TB **:** Total Bilirubin

TP **:** Total Protein

ALB **:** Albumin

GGT **:** Gamma Glutamyl Transpeptidase

MCV **:** Mean Corpuscular Volume

BFA **:** Bacterial Foraging Algorithm

Alkphos **:** Alkaline Phosphatase

TP **:** True positive

FP **:** False Positive

TN **:** True Negative

FN **:** False Negative

NSWKM **:** Non-Symmetrical Weighted K-Means

RABC **:** Rank-Based Artificial Bee Colony

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EXPERT SYSTEM DESIGN BY USING ARTIFICIAL INTELLIGENCE TECHNIQUES FOR THE DIAGNOSIS OF LIVER DISORDERS

SUMMARY

Nowadays, Expert System (ES)s are used widely in many areas to solve real world problems. Artificial Intelligence (AI) techniques are used to obtain timely and accurately decision about solution of daily problems in ESs designing because AI can mimic behaviours and thought system of people. Especially in medical area, there are many researches and applications using ESs based on various AI techniques to obtain diagnosis for any diseases.

The liver is a vital internal organ for a human body and it has many functions, which are associated with the other organs. Although the liver can renew itself in the face of a damage and ¼ of liver can even be enough for liver functions, a major damage is an obstacle for continual of the liver functions. For this reason, early diagnosis is very important in liver disorders.

In this study, it was intended to generate expert systems based on Firefly Algorithm (FA) and Support Vector Machine (SVM) techniques for the diagnosis of liver disorders by using C# programming language and "Indian Liver Patient Dataset (ILPD)" and "Liver Disorder Dataset (BUPA Dataset)". For performance evaluations of the proposed systems Accuracy, Positive Predictive Value, Negative Predictive Value, Sensitivity, Specificity, Precision and F-Measure were used.

For ILPD, the proposed system based on Firefly Algorithm (FA) gave 92% Accuracy, 92% Sensitivity, 84.61 % Specificity, 95.91 % Positive Predictive Value, 83.01 % Negative Predictive Value, 95.91 % Precision and 93.91 % F-Measure. The proposed system based on Support Vector Machine (SVM) gave 78.33% Accuracy, 79.9% Sensitivity, 75% Specificity, 87.16 % Positive Predictive Value, 63.71 % Negative Predictive Value, 87.16 % Precision and 83.37 % F-Measure.

For BUPA Dataset, the proposed system based on Firefly Algorithm (FA) gave 92.8% Accuracy, 96% Sensitivity, 90.66 % Specificity, 87.27 % Positive Predictive Value, 97.14 % Negative Predictive Value, 87.27 % Precision and 91.42 % F-Measure. The proposed system based on Support Vector Machine (SVM) gave 76.8 % Accuracy, 82% Sensitivity, 73.33% Specificity, 67.21 % Positive Predictive Value, 85.93 % Negative Predictive Value, 67.21 % Precision and 73.87 % F-Measure.

It was clearly observed that the proposed system based on FA gave more successful predictions than the proposed system based on SVM in both liver disorders datasets and it is hoped that the generated systems will make contribution to in researches of expert systems based on artificial intelligence.

KARACİĞER HASTALIĞININ TANISI İÇİN YAPAY ZEKÂ TEKNİKLERİ İLE UZMAN SİSTEM TASARIMI

ÖZET

Günümüzde uzman sistemler birçok gerçek dünya problemlerinin çözümünde yaygın olarak kullanılmaktadır. Uzman sistemlerde, yapay zekâ teknikleri insanların düşünce sistemlerini ve davranışlarını taklit edebildiği için, günlük problemlerin çözümü için zamanında ve doğru kararların elde edilmesi için kullanılır. Özellikle medikal alanda, herhangi bir hastalığın teşhisi için, çeşitli yapay zekâ tekniklerine dayanan uzman sistemleri kullanan birçok araştırma ve uygulamalar vardır.

Karaciğer insan vücudu için hayati bir iç organdır ve diğer organlarla ilişkili olan birçok fonksiyonu yerine getirir. Karaciğer bir hasarla karşılaştığı zaman kendini yenileyebilme yeteneğine sahip olmasına ve hatta karaciğerin ¼ ü bile karaciğer fonksiyonlarını gerçekleştirmek için yeterli olmasına rağmen, büyük hasarlar karaciğer fonksiyonlarının sürekliliği için engel teşkil eder. Bu yüzden karaciğer hastalıklarında erken teşhis çok önemlidir.

Bu çalışmada karaciğer hastalığının teşhisi için C# programlama dili ve "Indian Liver Patient Dataset (ILPD)" ve "Liver Disorder Dataset (BUPA Dataset)" kullanılarak Ateş Böceği Algoritması ve Destek Vektör Makinası tekniklerine dayalı uzman sistemler geliştirilmesi hedeflenmiştir. Önerilen Sistemlerin performans değerlendirmesi için Doğruluk, Pozitif Kestirim Değeri, Negatif Kestirim Değeri, Duyarlılık, Özgüllük Hassaslık ve F-ölçütü kullanılmıştır.

ILPD seti için, önerilen Ateş Böceği Algoritmasına dayanan sistem, %92 Doğruluk, %92 Duyarlılık, % 84.61 Özgüllük, % 95.91 Pozitif Kestirim Değeri, % 83.01 Negatif Kestirim Değeri, % 95.91 Hassaslık ve %93.91 F-ölçütü vermiştir. Yine ILPD seti için, önerilen Destek Vektör Makinası algoritmasına dayanan sistem %78.33 Doğruluk, %79,9 Duyarlılık, % 75 Özgüllük, % 87.16 Pozitif Kestirim Değeri, % 63.71 Negatif Kestirim Değeri, % 87.16 Hassaslık ve % 83.37 F-ölçütü vermiştir.

BUPA seti için, önerilen Ateş Böceği Algoritmasına dayanan sistem % 92.80 Doğruluk, %96 Duyarlılık, % 90.66 Özgüllük, % 87.27 Pozitif Kestirim Değeri, % 97.14 Negatif Kestirim Değeri, % 87.27 Hassaslık ve % 91.42 F-ölçütü vermiştir. Yine ILPD seti için, önerilen Destek Vektör Makinası algoritmasına dayanan sistem % 76.80 Doğruluk, % 82 Duyarlılık, % 73.33 Özgüllük, % 67.21 Pozitif Kestirim Değeri, % 85.93 Negatif Kestirim Değeri, % 67.21 Hassaslık ve % 73.87 F-ölçütü vermiştir.

Her iki veri seti için önerilen Ateş Böceği algoritmasına dayalı sistem, Destek Vektör Makinalarına dayalı sistemden daha başarılı tahminler yapmış olduğu açıkça anlaşılmıştır ve oluşturulan bu sistemlerin bu yapay zekâ algoritmalarına dayalı uzman sistem araştırmalarına katkı sağlaması umuluyor.

1. INTRODUCTION

Currently, accurate and timely diagnosis is very important and for this, expert systems with artificial intelligent techniques are used widely in medical diagnosis. For certain, there cannot be doubtful about diagnosis evaluation and decision of doctors because any system cannot substitute an expert in certain area but these systems can help probable errors ensuing from fatigued and unpractised experts [1] and as well as it can help to experts when the lack of a sufficient number of experts. Also in a clinic, a doctor decides diagnosis and process of treatments by using the medical knowledge of the patient, some physical or laboratory test results and according to answered questions by patients. Along the confusing process, various things can be mistake. For instance, when a patient especially suffers from complicated diseases, he can give answers including interference and unnecessary symptoms. On the contrary, he cannot adequately present the main syndromes or attributes for diagnosis to practitioners and he can ignore mistakenly because of suffering from complex diseases. These problems and misunderstandings often give rise to delay of timely and accurate diagnosis or even wrong diagnosis time-to-time [2].

The largest visceral organ for an adult is the liver and it has a lot of vital functions and duties for continuous the living such as excreting, secretions, storing and digesting nutrients, detoxification [3]. While it is fulfilling the duties, it is exposed to many detrimental substances. Firstly it starts to repair the damaged or deformed liver tissues after the other cells, which are responsible for the same tasks in the liver, carry out the damaged part's functions indefinitely or by the time the detriment has been rehabilitated [4]. However, problems of liver patients cannot be solved easily in the first phase because it continues normal functions as its partially damaged [5]. Even Hepatitis C is known "the silent epidemic." Generally, people do not notice that they have it because it does not show symptoms for years. Approximately 15.000 people in America die from chronic liver disease and liver cancer [6].

When all mentioned things are thought, accurate and timely diagnosis of liver disorders is very important for patients. At this point, expert systems, which are

developed by artificial intelligence techniques, help for timely diagnosis and to reduce mortality, waiting to date with practitioners and present some proposals [4].

In these fields, there have been many studies and some of them are given following part.

1.1 Literature

There are some studies based FA and SVM, papers that are about diagnosis of liver disorders and expert system studies based various algorithm. In [7], for liver disease diagnosis, C4.5, Support Vector Machine (SVM), Naïve Bayes Classifier, and Back Propagation Neural Network Algorithm are used and these algorithms are evaluated according to Accuracy, Precision, Sensitivity and Specificity criteria. In [8], SVM, Bayesian and K-Nearest Neighbour Classifier are used for semi automatically segmented and quantified for diagnosis of liver disorders and it is obtained 80.68%. In [9], it is obtained verification 91% with a fuzzy expert system to diagnose liver disorders. This system is faster, cheaper, more accurate and more liable, if it is compared with other traditional systems. In [10], Genetic algorithm (GA) is used to determine weight of attributes of Statlog Heart Disease and BUPA datasets. The weights are used in Artificial Immune System (AWAIS) and it is obtained new systems (GA-AWAIS). After AWAIS and GA-AWAIS is compared. In [11], it is used Machine Learning Algorithms to diagnose of liver failure and it is obtained the best performance from Neural Network for two-dataset 76% and 78%.respectively. In [12], SVM and Naïve Bayes Algorithm are used for predicting of liver diseases and test performance factors, which were execution time and classification accuracy of the results, are compared. SVM is given better classification for foreseeing the liver disease. In [13], SVM and Random forest algorithm is compared and random forest is given better accuracy with 71.8696 for prediction of liver disease. In [14], firstly, Neural Network is used for activation function and after Artificial Neural Network (ANN) and Artificial Immune Algorithm (AIA) is used to extract rules, which has been trained for classification. Thus, a set of rules is obtained for liver disorders. In [15], it is explored machine learning techniques in liver disorders by using C4.5, Decision Tree Algorithm and Random Tree Algorithm, which presents 100 percentages to classified two liver disorders datasets. In [16], Statistical Based, Rule Based, Tree Based, Neural Networks Based, and Lazy Learners are combined to select feature

selection technics and classification algorithm. The combination of these algorithms and feature selection technique are analysed with Modified Rotation Forest to obtain accurate liver data sets classification. In [17], Liver disease data sets are classified by using SVM and evaluated the accuracy, error rate, sensitivity, prevalence and specificity. In [18], FA is studied to understand its viability for clustering of artificial and benchmark datasets and the results of clustering has been compared with Differential Evolution (DE) and Particle Swarm Optimization (PSO) algorithms according to statistical criteria. It is obtained more successful in FA than others are. In [19], a computer- aided breast cancer diagnosis is studied using 675 real medical images are taken from Regional Hospital. FA is used for generating nuclei markers that is used for marker –controlled watershed segmentation and it is obtained highly satisfactory results. In [20], breast cancer tumour is classified by using FA to improve the parameters of local linear wavelet neural network. In [21], it is studied clustering that presents a new method to using FA that is swarm based algorithm and then Firefly and K-means Algorithm is used together. Thus, it is obtained a new hybrid algorithm called K-FA. In [22], Radial Basis Function Network for data classification and diagnosis of diseases is trained by using Firefly Meta-Heuristic Algorithm and is compared with Genetic Algorithm, Gradient Descent, PSO and Artificial Bee Colony algorithms on UCI repository. In [23], solving network and dependability constrained Unit Commitment problem the Binary Real Coded Firefly (BRCFF) algorithm is used. In [24], solving non-linear design problems is done by using FA and it is presented better solution then before algorithms. In [25], for image thresholding, Minimum Cross Entropy Thresholding (MCET) is used commonly. FA is applied to segmentation of image thresholding to evaluate its performance. FA is compared with the PSO, the Quantum Particle Swarm Optimization (QPSO) and Honey Bee Mating Optimization (HBMO) and multilevel minimum cross entropy threshold selection based on the FA is more efficient technic than others. In [26], it is proposed a new technic to make the codebook of vector quantization, which is an efficient technic to apply to digital image compression, by using FA. Vector quantization technic based on FA gets more quality images than based on Linde–Buzo–Gray (LBG) algorithm, PSO and the Quantum Particle Swarm optimization (QPSO). In [27], stock market price forecasting had three stage and in second stage, chaotic FA is used to optimize support vector regression hyper parameters. In [28], it is presented Discrete Firefly Algorithm (DFA) for solving of discrete optimization problem. The performance

evaluations are showed effective results for DFA. In [29], Economic Dispatch (ED) problems are tried to solve with FA and evaluation f result compared with some solving methods, which are used to solve ED problems and suggested solving based on FA is more economical solving than the others are. In [30], solving mixed continuous/discrete structural optimization problems are obtained by using FA, analysed and discussed features implementations for future studies. In [31], Clustering of Benchmark Problems is solved by using FA and evaluated performance of FA. After, it is compared with Artificial Bee Colony (ABC), PSO, and other nine methods that are used in the literature. Efficient result for clustering is obtained with FA. In [32], expert system technics is applied to loss reduction and restoration of distribution systems. In [33], it is reported a new solution for segmentation problems of images based on a designing of rule based expert system. In [34], it is designed an expert system based Fuzzy Logic and Neural Network for motion control and power electronics. In [35], it is reported evaluation of expert systems features of Iranian Digital Library Software. In [36], it is developed an expert system based neural network mechanism for predicting the diagnosis of object state. In [37], it is presented a build of an expert system for teaching materials quality evaluation. In [38], it is presented an original method of evaluating of material choice that could be applied as a possible part of an implication engine for an expert system in selection of material. In [39], it is studied an expert system for diagnosis of Epistaxis Diagnosis by using fuzzy system. In [40], it is presented an expert system to diagnose Fetal Alcohol Syndrome using Close Range Photogrammetry. In [41], it is designed and implemented an expert system for detection of body size. In [42], it is studied a new solution to obtain reliable heartbeat recognition and used SVM in classification model for recognition. In [43], it is evaluated smoking cessation by using an expert system intervention, which is stage based, and the system produces high participation and abstinence rates. In [44], a based Bayesian algorithm expert system for protein identification is studied by using mass spectrometric peptide mapping information and enlightening of protein examples are supplied. In [45], it is aimed that an expert system for foresee daily trading decrees in typical environment of financial market. In [46], it is studied an expert system based a new approach to rule base grounded in actual facts for Forex trading to make new technical analysis indicators. In [47], it is generated an expert system based GIS fuzzy system for evaluation of ecosystem susceptible to fire in administrating Mediterranean naturel protected areas. In [48],

Hybrid Genetic Algorithm and Artificial Neural Network are used for data classification to design an expert system for valuation viability of regent of two stages to orbit vehicle. In [49], it is developed a computer-based expert system to make ergonomic risk evaluation musculo-skeletal disorders depending on working.

1.2 Some Definitions and Knowledge

1.2.1 Algorithm

Algorithm is well-defined numerical method that tackles some values or an alliance of values qua input and generates some values or an alliance of values qua output. Thus, algorithm can be defined sequences of numerical steps that convert the input into the output. It can be also viewed an algorithm as a tool to solve a well-defined numerical problem. The algorithm identified a specific numerical procedure for obtaining relationship between input and output [50].

Algorithms are generally used computer programming and basis of all programming languages based on algorithm. There are two approaches as algorithmic and heuristic in solving of a problem [51].

In algorithmic approach, the most appropriate solution from among possible methods is selected and put forward step by step what to do [51].

Heuristic approach is problem learning and solving or discovery that uses practical technic not warranted to be perfect or the most appropriate, but adequate for the immediate targets. Heuristic algorithm can find satisfactory solution speedily and it can reduce process of finding point of optimal solution with impractical and impossible way. Heuristic method finds optimal solution by using experience that obtains from similar problems [52].

Algorithms can be operated by means of a computer programming language. First Algorithm was presented by El-Harezmi in the"Hisab el-cebir ve el-mukabala" book and algorithm words were originated from European pronunciation of El-Harezmi [53].

1.2.2 Intelligent systems

Intelligent can be defines as a group of the properties of mind which includes the ability of making plan, solving problems in general reason and making right decision according to conditions and given inputs [54].

For being intelligent computer systems, they must present modelling capabilities of specific human-related tasks as a sub model of human intelligence. Furthermore, intelligent systems do not have to behave like independent agents to replace human experts in a defined situation [55].

Rather, their function is being intelligent assistants that support or augment the degree of human expertise while increasing productivity [55].

Some intelligent system' characteristics are:

- Behaving logically,
- Solving complex problems,
- Being responsive and adaptive,
- Providing non-linear program navigation,
- Making effective use of existing knowledge,
- Being user-friendly and immensely interactive [55].

1.2.3 Artificial intelligence (AI)

Homo sapiens are the general name of humankind because their rational capacities and intellect are very important for social life and self-ego sense. The area of AI tries to find out intelligent beings and at the same time, AI attempts to build intelligent being. Namely, building intelligent being is the result of desire of understanding humankind. Work on AI and intelligent entities are both useful and interesting for humanity.

Although its development is at the early stage, AI has produced many significant and effectual products. In the future, it is show that the computers, which have human intelligence standards (or better), would have major roles and profound impacts in humans daily life. [56]

AI mentions about an ultimate puzzle and searches for answers of complex and hard questions as following:

1. How can it be possible to comprehend, predict, understand and have manipulation ability for slow and teeny-weeny brain in terms of biological and electronically?
2. How can humankind approach and decide making something with those properties?

To find an answer for these hard and complex questions humankind has to look in the mirror. There are some definition of AI in Table1.1 and they are organized into four categories:

Table 1.1: Some AI definitions [56].

Thinking like humans:	• "The exciting new effort to make computers think . . . *machines with minds,* in the full and literal sense" (Haugeland, 1985) • "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving,learning . . ." (Bellman, 1978)
Acting Like Humans:	• "The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil,1990) • "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)
Thinking rationally:	• "The study of mental faculties through the use of computational models." (Chamiak and McDermott, 1985) • "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Rationaly	• "Computational Intelligence is the study of the design of intelligent agents." (Poole et al., 1998) • "A1 . . .is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

AI has focused on games and solving of general problems in earliest applications. At this time, people believed that machines could do things, which people can do and perhaps do difficulty [54].

“The Logic Theorist” program is the first AI program to find proofs for equations and Allen Newell, Herbert Simon and J.C. Shaw have developed it in 1956. After in 1957, this program built on it to develop the General Problem Solver (GPS) by Simon and

Newell. GPS was used for solving of means-end analysis and limited to toy problems in general [54].

In the earlier 1950s, for two complex games, Checkers and Chess, game-playing programs were developed at Oxford University in UK. After these studies and applications, researches on the AI focused on mimicking the mind and sapient entity with intelligence of human, consciousness and self-awareness [54]. Figure 1.1 shows a protection based on artificial intelligence.

Figure 1.1 : A protection based on artificial intelligence. [68]

The Researchers were supported financially in U.S. by the Department of Defence by the middle of the 1960s [57] and the laboratories and research interest had been instituted across the globe for researches [58]. The founders of AI were substantially optimistic about futurity of the new area, AI. Herbert Simon estimated that "machine will be capable of doing any work a man can do within 20 years," and Marvin Minsky agreed the idea that AI creating problem would be solved in future generation too. [59]. However, these researchers did not predict some troubles which they could encounter [60]. In 1974, U.S. and British Governments cut down their financial support because of giving a support for more effective and productive project. Thus, "AI winter" started in the next few years [61, 62]. In the early 1980s, Expert Systems, which are model of AI, have simulated cognitions and analytic skills of human experts [63]. The merchandise of AI had attained over a billion dollars. When U.S. and British governments gave importance to academic research of Japan's fifth generation computer project and the Lisp Machine market started to collapse in 1987, AI was exposed to disrepute and longer lasting second AI winter began [64,65]. In the 1990s, AI was on the rise and in the early 21st century, it gained greatest successes. Generally AI is used for data mining, logistic, medical diagnosis and other technology industry

areas.[66] The increasing computational developing of computers, collaboration and compatible studying between AI and the other areas working on like problems, putting emphasizing on finding specific sub problems and a new undertaking by research workers to solid mathematical techniques and meticulous academic standards [67]. Deep Blue was the first game playing chess and Garry Kasparov, who is regnant, masterful chess champion of the world, was beat by Deep Blue on 11 May 1997 [57]. In February 2011, in an exhibition match of "Jeopardy!", which is an American television quiz show presenting with general knowledge, "IBM(International Business Machines Corporation)'s question answering system" and "Watson", defeated the two greatest Jeopardy champions, Brad Rutter and Ken Jennings, by a significant margin [57].

AlphaGo is a computer program using a combination of neural networks, machine learning and Monte Carlo tree search techniques and In March 2016, it won 4 out of 5 games in a Go Match against professional Go player Lee Sedol and it became the first computer Go-playing system to defeat a professional human Go player lacking of handicaps [69].

Nowadays, AI is used in many fields like computer science, finance, hospitals and medicine, heavy industry, telecommunications, online and telephone customer service, transportation, toys and games, maintenance, music, aviation, news, publishing and writing.

1.2.4 Expert system (ES)

The studying area of AI interests regulation ways of programming a computer by acting intelligently. In another saying, when a computer carries out a task simulating behaviour of human, it exhibits AI. Game playing, robotics, speech recognition, computer vision and natural language processing are demonstrating of AI [55].

Another fundamental activity of intelligence is decision-making. The capability of analysing of a situation, determining possible responses and choosing the most effective action by using these responses are exactly work of intelligent. When people learn enough knowledge to make decision on a particular area, they called "expert" on it. So, the software of simulations expert knowledge and experiences by a computer is named as an "expert system" [55].

Knowledge base is a technic used for storage of complex structured and non-structural information by a computer system and inference engine is a tool of AI. Knowledge base and inference engine generate expert system namely they are two sub-system of it. In typical expert system, the knowledge base makes information storage about facts of the world and logical rules are applied to the knowledge base and are made deduction by inference engine. This process will repeat each new fact in the knowledge base can stimulate supplement rules in the inference engine [70].Figure 1.2 shows architecture of an expert system.

Expert systems were emphasized from the end of the 1960s. These systems had own inference systems based on rules about the area, which they tackled, and the systems are executing detective steps. The first expert systems were on medical diagnostic field. For instance, the MYCIN system had effectiveness of the human experts with its 450 rules and presented a more significantly success according to the beginner physicians. In 1970s, Prolog was developed for logical programming and Prolog is a significantly extensive tool in forming expert systems(on judiciary, medical and other scopes) but this language were formed too by using natural language parsers. R1 that is the first successful expert system helped to structure computer system and this system save 40 million dollar in a year for developer company, DEC by 1986.

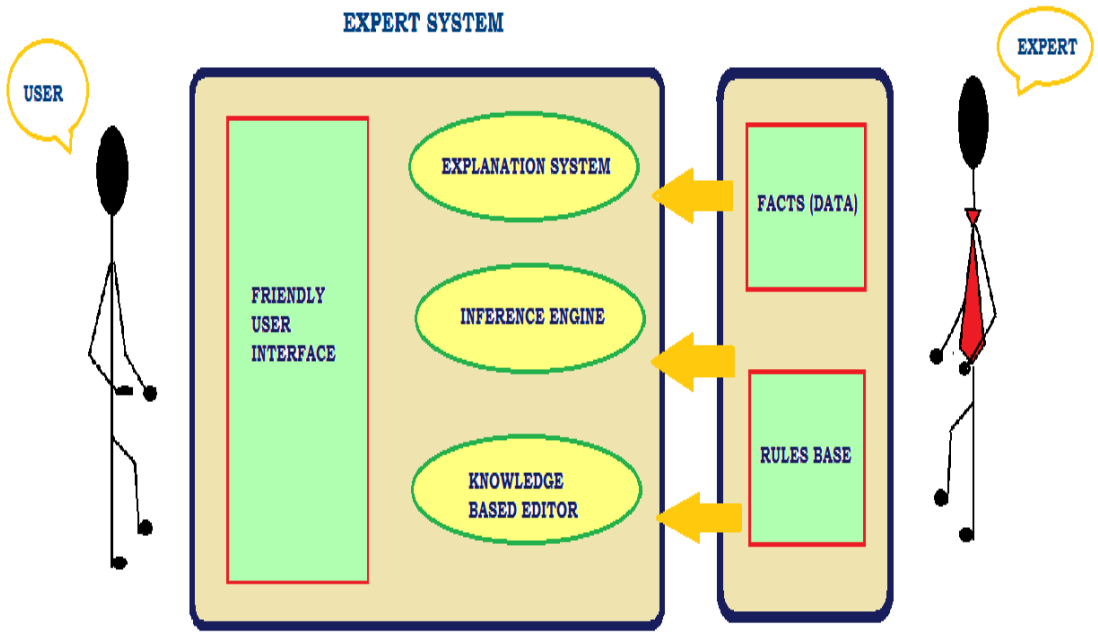


Figure 1.2 : The architecture of an expert system.

In 1988, “fifth generation computer” project was announced by Japanese and 10 years were planned to develop an intelligent computer system by using Prolog as a machine code. After Japanese announcing of the project, USA and the other leading countries of Europe began long-term projects for same goals. All in all the yearly revenue of AI industry went up to 2 billion dollars because of using expert system on many fields (medical diagnostics, chemistry, geology, industrial process control, robotics, etc.) by 1988. Together with expert systems, long-forgotten and new technologies have emanated. A huge class of these methods includes statistical AI-methods, whose research obtained a boost with the (re)discovery of neural networks in the early years of the1980’s [71].

There are many benefits of expert system and they have highly effectiveness in daily life. By using expert systems, following benefits can be obtained:

- saving time,
- increasing revenue and cutting cost,
- preserving of endangered and propagated knowledge,
- Improving consistency by training, integrating with other software and reducing development time [55].

2. LIVER

2.1 Liver and Liver Disorders and Liver Function Tests

Weight of the liver is approximately is 2% of adult body weight and it is 1400 gr in female and 1800 g in males [72]. Figure 2.1 shows a normal liver in a human and Figure 2.2 shows some damages of liver diseases on the liver.

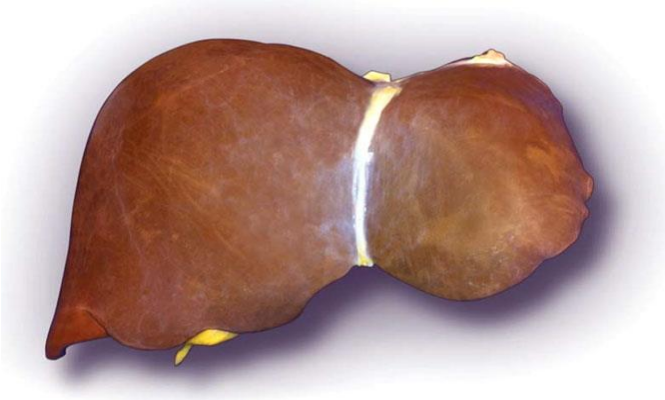


Figure 2.1 : A Normal Liver in a human [72].

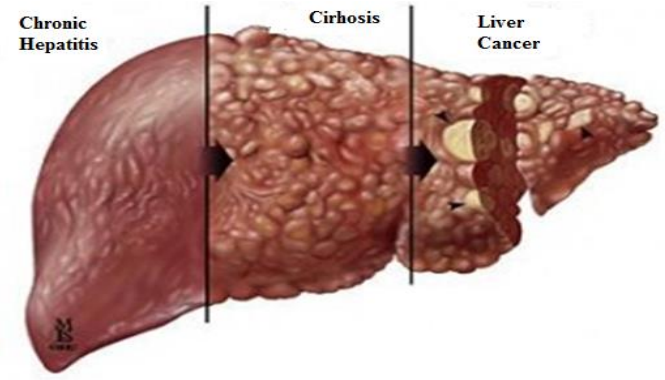


Figure 2.2 : Damages of Liver Disorders [73].

It is ensconced at the upper right quadrant of the abdomen against the inferior surface of the diaphragm. Two major lobes, left/right, and two minor lobes, caudate/ quadrate, constitute the liver [74].

The liver lobes are divided into hexagon-shaped lobules with a central vein in the centre of each lobule and a portal triad at each corner. The hepatic artery, the hepatic

portal vein, three vessels and hepatic duct are located in triads. Hepatic streaks formed with many layers of spread out through central vein of each lobule. The gaps among the hepatic cords are hepatic sinusoids and fenestrated liver capillaries, very thin sinusoidal endothelial cells, and hepatic phagocytic cells undercoat the sinusoids [74].

The liver lobes are divided into hexagon-shaped lobules with a central vein in the centre of each lobule and a portal triad at each corner. The hepatic artery, the hepatic portal vein, three vessels and hepatic duct are located in triads. Hepatic streaks formed with many layers of spread out through central vein of each lobule. The gaps among the hepatic cords are hepatic sinusoids and fenestrated liver capillaries, very thin sinusoidal endothelial cells, and hepatic phagocytic cells undercoat the sinusoids [74].

For proper liver function, the sinusoidal structure of liver is substantial and losing liver functions in the liver fibrosis and a trauma arise from hepatic architecture damage [74].

The liver is separated eight unconnected functional segments. Each segment possesses itself portal pedicle being composed of portal branch, hepatic arterial branch and the bile duct by dividing hepatic venous branch that supplies outflow. These segmentation numbers are given according to clockwise manner. The anterior and posterior segments for the left lobe are named Segment II and III and also they are mentioned completely as the liver's left lateral segment and topographic left lobe. The medial segment of the left lobe is mentioned Segment IV. These execute the functions of left lobe of the liver. Segment V and VIII, the anterior segments, and Segment VI and VII, the posterior segment executes the functions of right lobe of the liver. Segment I is placed posteriorly. Three hepatic veins provide the out low of the liver. The right lobe of the liver is divided into posterior and anterior segments by the right hepatic vein. Liver is divided into right and left lobes via the middle hepatic vein. The left liver is divided into medical and lateral segments by the left hepatic vein. The portal vein separates the liver as the upper and lower segments [72]. Figure 2.3 shows segmentation of the liver and in Table 2.1, it is given hepatic anatomy and resection nomenclature.

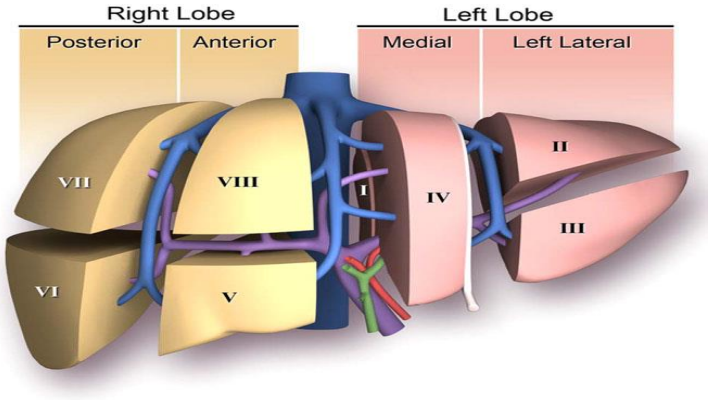


Figure 2.3 : Segmentation of Liver [72].

Table 2.1. Hepatic Anatomy and Resection Nomenclature [72].

Left Lateral	• II, III
Left Medial	• IV
Right Anterior	• V, VIII
Right Posterior	• VI, VII
Left Hepatectomy	• II,III,IV
Right Hepatectomy	• V, VI, VII, VIII
Extended Left Hepatectomy	• II,III,IV,V,VIII
Extended Right Hepatectomy	• IV, V, VI, VII, VIII

The segmental anatomy of liver is substantial for surgeons and radiologist, especially for needing of an exact preoperative localization of focal hepatic lesions. Liver resections base on knowledge of liver anatomy and accurate localization of the hepatic lesions and it is used widely with decrease mortality and morbidity [72].In figure 2.4 it is shown that liver anatomy.

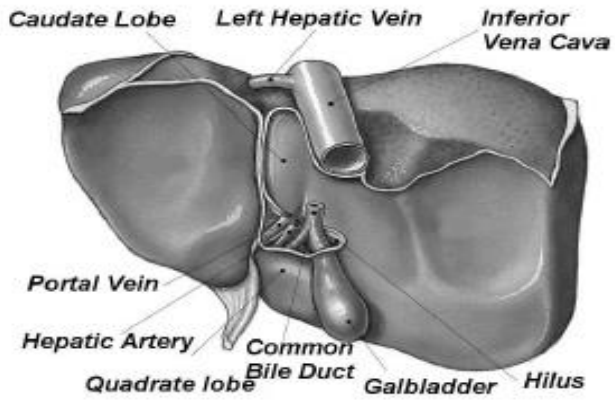


Figure 2.4 : Anatomy of Liver

2.2 Liver Functions and Diseases

Mainly Functions of liver are excretory, secretion, store and digest nutrients, detoxification. The liver; stores iron, glucose, vitamins, other essential nutrients, products certain proteins, cholesterol, bile, converses harmful ammonia to urea, regulates blood clotting, clearances of bilirubin [4]. Because the liver is exposed to many harmful substances, it protects itself against disease in two main ways. First, it repairs or replaces deformed and damaged tissue. Thus, it can regenerate itself. Second, there are many cell units responsible for the same duty in the liver.

Therefore, if one area is damaged, other cells will carry out the functions of the damaged part indefinitely or until the damage has been repaired. It is some specific types of liver disease

- **Alcohol-related liver disease:** abusing of alcohol during years damages the liver and it causes to cirrhosis (scarring of the liver) ,
- **Non-alcoholic fatty liver disease:** it is occurred fat within liver cells and it is usually seen in overweight people or these who have obesity,
- **Hepatitis:** viral infections cause swelling(inflammation) of the liver or detrimental substances like alcohol cause it ,
- **Hemochromatosis:** it is an inherited disorder where there is a gradual accumulation of iron around the liver.
- **Primary biliary cirrhosis**: it is seen rarely and it is long-term type of liver disease that harms the bile ducts liver [4].

There are many types of liver diseases which have unknown causes yet the following factors generally cause the liver diseases.

- **Viral Hepatitis**

  It is caused from viruses that assault to the liver and it has many forms. The most prevalent forms in the world are Hepatitis A, B and C. there is vaccine for hepatitis A and B for preventing them but hepatitis C cannot be prevent via vaccine [75].

- **Obesity**

  In latest research, it is determined that the obesity disease that causes to fatty liver disease [75].

- **Alcohol**

  A different factor such as nationally, weight, age, gender and health can change reaction of personal liver metabolizes alcohol. Excess alcohol consumption may cause interrupting of normal liver functions by leading to chemical imbalance. When the liver has to detoxify alcohol uninterruptedly, liver cells can be demolished and changed in fat deposits and more severely, it can be alcoholic hepatitis or cirrhosis. The worst result of this situation is liver cancer [75].

- **Genetics**

  Defective genes can cause several liver disease forms and these forms may be diagnosis in infancy of patients or may not appear until next in life, for instance, Wilson Disease, Hemochromatosis, alpha 1, Glycogen Storage disease, tyrosinemia and antitrypsin [75].

- **Autoimmune Disorders**

  The immune system might sometimes start attacking the liver or bile ducts and it causes inflammation and leads to acute form of liver disorders, which are autoimmune hepatitis, primary biliary cholangitis (PBC), and primary sclerosing cholangitis (PSC) [75].

- **Drugs and toxins**

  Responsibility of the chemical and medication processes in the body is carried out by the liver. Chemicals cause the chronic and acute liver diseases so the body is vulnerable of them without liver responsibility. In some instance, this is foreseeable consequence of over consumption or over exposure of some

chemicals such as industrial toxins or acetaminophen. In other instances, chemicals can give an unpredictable reaction [75].

- **Cancer**

  Even though primary liver cancer is relatively rare, the other forms of cancer frequently metastasize in the liver. A form of secondary cancer develops in liver due to duty of filtering most of the blood and the blood may can carry cancer cells. The cancer developing out of the liver is caused by hepatitis B and hepatitis C or if there is cirrhosis, advanced liver disease develops [75].

There are a number of liver function tests to test the genuine function of the liver. Therefore, enzymes in blood that are in the tissue or the products are determined. The tests: serum proteins, serum albumin, serum globulin, alanine transaminase, aspartate transaminase, prothrombin time, partial thromboplastin time [76]. A liver biopsy may also be performed to confirm the diagnosis [77]. However, problems of liver patients cannot be solved easily in the first phase because it continues normal functions as its partially damaged [50]. Even hepatitis C is called "the silent epidemic." People do not know they have it because of it does not show symptoms for years. Approximately 15.000 people in America die from chronic liver disease and liver cancer [78].

Poor appetite, jaundice, light coloured stool, dark urine, acedia, exhaustion, Abdominal pain or /and swelling, nauseating, throwing up and scratch oneself can be signs and symptoms of liver disorders.

2.3 Liver Disorders Laboratory Tests

2.3.1Alanine aminotransferase (ALT)

It is frequently used to confirm liver injury. Its normal level is low in the blood. Very high degrees of ALT (>10 times normal) are generally due to acute hepatitis or viral infection rarely. ALT is frequently evaluated with aspartate aminotransferase (AST) to screen for helping of diagnosis of liver disease.

AST and ALT are the most important two tests to determine liver injury though ALT is more special to the liver than is AST. As ALT is sometimes compared with AST, it can be made an assessment by calculating of AST/ALT ratio. ALT degrees are frequently compared with the other tests, for instance, alkaline phosphatase (ALP),

total protein, and bilirubin to help determine which form of liver disease is present [79].

The ALT degree is higher than AST in most types of liver disease and the AST/ALT ratio is less than 1 but in heart or muscle injury alcoholic hepatitis and cirrhosis this may be greater than 1 [79].

2.3.2 Aspartate aminotransferase (AST)

AST is an enzyme, which placed in cells, but largely it is in the heart and liver and less manner in the kidneys and muscles. Normally AST degree in the blood is low. When muscle and liver cells are injured, they let AST out the blood. In this respect, it makes AST helpful test to detect liver damage [79].

Very high values of AST, respectively higher 10 times of its normal value, are generally in so far as a viral infection. In acute hepatitis, generally AST degrees continue high level for about 1-2 months but returning to normal value of it can take so long as 3-6 months. Sometimes to use excess drugs or other substances, which has toxic effects, makes higher levels of AST, more than 100 times normal degree, in blood [79].

In chronic hepatitis, AST degrees are not high generally, less than 4 times normal degree, and are more normal than ALT degrees. AST frequently changes between slightly and normal increased according to chronic hepatitis, so this test can help to determine the liver disorders pattern. Such increases can be seen in other liver diseases, especially with cirrhosis or certain cancers or when the bile duct is inhibited. Hearth attacks and muscle injury might be increased the AST degrees [79].

2.3.3 Alkaline phosphatase (ALP)

Alkaline Phosphatase (ALP) is an enzyme, which there is in several tissues as liver, kidney, bone, bowel and the placenta in a pregnant woman. Maximum concentrations of ALP are in existence within the liver and bone cells. ALP is found on the edges of cells in liver and in the bone, it is produced by special cells named osteoblasts. Different tissue types produce distinct forms of isoenzymes ALP [79].

Liver cancer and bone disease are most commonly given rise to high degrees of ALP. ALP degree is higher in adolescent and children because of growing their bones still. For this reason, ALP degree is evaluated differently according to age [79].

2.3.4 Total protein and A/G ratio

Protein is significant for building of all cells and tissues and for body development growth and health. They are in most of the organs structures and make hormones and enzymes regulating functions of body. This test evaluates the total proteins that are various types in blood [79].

There are two classes of protein in blood: albumin and globulin. Albumin makes 60% of the total protein and 40% of total protein is made up by globulin, which are heterogeneous group includes enzymes, hormones, antibodies carrier proteins and other types of proteins. A/G ratio is calculated by using evaluation of albumin and globulin [79].

The degree of Total Bilirubin (TB) in the blood is generally a stable value [79].

Results of Total Protein (TP) tests give the medical experts information of general health of patients related with conditions or/and nutrition of major organs, for instance, liver and kidney [79].

If there is a problem in results, next tests is applied to understand of disease changing protein levels in the blood:

- A low total protein degree shows that there is liver disease, kidney disease or a disorder about digesting or absorbing of protein properly [79].
- A high total protein degree might be seen with infections or chronic inflammation such as HIV or viral hepatitis. Sometimes it is also related with bone marrow diseases like multiple myeloma [79].

Albumin and globulin ratio A/G gives a clue about changing about proteins degree in the blood:

- A low A/ G ratio refers to over- production of globulins as in autoimmune diseases or under-production of albumin as in cirrhosis or selecting loss of albumin during the circulation as in kidney disease [79].

- A high A/ G ratio refers to under-production of immunoglobulin as in some leukaemia and a in some genetic deficiencies. In this situation, more tests are needed for accurate diagnosis, for instance, liver enzymes tests and serum protein electrophoresis [79].

2.3.5 Albumin (ALB)

Albumin is a protein being produced by the liver and it is constituted 60% of total protein in the blood. Keeping liquid from leaking out of blood vessels, transporting of hormones, ions vitamins, and drugs throughout the body is realised by ALB. Status of nutrition reflection and liver function reflection result of concentration of albumin [79].

A low albumin can foreshadow of liver disorders when the other tests can give information which type of liver disorders. A liver disease patient has a normal and near-normal albumin degree till the situation has gotten a high level. For instance, in a cirrhosis patient, albumin degree generally low but in many of chronic liver diseases albumin degree is normal [79].

2.3.6 Bilirubin

Bilirubin test is used to detect bilirubin degree in blood. It helps to determine the jaundice and diagnose states like liver disease, congestion of the bile ducts and haemolytic anaemia. Bilirubin is a pigment, which is yellow-orange colours and waste product procured by the normal dissection of heme being a component of haemoglobin in red blood cells. There a two forms of bilirubin:

- **Unconjugated Bilirubin (Indirect Bilirubin):**
  It exists in blood small amount and is moved by proteins into the liver.
- **Conjugated Bilirubin (Direct Bilirubin):**

  It is constituted in the liver when the sugar is fastened to bilirubin. It goes in the bile that transfers from the liver to the intestines, and is finally defecated. Generally, no conjugated bilirubin is in existence in the blood.

  Total bilirubin = Unconjugated Bilirubin + Conjugated Bilirubin

In older children and adults, bilirubin help to detect and evaluate liver and bile duct, sickle cell and anaemia diseases and detect of causes of jaundiced in new-borns [79].

2.3.7 Gamma-glutamyl transpeptidase (GGT/ GAMMAGT)

When a patient has a high ALP degree, GGT test is used and GGT test show the source of high ALP degree resulting from bone, not liver disorder. A raised GGT degree suggests that liver is damaged by something, which does not specified particularly what. Generally the higher degree of it may be seen in greater damage or insult in the liver. A raised degree may be due to liver disorders like cirrhosis or hepatitis or the other conditions such as diabetes, pancreatitis or congestive heart failure. Also abusing of alcohol or using drugs has toxics for liver may cause those [79].

2.3.8 Mean corpuscular volume (MCV)

The MCV is a size of average volume of a red blood cell. The size is gotten by multiplying the proportion of blood by a volume of blood. In anaemia patients, the MCV size that permits classification as a normocytic anaemia (in normal range of MCV), macrocytic anaemia (in above normal range of MCV) or microcytic anaemia (below normal range of MCV) [80].

3. FIREFLY ALGORITHM (FA)

3.1 Behaviour of Fireflies

Among all insects, fireflies are the most impressive and charismatic insects. Their magnificent courtships like a dance dark are an inspiration to poets and scientists. Usually they live in tropical and various warm places. Generally, they fly in warm summer nights by shining. [81]

In nature, 2000 species of fireflies are in existence and majority of them generate rhythmic and short flashes. These flashes are indigenous for a special species and they are generated with bioluminescence process. Aim of this flashing system is still debating. In addition to this, there two basic functions of it:

- To establish communication to lure mating wives
- To attract potential hunt.

In addition to these, flashing performs a duty as a protective warning system [82].

In fireflies, bioluminescent reactions take place from light-producing organs called lanterns. All of the bioluminescent organisms generate just slowly modulated flashes and they also glow. Conversely, adults of many firefly species can provide the control of their bioluminescence because of emitting discrete and high flashes. The production of lanterns light is commenced by signal originating in the central nervous system of them. Most fireflies count upon bioluminescent signals. The male fireflies can fly and female fireflies live on the ground but some of female fireflies can fly too. First signals are sent by male fireflies to the female fireflies to attract them. In return for these signals, the females cast flashing or continuous lights. Both of their flashlights are encoded consisting of species sex and identity and these signals are distinct flash patterns. The females generally attract from brighter male flashes and the intensity of flash changes with the distance from the source. Luckily, the females do not show favouritism between closer flashes generated by weaker light sources and flashes that are more distant are generated by stronger light sources [83].

Signal of firefly flashes are immensely attention-grabbing and may therefore obstacle for potential predaceous animals [83]. Fireflies in nature are showed in Figure 3.1.

Figure 3.1 : Fireflies in nature [84].

3.2 Firefly Algorithm (FA)

In 2008, Firefly Algorithm is developed by Xin-She Yang at Cambridge University. Firefly Algorithm is nature-inspired, metaheuristic, optimization algorithm is predicated behaviours of social flashing and swarm of fireflies in the summer and spring night sky in the tropical places. Special, the Firefly Algorithm has some similarities with other swarm intelligence algorithm such as Artificial Bee Colony optimization _ABC_, Particle Swarm Optimization _PSO_, and Bacterial Foraging _BFA_ algorithms etc. and however it is easier both as concept and as implementation. Additionally recent bibliographies show that it is give better results from other conventional algorithms in solving of many optimization problems. The principle advantage of FA is the fact that it operates major real random numbers, and it is predicated on the global communication among the swarm. [82].

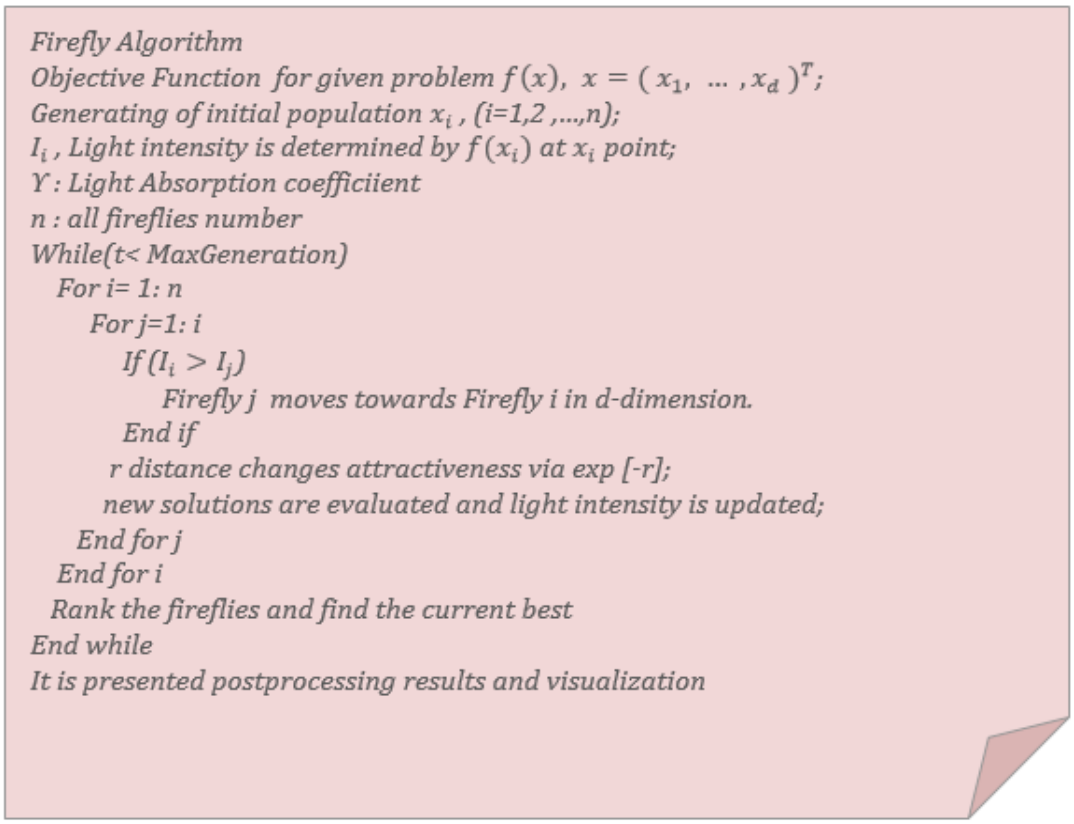
The Firefly Algorithm uses three main rules, which are based on flashing of real fireflies in nature. These are the following:

1. All fireflies are unisex. The case of a firefly is affected the other fireflies regardless of its gender.

2. Attractiveness of a firefly proportionally depends on its brightness. While their distance increases, attractiveness and brightness is decrease. Namely, the less bright firefly heads for the brighter firefly.
3. The brightness (light intensity) is identified by objective function of a problem.

The basic steps of the firefly algorithm (FA) which based on these rules can be summed up as the pseudo code shown in Figure 3.2 [82].

Figure 3.2 : Pseudo code of the Firefly Algorithm (FA) [85].



3.2.1 Attractiveness

Two important matters in FA are variation of light intensity and formulation of the attractiveness. While the brightness is connected with objective function of the problem, attractiveness depends on brightness. Namely, brightness I of a firefly at a certain position x can be defined as I(x) α f(x). The attractiveness shows variety according to view in the eyes of the other fireflies and namely changes depending on distance r_{ij} between firefly i and firefly$j$. Additionally, when the distance between the light source increases, light intensity is lowered and it is regarded that whether

absorbs light. Therefore, degree of absorption varies the attractiveness. Briefly light intensity I(r), changes depending on the inverse square law $I(r) = I_s/r^2$. I_s is intensity of the light at the source. The light intensity I changes depending on distance r for a given media with a constant coefficient of the light absorption γ [82].

Light absorption coefficient ϒ, Light intensity I that varies r (distance)

$$\text{I(r)} = I_0 e^{-cr2} \qquad (3.1)$$

I_0 is the initial light intensity and sometimes it is needed a function decreasing monotonically by slower rate. In this situation, following approximation is used:

$$I(r) = \frac{I_0}{1+\gamma r^2} \qquad (3.2)$$

Equations (1) and (2) are the same at a shorter distance and the series expansions are

$$e^{-\gamma r2} \approx 1 - \gamma r^2 + \frac{1}{2}\gamma^2 r^4 + \cdots, \qquad \frac{I_0}{1+\gamma r^2} \approx 1 - \gamma r^2 + \frac{1}{2}\gamma^2 r^4 + \cdots, \qquad (3.3)$$

at about r =0.

Attractiveness β is defined by

$$\beta(\text{r}) = \beta_0 e^{-\gamma r^2} \qquad (3.4)$$

β_0 is the attractiveness at r = 0 [6]. Because of calculating of exponential function, $\frac{1}{1+r^2}$ can be used and then $\beta(r) = \frac{I_0}{1+\gamma r^2}$ is defined.

In equation (4), a characteristic distance $\Gamma = 1/\sqrt{\gamma}$ is defined and Γ is over which the attractiveness varies in a considerable extent from β_0 to $\beta_0 e^{-1}$. For implementation, $\beta(r)$ can be any monotonically decreasing functions like following generalized form

$$\beta(\text{r}) = \beta_0 e^{-\gamma r^m}, \qquad (m \geq 1) \qquad (3.5)$$

For a constant ϒ, the characteristic lengthiness makes $\gamma^{-1/m} \to 1$ whilst $m \to \infty$ [82].

3.2.2 Distance and Movement

It can be used Cartesian distance formula for the distance between any two fireflies i and j at x_i and x_j distance

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \qquad (3.6)$$

$x_{i,k}$ is the kth component of the spacial coordinate xi of ith firefly. Here, d is dimension of problem.

The movement of firefly i to firefly j, which is more attractive than firefly i, is defined as the following

$$x_i = x_i + \beta_0 e^{-\Upsilon r_{ij}^2}\left(x_j - x_i\right) + \varepsilon(rand - 1/2) \qquad (3.7)$$

$\beta_0 = 1$, $rand$ is a random number and $rand \in [0,1]$, $\varepsilon \in (0,1)$.

The parameter Υ qualifies the variety of the attractiveness, and its value is vitally important in detection the speed of the convergence and FA algorithm behaviours. In theory, $\Upsilon \in [0, \infty)$, but in practice, it typically varies from 0.01 to 100 [82].

3.3 Classification of Firefly Algorithm

Recent studies have demonstrated that Firefly Algorithm is a very effectual algorithm. In fact, a quick search in Google Scholar by using" Firefly Algorithm" as the keyword gave 5.170 hits at the time of writing this chapter in April 2016. It is show that FA is used variety studies for different purposes. Figure3.3 shows that variants of FA in literature [85].

The standard Firefly Algorithm has three basis advantages

1. Firefly Algorithm can solve multi model optimization problems easily
2. Firefly algorithm has distinctive attractiveness mechanism among its multi agents and this attractiveness can expedite the convergence. The attractiveness is non-linear and it may have rich dynamic properties.
3. Firefly Algorithm can cope with optimization problems has various ranges.

Firefly Algorithm is used by many researchers to solve various range of problems and they tried to improved several variants to be in accordance with especial types of applications with developed efficiency. Firefly Algorithm can be separated into hybridized and modified algorithms as in Figure 3.3 shows about 20 diversified Firefly Algorithm variants [85].

3.3.1 Modified firefly algorithm

While modified firefly algorithms are analysed, it is based on the setting of their algorithms-bound variables. In the direction of this, they are categorised by the following properties:

- Consideration of objective functions;
- Scheme of the population (Multi swarm, swarm);
- Fireflies' random movement (Levy flights, Gaussian, Chaos quantile, uniform);
- Fireflies representation (real value, binary);
- Identification of the best solution(elitism, non-elitism);

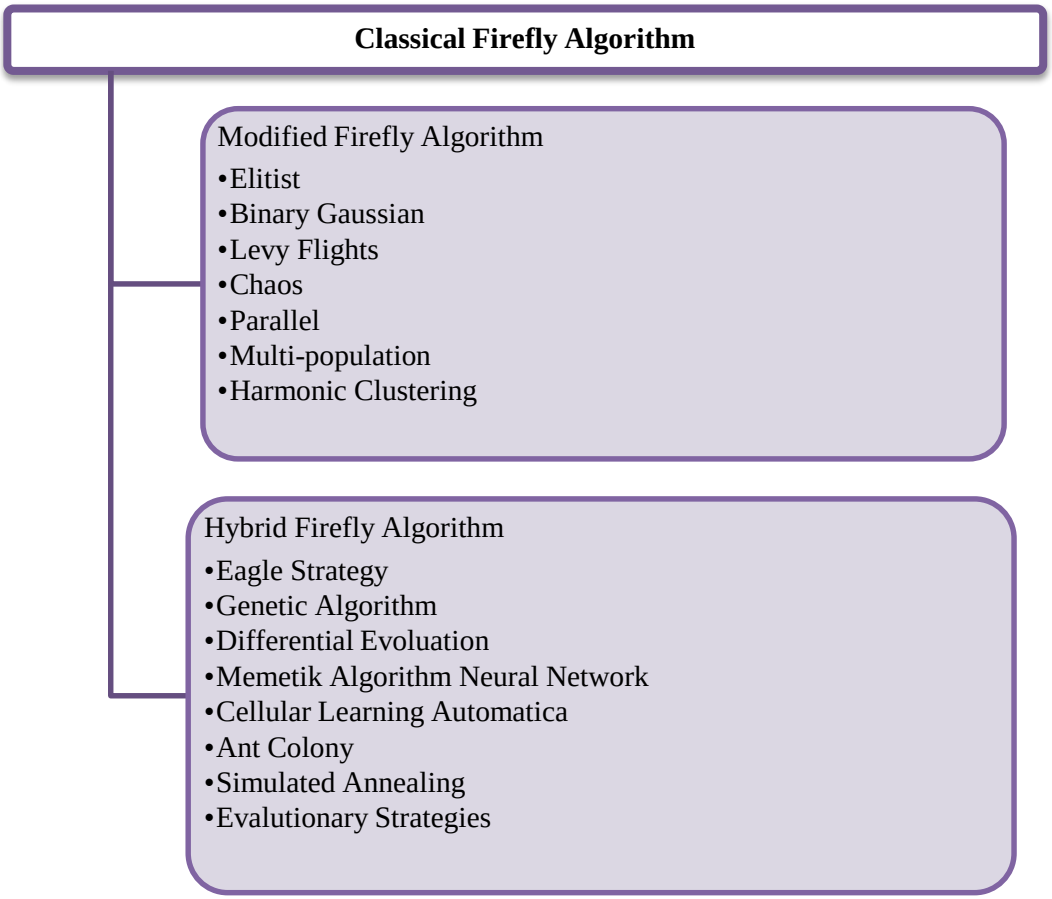


Figure 3.3 : Variants of Firefly Algorithms [86].

3.3.2 Hybrid firefly algorithms

The Firefly Algorithm has been purposed as a solver for global problems that should attain the optimal result on optimization problems the all classes. However, the No-Free-Launch theorem generally brings some restrictions. Hybrid methods are disposed to be used to improve new different of nature-inspired algorithms encapsulating the alternatives of firefly algorithms. Several hybridizations have been implemented to Firefly Algorithm to search developments. Hybridization contains certain problem-especial knowledge to Firefly Algorithm [86].

In recent years, since 2008, Firefly Algorithm has been applied to several areas such as classifications, optimizations, scheduling, engineering design travelling salesman problems and image processes. Some applications areas of influence become more theoretical while the other applications have stayed focused on the real problems in the world. Figure3.4 shows taxonomy of firefly algorithms [86].

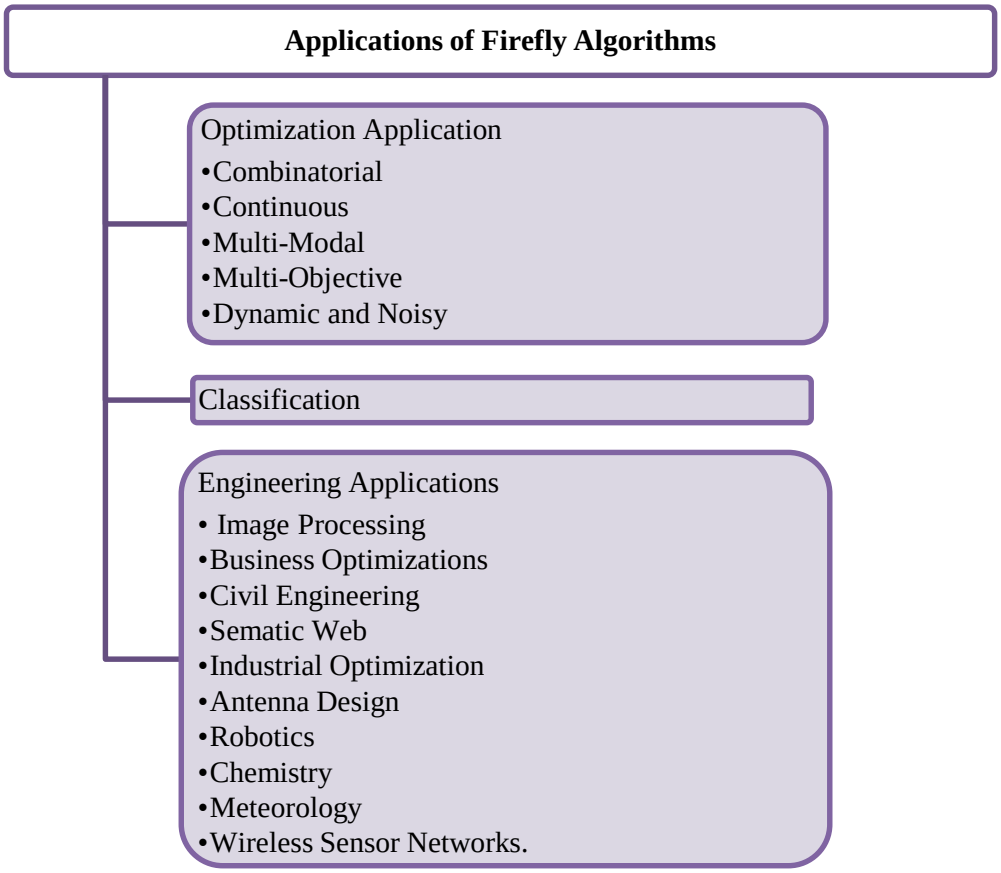


Figure 3.4 : Firefly Algorithm Applications' taxonomy [86]

4. SUPPORT VECTOR MACHINE (SVM)

SVM is a machine learning method developed by Vlademir Vapnik, Boser and Guyan in1992. Recently SVM method is especially has been used for classification problems in which unknown association of between patterns of the dataset.

Firstly, this method had been basically considered to use for solution of two-class problems as linear classifier. After, SVM has been used for solution of non-linear problems and multi-class classification problems by using generalizing method.

SVM algorithm is an application, which is intersection of learning theory and practice. Real world applications are complex and difficult applications to solve theoretical. SVM algorithm can also simply remove these two challenges and bring solutions to complex models [87-90].

SVM has a well-established theory as statistical learning and is suitable for the solution of the classification and regression problems [87-90].

SVM can smoothly classify unobserved new data during training and this case shows the ability of SVM for generalizing. SVM is a good alternative due to generalizing ability when it is compared with the other techniques (Artificial Neural Network, Decision trees, etc.) [87-90].

The basis of the SVM is classification process by separating of data with a plane or hyperplane. Therefore, it determines the most appropriate plane or hyperplane that can separate the data into two classes [87-90].

While linearly separable data can be distinguished with a plane in the dimension they belong, linearly inseparable data can be possible to distinguish by carrying to a higher dimensional space than they are in or belong by using hyperplane [87-90].

When linearly separable data come into question, SVM aims to choose a line, which can distinguish data from between number of infinitive line. However, in linearly inseparable data, SVM carries original data to a higher dimensional space by using mapping technique and here it tries to find linear discriminant hyperplane, which have optimum solution for classification of data [87-90].

4.1 Linearly Separable Data:

This form of SVM is valid only for linearly separable feature space but it is rarely encountered with these situations in real life problems. Linearly separable classification problems constitute basis of SVM and they are important to understand more advance systems [88].

Two-class data, which is in Figure 4.1, are linear and they can be distinguished by using a lot of straight line [90]. Nevertheless, when an unknown dataset is encountered, SVM aims to find a hyperplane, which makes minimum classification error. This hyperplane must be equidistant from two class groups and it is offered that maximum margin hyperplane technique [89]. The hyperplane in Figure 4.2 is defined below:

$$< \mathrm{w}, \mathrm{x} > + \mathrm{b} = 0 \qquad (4.1)$$

w in equation (4.1) is a normal of hyperplane (or weight vector) and b is a value which shows bias, x is any point on $< w, x > + b = 0$ hyperplane. In here <w, x > is an inner product and it define as

$$< w, x > = w^t x \qquad (4.2)$$

It is considered a dataset, which has two-class for training of SVM, in linearly separable classification problem, a training set which has number of k component, {xi,yi}, i= 1,2, … ,k , classes i yi∈{-1, +1} and an input values xi $\in R^d$. It is assumed that the feature vectors are separable and can be separated by linear decision boundaries [95].There is a hyperplanes cluster all data points belong to the same class

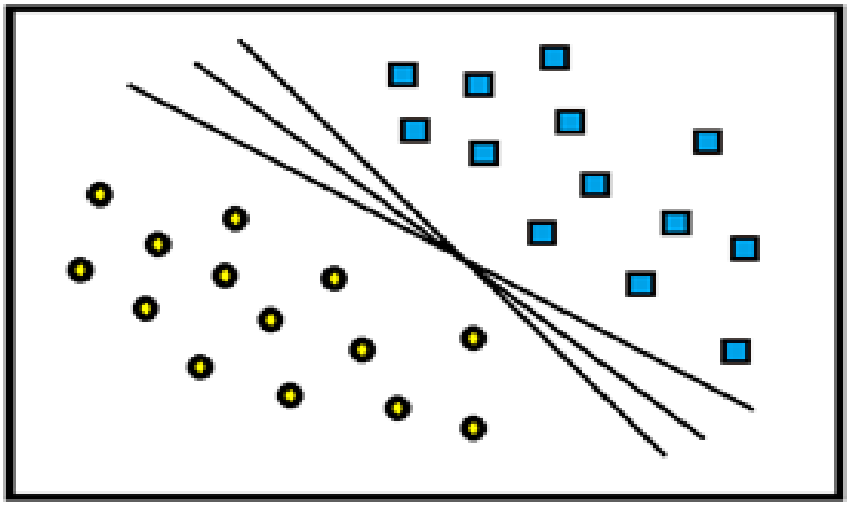


Figure 4.1 : Linearly separable two-class classification problems [87,90].

can be possible to leave on the same side of hyperplane for linear separable data according to label given set of data.

$$\frac{|b|}{||w||} = perpendicular\ distance\ from\ hyperplane\ to\ origin$$

$$||w|| = Euclidian\ norm\ of\ w.$$

The hyperplane, which is seen in Figure 4.2, makes maximum border for optimal separation and it is defined "optimal separating hyperplane". The points determined widths of the border are named "Support Vectors" (SV). To determined optimum hyperplane firstly two hyperplanes which are parallel to optimum hyperplane and constitute the borers must be determined [91]. The distance between these two hyperplane is name "Margin" and these two hyperplane are formulated as below:

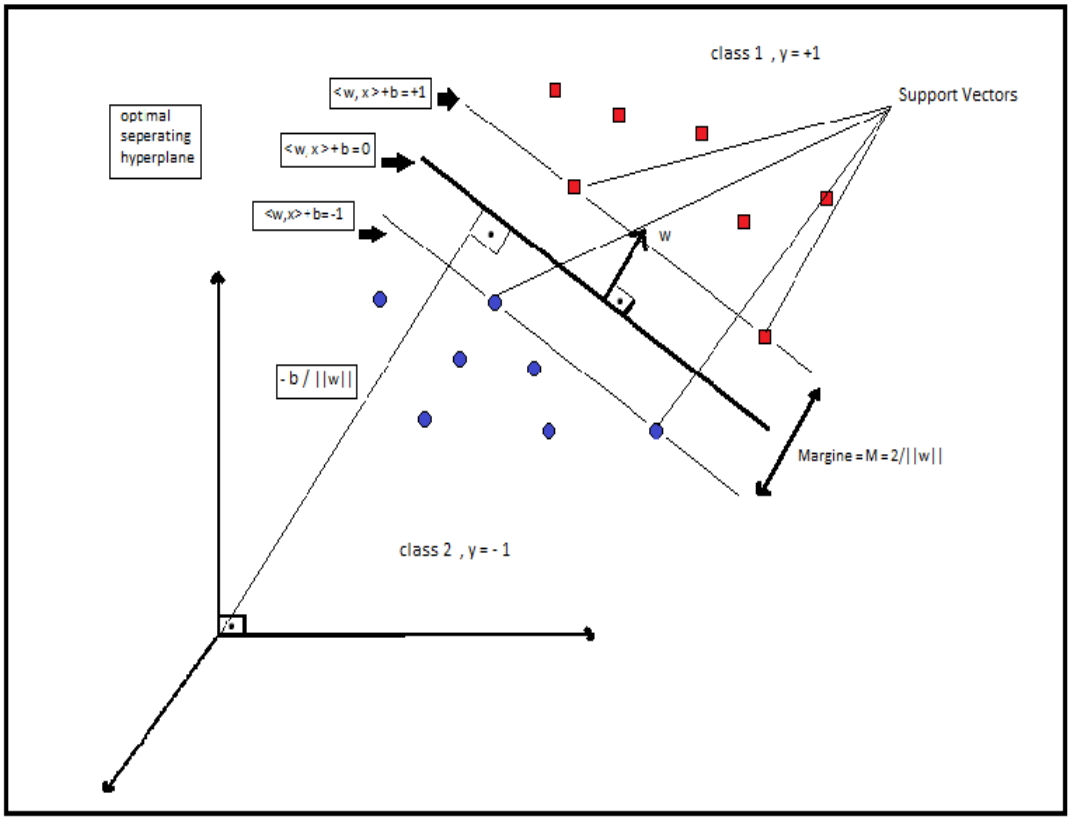


Figure 4.2 : Linear discriminant hyperplane for situations where all of the data separated [87].

$$w^t x^+ + b = +1,\ \ yi = +1, \qquad (4.3)$$

$$w^t x^- + b = -1,\ \ yi = +1, \qquad (4.4)$$

These two equation are subtracted from each other

$$w^t(x^+ - x^-) = 2 \qquad (4.5)$$

$$\rightarrow \frac{w^t(x^+ - x^-)}{||w||} = \frac{2}{||w||} \qquad (4.6)$$

is obtained.

$||w|| = \sqrt{\sum w_i{}^2}$ Euclidian norm and $\frac{w^t}{||w||} = 1$. Therefore, margin is defined as

$$M = (x^+ - x^-) = \frac{2}{||w||} \qquad (4.7)$$

Besides hyperplane has to provide following conditions

$$w^t xi + b \geq +1, \quad yi=+1, \qquad (4.8)$$

$$w^t xi + b \leq -1, \quad yi=+1, \qquad (4.9)$$

If formula (4.8) and (4.9) are expressed as a single formula

$$yi\ (w^t xi + b) \geq 1 \quad i= 1,2,\ldots, n \qquad (4.10)$$

is obtained.

For the given training data, all separation hyperplane can be shown in this form. Optimum separation hyperplane is a hyperplane, which makes maximum margin value. Thus, to find optimum separation hyperplane problem converts to finding w value which makes maximum margin.

If it is minimized $||w||$ value, namely $||w||^2$ value, then it can be find maximum value of $\frac{2}{||w||}$. $||w||^2$ is equal to $w^t w$. $||w||^2 = w^t w$

The solution of following equations must be solved to find the most separating plane:

$$min_{wb} \frac{1}{2} ||w||^2 \qquad (4.11)$$

$$y_i (w^t x_i + b) \geq 1 \ , \quad \forall i, \qquad (4.12)$$

Formula (4.11) is the problem that will solve and Formula (4.12) is constraint function during solution of problem. Formula (4.11) is a second-order in equation that is constricted non-linear optimization problem and when this optimization problem is solved by using Lagrange Multipliers Method and it is converted to a new optimization problem by using positive Lagrange Multipliers as following:

$$L_p = \frac{1}{2} w^t w - \sum_{i=1}^{n} \alpha_i y_i (w^t x_i + b) + \sum_{i=1}^{n} \alpha_i \qquad (4.13)$$

To solve this complex formula w and b parameters are have to define with α_i parameters. For this Karush-Kuhn Tucker (KKT) method is used and Formula (4.13) converted to a dual problem, which must be maximized according to α_i Lagrange multipliers. To solve Formula (4.13) by using KKT condition, Formula (4.13) is differentiated according to w and b,

$$\frac{\partial}{\partial b} L_p = 0 \rightarrow \sum \alpha_i y_i = 0 , \quad \alpha_i \geq 0 \qquad (4.14)$$

$$\frac{\partial}{\partial w} L_p = 0 \rightarrow \sum \alpha_i y_i \, x_i = 0 , \quad \alpha_i \geq 0 \qquad (4.15)$$

Because contains unknown α_i Lagrange multipliers, these formulas do not generate (produce) a solution. For this, at (x_i, y_i) points Formula (4.12) is converted to an equality by using $\alpha_i \neq 0$.

$$\alpha_i[y_i < x_i, w > +b) - 1]=0, \quad \text{i} = 1, 2, \ldots, \text{m} \qquad (4.16)$$

In this equation (x_i, y_i) vectors are support vectors and they placed on margin which are parallel to separator vector. If Formula (4.14) and (4.15) are written in Formula (4.13), the dual problem is obtained following.

$$L_D = \sum_{i=1}^{n} \alpha_i - \frac{1}{2} \sum \alpha_i \alpha_j y_i y_j x_i^T x_i \quad , \alpha_i \geq 0 , \ \forall i, \qquad (4.17)$$

By using formula (4.15) and (4.16)

$$f(x) = (\sum \alpha_i y_i \, x_i . x) + b \qquad (4.18)$$

decision function is obtained. After decision function is found a class which the new example belongs to, is defined following:

$$f(x) > 0 \rightarrow class\ 1 \qquad (4.19)$$

$$f(x) < 0 \rightarrow class\ 2 \qquad (4.20)$$

4.2 Linearly Inseparable Data:

In practice, the situation that data distinguished as linear is not encountered and linear SVM cannot solve most of practice application. When SVM faces non-linear problems, it moves data from n dimension space (original input space) to higher

dimension space (decisive space) by making nonlinear mapping to classify from original data.

$$x \in R^n \rightarrow \emptyset(x) \in R^f \qquad (4.21)$$

Non-linear SVM in the new higher dimension space searches optimum hyperplane, which will distinguish data by studying as linear SVM. The function, which is used for conversion process, is defined $\emptyset(x)$. In the circumstances $\emptyset(x)$ replaces x in Formula (4.18) and Formula (4.22) is obtained.

$$f(x) = \sum \alpha_i y_i \emptyset(x_i)^T \emptyset(x_j) + b \qquad (4.22)$$

Generally $\emptyset(x)$ cannot be obtained, calculated even it does not exist. Although applied mapping function is even known, the solution of the optimization problem in space can be complex and will need difficult calculation. For this reason it is used Kernel Trick Method which is named regulation of kernel. It is used $K(x_i, x)$ kernel functions compatible with Mercer conditions for calculation of inner product in non-linear mapping $\emptyset$, support vector $\emptyset(x_i)$ and pattern vector in feature space [92].

In Figure 4.3, it is showed that transferring of linearly inseparable data to the different dimension space

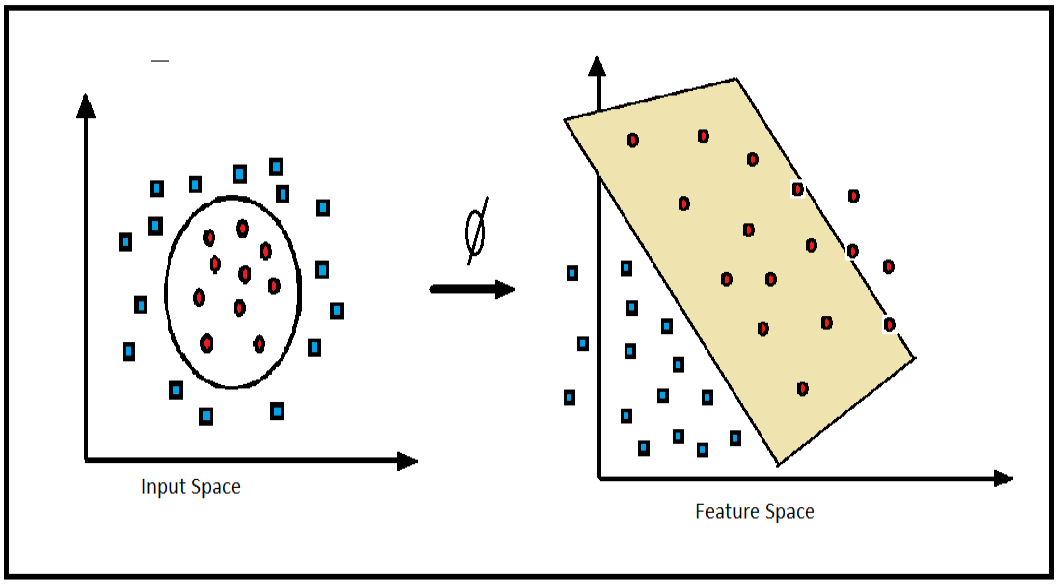


Figure 4.3 : It can be transferred linearly inseparable data to the different dimensions space

4.2.1 Kernel functions

SVM generally moves data to a higher dimension space from data input space to find best border between non-linear two classes via mapping method. However, understanding and obtaining function is generally difficult. Therefore, it is utilised from Kernel function as in Figure 4.4.

Kernel functions allow calculation of dot product in higher dimension space without a known mapping function. It is not needed to know Ø transformation as analytic because kernel functions fulfil inner product in feature space. Namely, it is more effective using Kernel functions give directly inner product value of two vectors substituted for calculating inner product value by moving vectors to a higher dimension feature space [93].

Performance of SVM methods are used in non-linear method depends on kernel function uses for classification and this function moves non-linear data a higher dimension feature space.

The decision function for non-linear situation is

$$f(x) = \sum \alpha_i y_i \, \emptyset(x_i)^T \emptyset(x_j) + b \qquad (4.23)$$

$\emptyset(x_i)^T \emptyset(x_j)$ is an inner product in formula (4.23) and Kernel function is define a function associates with inner product of two feature vector in expected feature space. In SVM Kernel functions forms Gram matrix that is formed by using inner products between all feature vectors and epitomizes all data [94-96].

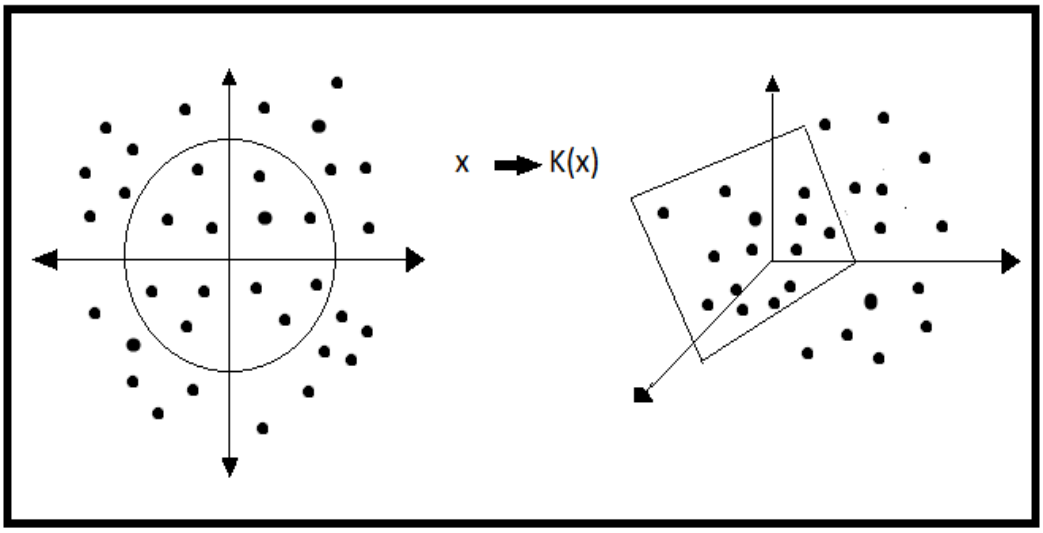


Figure 4.4 : Moving the all data to feature space by using the Kernel Function

$K(x_{i,}\, x_j) = \emptyset(x_i)^T \emptyset(x_j)$ is a transfer function and it is used for transformation of non-linear data to linear data. $K(x_{i,}\, x_j) = \emptyset(x_i)^T \emptyset(x_j)$ is written in formula (4.23)

$$f(x) = \sum \alpha_i y_i K(x_{i,}\, x_j) \qquad (4.24)$$

b term is slighted because a linear hyperplane is not a matter of and actually Kernel function contains b term in itself. For non-linear situation in SVM a solution, can be produced and different performance can be obtained.

In literature, there are a lot of Kernel function but Linear, Polynomial, Sigmoid and Radial Based Functions in Table 4.1 are most of used. Most estimating problems can be solve by using Polynomial and Radial Based functions [90].

Table 4.1 Formulations of Kernel Functions [87].

Name of Kernel Function	**Mathematical formula of Kernel Function**
Linear Function	$K(x_{i,}\, x_j) = {x_i}^T x_j$
Polynomial Function	$K(x_{i,}\, x_j) = (1 + {x_i}^T x_j)^d$
Sigmoid Function	$K(x_{i,}\, x_j) = \tanh(k{x_i}^T x_j - \delta)$
Radial Basis Function	$K(x_{i,}\, x_j) = \exp\left(-\frac{\left\|\|x_i - x_j\|\right\|^2}{2\gamma^2}\right)$

5. MATERIAL METHOD

5.1 Datasets

5.1.1 ILPD (Indian Liver Patient Dataset) information and description

There are 10 variables in the dataset. These are respectively Age, Gender, Total Bilirubin, Direct Bilirubin, Total Proteins, Albumin, A/G ratio, SGPT, SGOT and Alkphos.Table 5.1 gives some information of ILPD

Table 5.1 Some information of ILPD

Data Set Characteristics:	Multivariate
Attribute Characteristics:	Integer, Real
Associated Tasks:	Classification
Number of Instances:	583
Date Donated	2012-05-21

Dataset characteristics are multivariate and characteristics of attributes real and integer values. There are 583 instances in the dataset. The dataset was donated in 2012-05-21 by following researchers: Bendi Venkata Ramana , Prof. M. Surendra Prasad Babu, Prof. N. B. Venkateswarlu.

This dataset involves 167 records of non-liver patient and 416 records liver patient. It was composed by collecting from Andhra Pradesh, India and researchers classified it as two groups have liver disorders or not. There are 142 female patients and 441 male patient tests results. Any patient whose age surpasses 89 is written as being of age "90" In following, it is given open spelling of attributes in the dataset.

1. Age : Age of the patient
2. Gender : Gender of the patient

3. TB : Total Bilirubin
4. DB : Direct Bilirubin
5. ALKPHOS : Alkaline Phosphotase
6. SGPT : Alanine Aminotransferase
7. SGOT : Aspartate Aminotransferase
8. TP : Total Proteins
9. ALB : Albumin
10. A/G : Ratio Albumin and Globulin Ratio
11. Selector field used to split the data into two sets (labelled by the experts) [97].

5.1.2 Liver Disorders Dataset (BUPA) information and description

There are 7 variable in the dataset. These are respectively MCV, Alkphos, SGPT, SGOT, Gammagt, drinks and selector. Table 5.2 gives some information of BUPA Dataset.

Table 5.2 Some information of BUPA Dataset

Data Set Characteristics:	Multivariate
Attribute Characteristics:	Categorical, Integer, Real
Associated Tasks:	N/A
Number of Instances:	345
Number of Attributes:	7
Date Donated	1990-05-15

The dataset characteristics are multivariate and characteristic of attributes are categorical, integer and real. There are 345 instances and Richard S. Forsyth from BUPA Medical Research Ltd. donated it in 1990-05-15.

In this dataset, the first 5 attributes are all blood test and these tests arise from overabundant alcohol consumption.

1. MCV : Mean corpuscular volume

2. ALKPHOS : Alkaline Phosphotase
3. SGPT : Alamine Aminotransferase
4. SGOT : Aspartate aminotransferase
5. GAMMAGT : Gamma-Glutamyl Transpeptidase
6. Drinks : Number of half-pint equivalents of alcoholic beverages drunk per day
7. Selector field used to split data into two sets [98].

In Table 5.3, normal values of liver disorder laboratory tests are given.

Table 5.3 Normal values of liver disorder laboratory tests [99-100].

LIVER DİSORDER TESTS	NORMAL VALUES
TB	(0.2 - 1.0 mg/dl)
DB	(0 - 0.2 mg/dl)
ALKPHOS	(110 - 310 U/L)
SGPT	(5 - 45 U/L)
SGOT	(5 - 40 U/L)
TP	(5.5-8gm/dl)
ALB	(3.5-5gm/dl)
A/G	(>=1)
GAMMAGT	(0 - 42 IU/L)
MCV	80-96 fL / red cell

5.2 General Idea

In this study, a liver disorder's diagnosis inference system, which is based on FA and SVM techniques, is proposed to inference diagnosing of liver disorders patients by using ILPD and BUPA datasets. In order to achieve this, a software system, which supplies interfaces to be in interaction with user, is developed. The user enters the liver disorders laboratory test values in the system and these values are evaluated by FA or SVM techniques. As a result, the system gives result of diagnosis whether the patient has liver disorders or not via these interfaces.

At the beginning, the user faced with a main interface that presents options to the user to select FA or SVM techniques. In accordance with the user's selection, related technique's interface is opened and user enters the liver disorders laboratory test values in relevant boxes, which are included in this interface. Based on the liver Disorder Laboratory Test Values, FA or SVM executes in the background and evaluated accurate diagnosis result for user. Figure 5.1 and 5.2 show the general idea of the two systems that are prepared for ILPD and BUPA datasets.

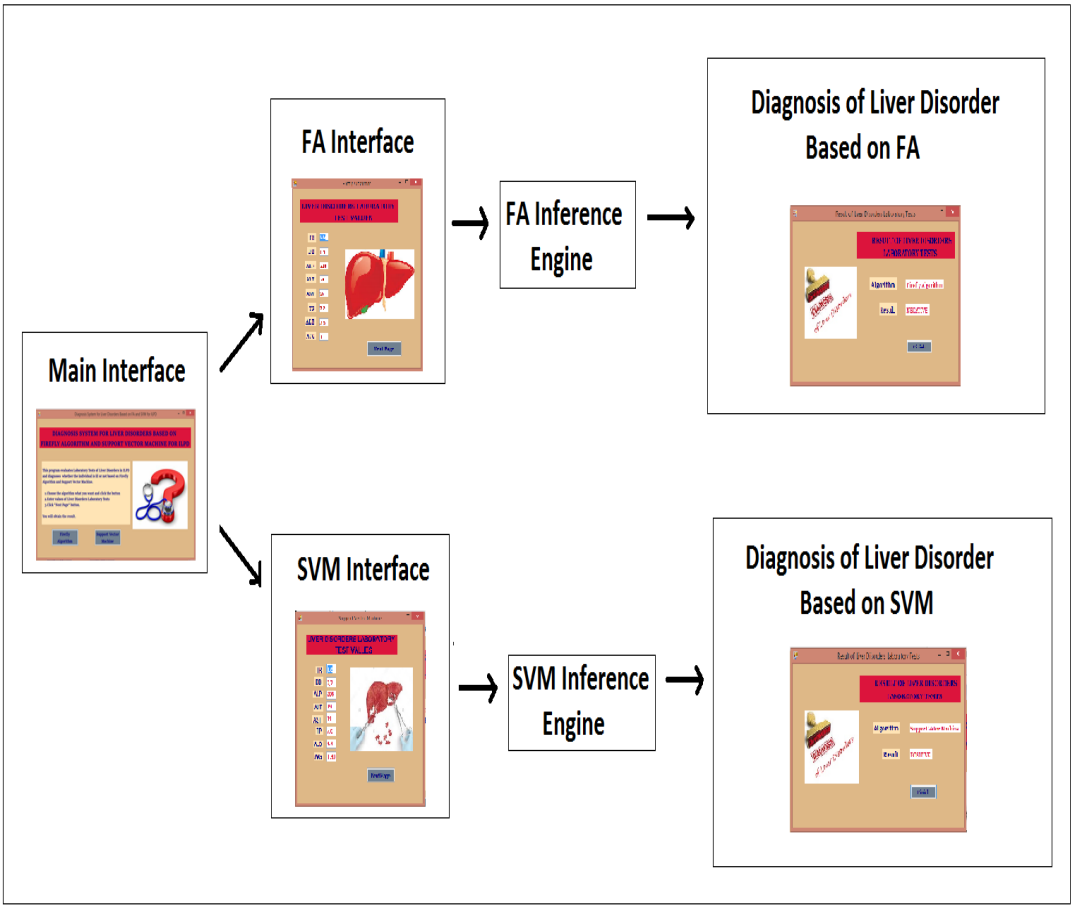


Figure 5.1 : General idea of proposed system for ILPD.

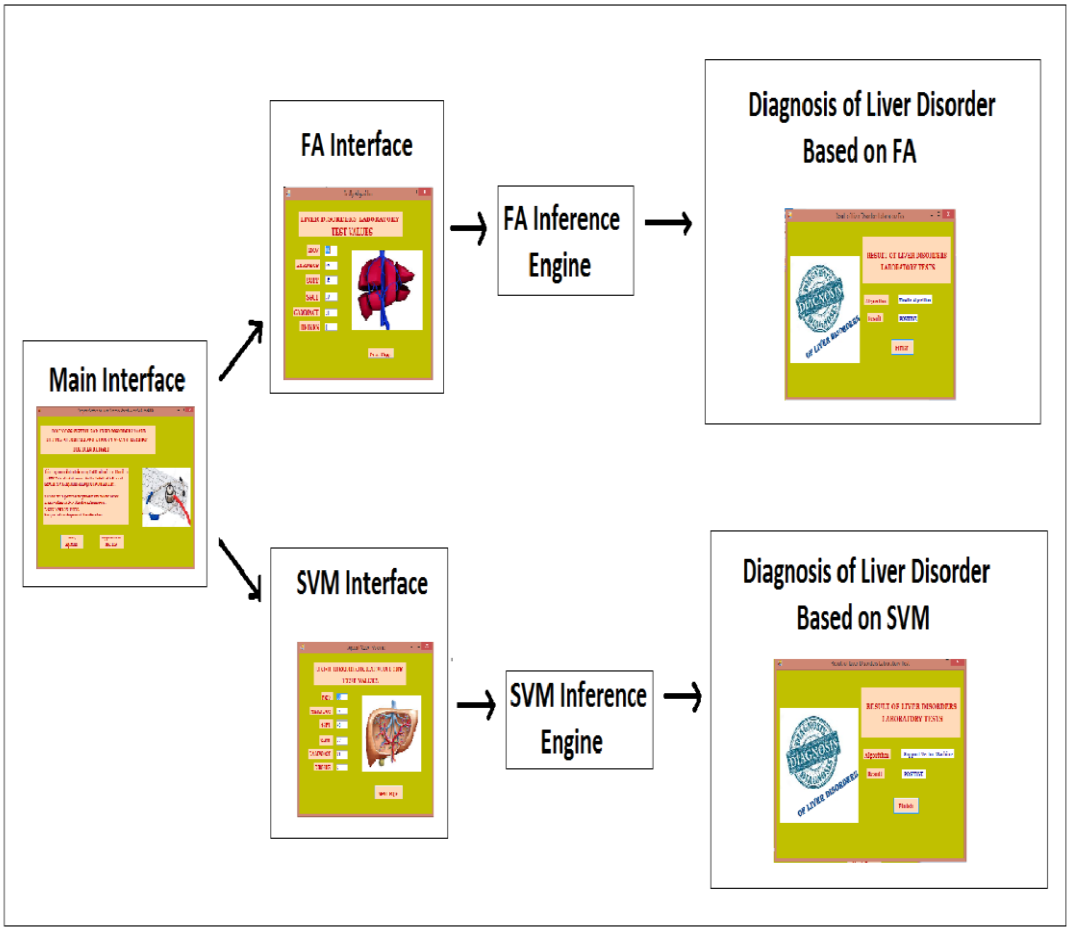


Figure 5.2 : General idea of proposed system for BUPA Dataset.

5.3 Interfaces

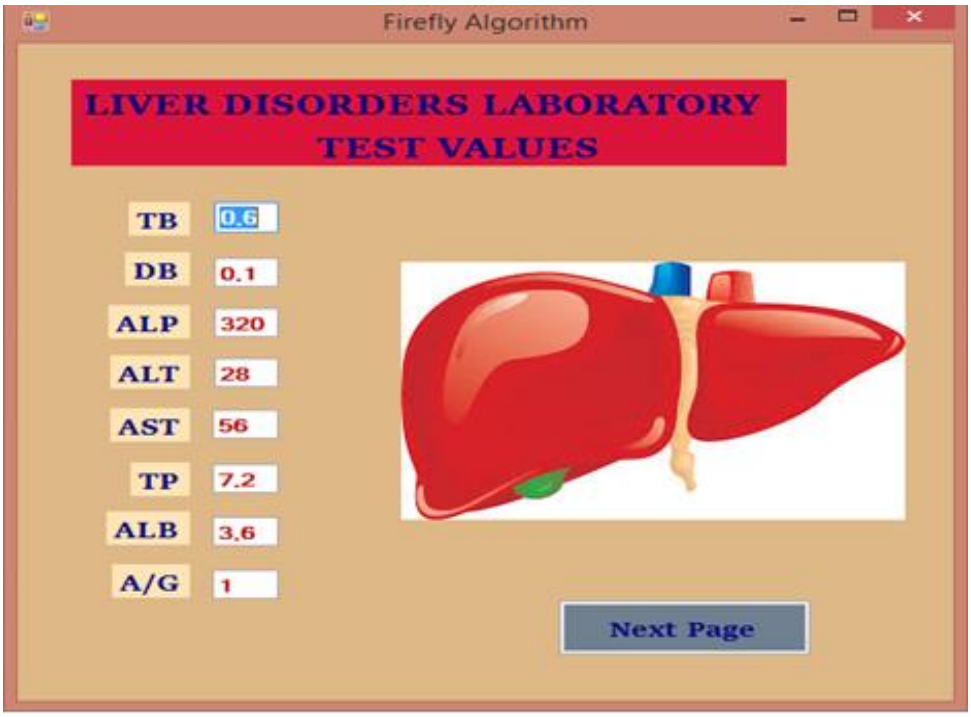
5.3.1 ILPD interface

In order to make contact with user, interfaces, which present algorithm options, entering laboratory test values and diagnosis results to the user, are developed by using C# programming language. There are two choices in the main interface as in Figure 5.3, namely Firefly Algorithm and Support Vector Machine Algorithm are presented to the user to select one of them.

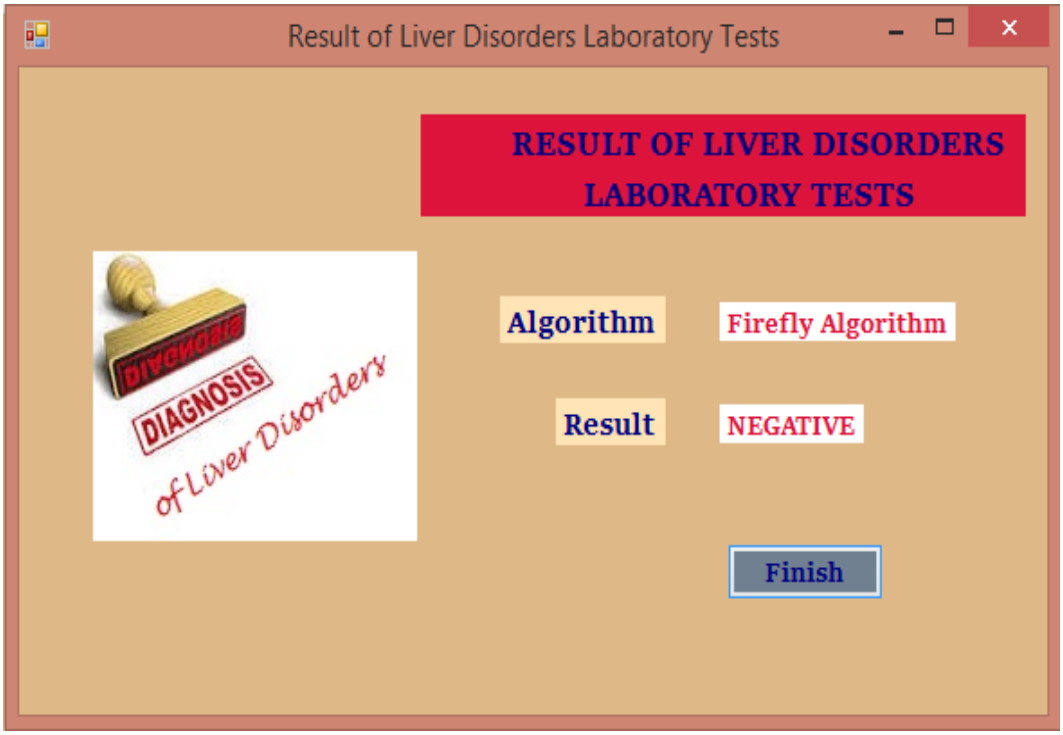
Figure 5.3 : Main interface of the proposed system to start diagnosis of liver disorders for ILPD

In accordance with choice of the user, interface including title boxes of liver disorder laboratory tests is opened. A person who has the liver disorder laboratory test values, enters the own test values.

- If the user clicks the “Firefly Algorithm” button, interface of Figure 5. 4 (a) will be seen and when the user enters the own laboratory test values and clicks the next page button the user will see own result of the laboratory test values according to evaluating of Firefly Algorithm in Figure 5.4 (b).



(a)

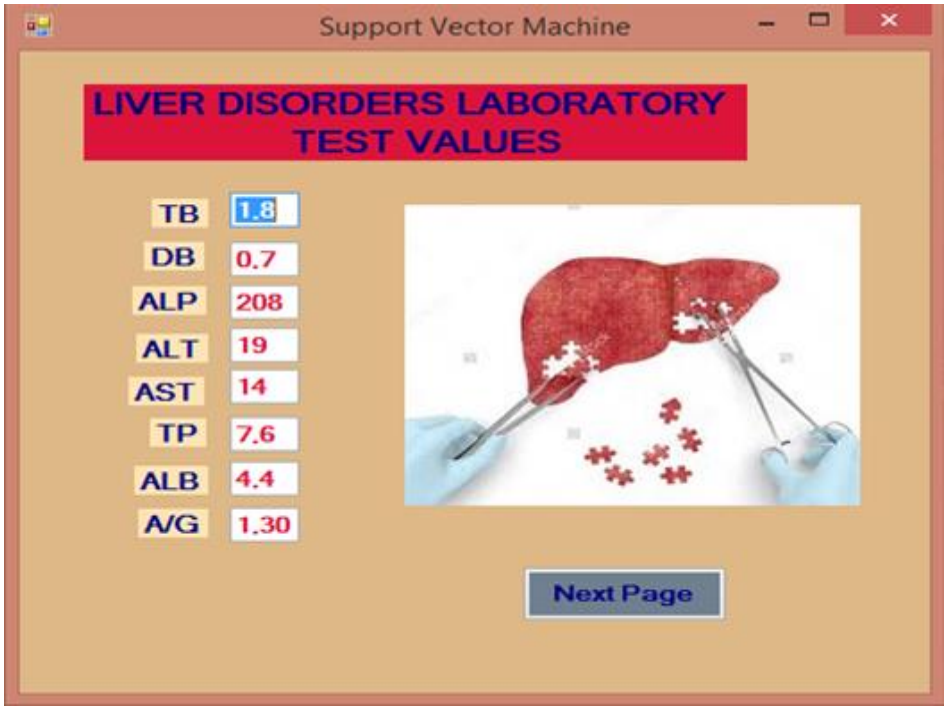


(b)

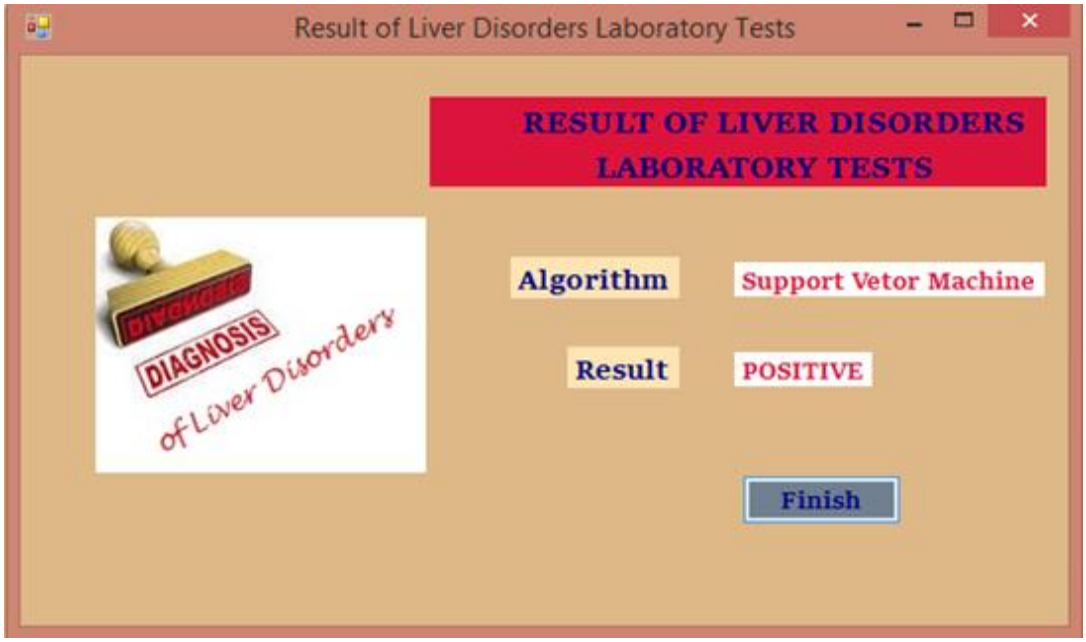
Figure 5.4 : (a) Entry interface of liver disorders laboratory test values based on FA for ILPD (b) Result interface liver disorders laboratory test based on FA for ILPD

- If the user clicks the "support vector machine "button, interface of Figure 5.5 (a) will be seen and when the user enters the own laboratory test values and clicks the next page button the user will see own result of the

laboratory test values according to evaluating of support vector machine algorithm in Figure 5.5 (b).



(a)



(b)

Figure 5.5 : (a) Entry interface of liver disorders laboratory test values based on SVM for ILPD (b) Result interface liver disorders laboratory test based on SVM for ILPD

5.3.2 BUPA Dataset interface

In order to make contact with user, interfaces, which presents algorithm options, entering laboratory test values and diagnosis results to the user, are developed by using C# programming language. There are two choices in the main interface as in Figure 5.6, namely Firefly Algorithm and Support Vector Machine Algorithm are presented to the user to select one of them.

In accordance with choice of the user, interface including title boxes of liver disorder laboratory tests is opened. A person who has the liver disorder laboratory test values, enters the own test values.

- If the user clicks the "Firefly Algorithm" button, interface of Figure 5. 7 (a) will be seen and when the user enters the own laboratory test values and clicks the next page button the user will see own result of the laboratory test values according to evaluating of Firefly Algorithm in Figure 5.7 (b).

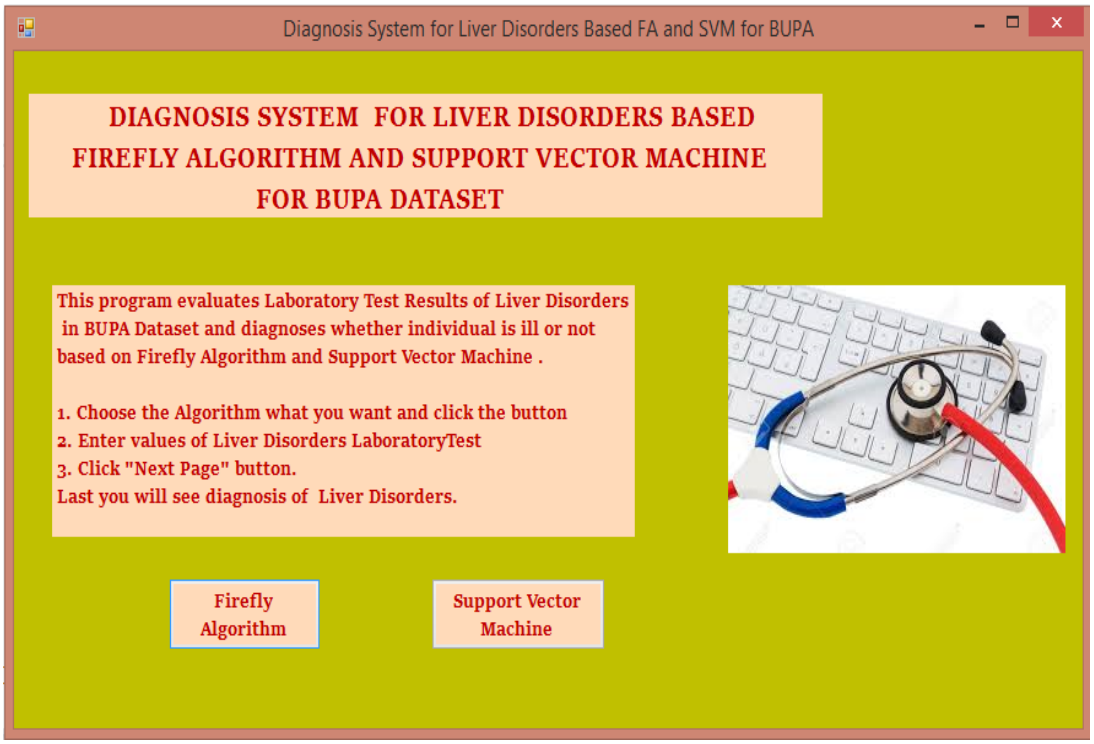
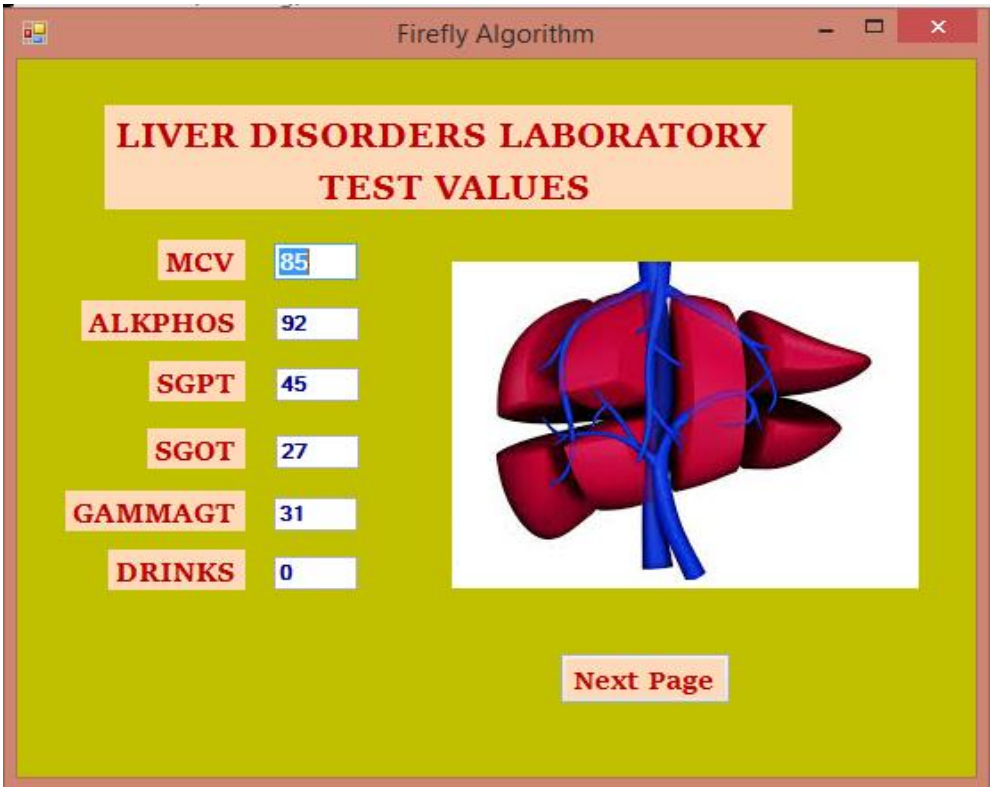
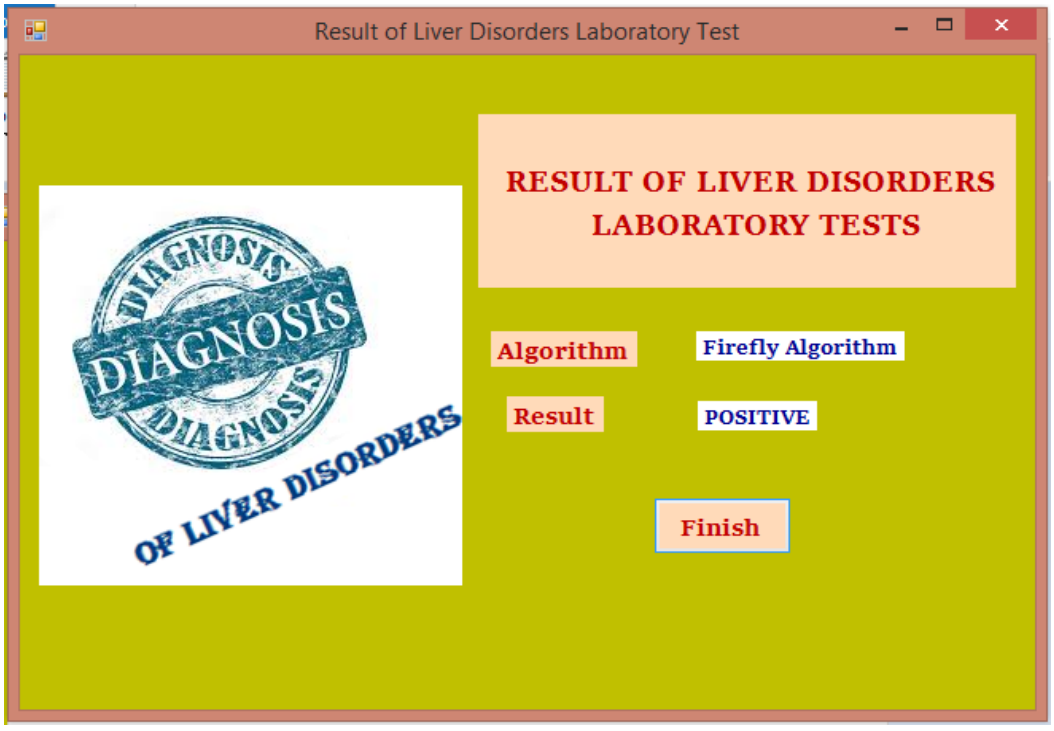


Figure 5.6 : Main interface of the proposed system to start diagnosis of liver disorders for BUPA Dataset



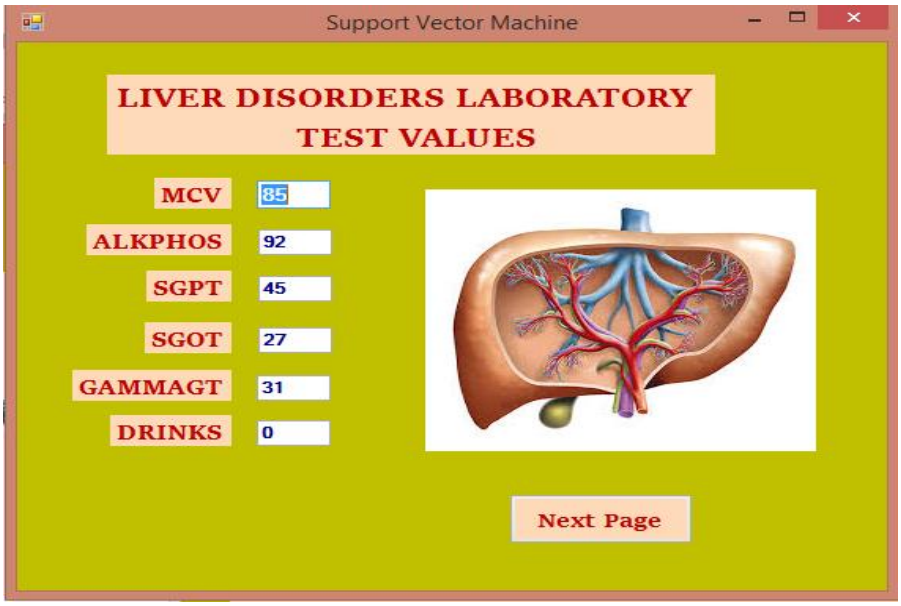
(a)



(b)

Figure 5.7 : (a) Entry interface of liver disorders laboratory test values based on FA for BUPA Dataset (b) Result interface liver disorders laboratory test based on FA for BUPA Dataset

- If the user clicks the “support vector machine” button, interface of Figure 5. 8 (a) will be seen and when the user enters the own laboratory test values and clicks the next page button the user will see own result of the laboratory test values according to evaluating of Support Vector Machine in Figure 5.8 (b).



(a)

(b)

Figure 5.8 : (a) Entry interface of liver disorders laboratory test values based on SVM for BUPA Dataset (b) Result interface liver disorders laboratory test based on SVM for BUPA Dataset

6. METHOD OF THE PROPOSED SYSTEMS

6.1 Expert System for ILPD

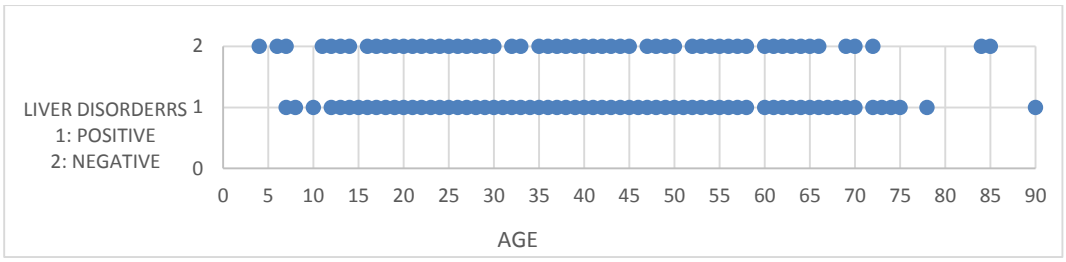
In the proposed expert system, Firefly Algorithm and Support Vector Machine Algorithm were used for the diagnosis of liver disorders by using datum in ILPD and are designed in C# programming language. For initial population, 70 data values were used for training set in liver disorder and some of them are given in Table 6.1

Table 6.1 Some of the training set in liver disorder in proposed system for ILPD

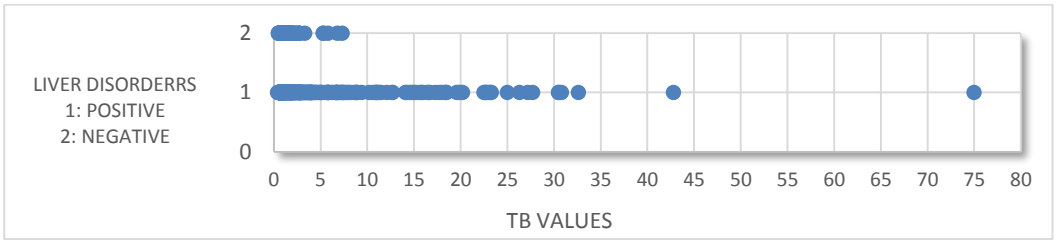
Age	Gender	TB	DB	Alkphos	SGPT	SGOT	TP	ALB	A/G	Diagnosis Result
70	Male	0.6	0.1	862	76	180	6.3	2.7	0.75	1
21	Female	0.6	0.1	186	25	22	6.8	3.4	1	1
50	Male	0.6	0.2	137	15	16	4.8	2.6	1.1	1
45	Male	0.6	0.1	196	29	30	5.8	2.9	1	1
40	Male	0.6	0.1	98	35	31	6	3.2	1.1	1
27	Male	0.6	0.2	161	27	28	3.7	1.6	0.76	-1
28	Male	0.6	0.1	177	36	29	6.9	4.1	1.4	-1
60	Male	0.6	0.1	186	20	21	6.2	3.3	1.1	-1
52	Male	0.6	0.1	178	26	27	6.5	3.6	1.2	-1
66	Male	0.6	0.2	100	17	148	5	3.3	1.9	-1
55	Male	0.8	0.2	482	112	99	5.7	2.6	0.8	1
37	Male	0.8	0.2	147	27	46	5	2.5	1	1
61	Male	0.8	0.1	282	85	231	8.5	4.3	1	1
61	Male	0.8	0.2	163	18	19	6.3	2.8	0.8	-1

The structure of the diagnosis of liver disorders is a nonlinear problem. Figure 6.1 shows the comparison between Attributes of ILPD and Results of them respectively.

As a result of this comparison, it is understood that problem of diagnosis of liver disorders in ILPD is a nonlinear problem because same attribute values give different results. For example, if the SGOT Values of Liver Disorders are examined in Figure 6.1, 0-200 values of SGOT are equal to 1 and 2 at the same time.



(a)



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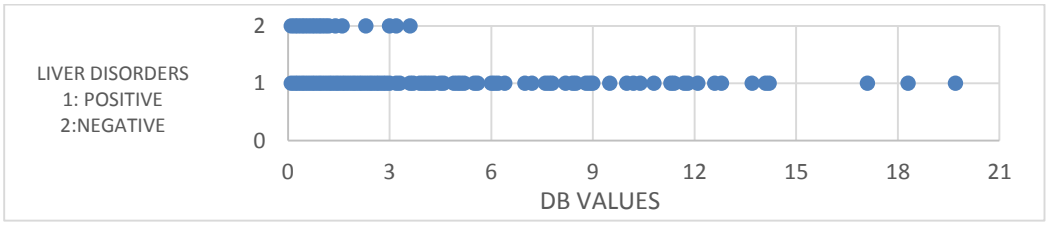

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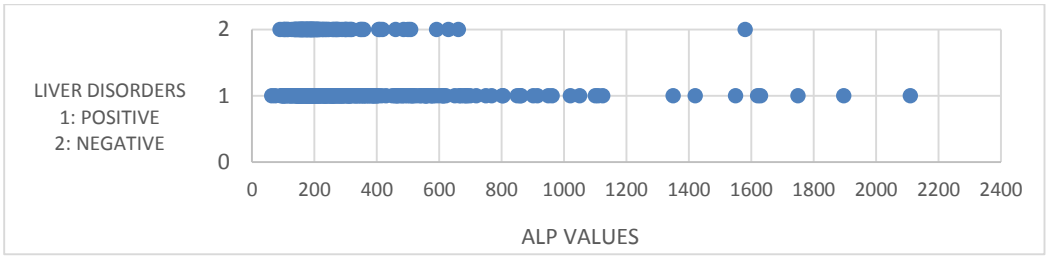
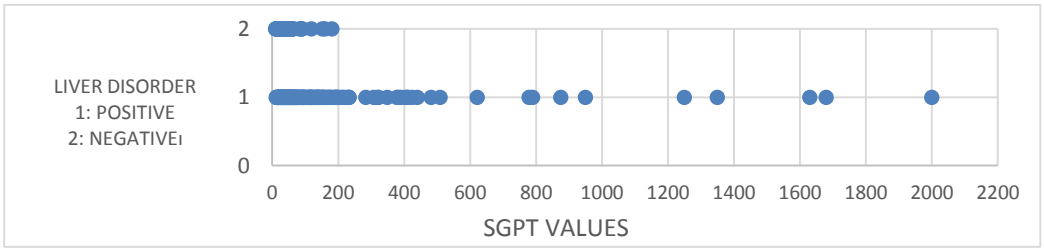


(d)



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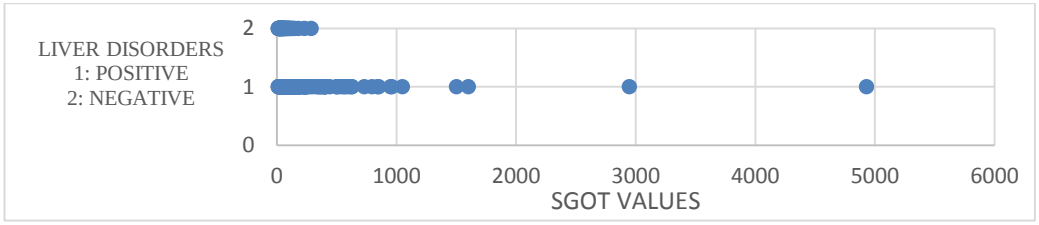

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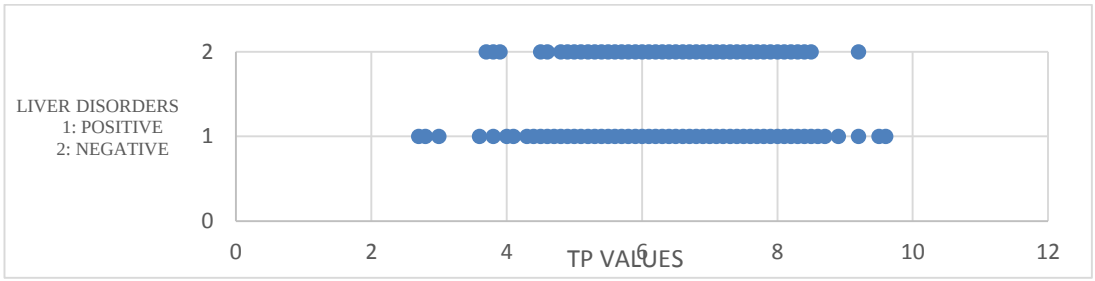
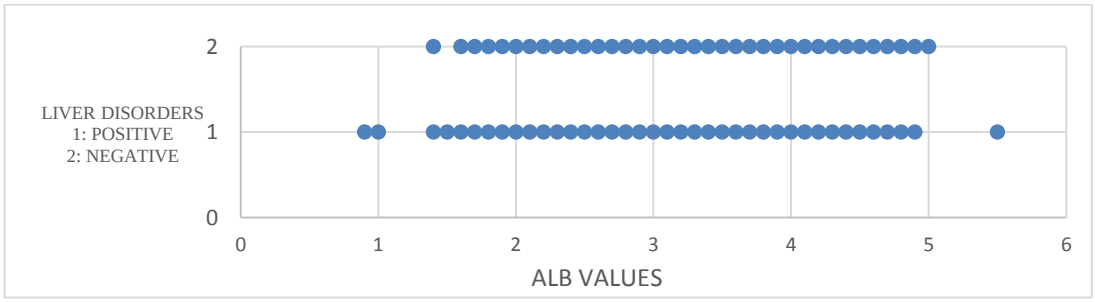


(g)



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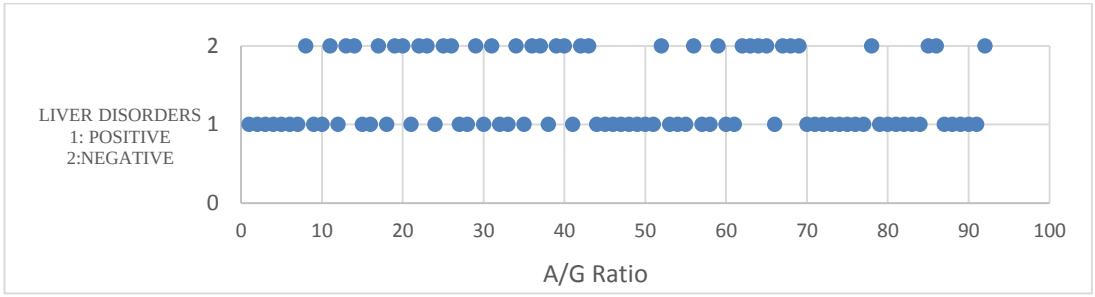


(i)

Figure 6.1 : Comparison between attributes of ILPD and diagnosis result of ILPD

Because the given problem is non-linear, objective functions are defined as follows:

$$f(x) = \sum \alpha_i y_i K(x_{i,} x_j) \qquad (6.1)$$

$K(x_{i,} x_j)$ is the Kernel function and in application it was chosen Radial Bases function is determined as follows :

$$K(x_{i,} x_j) = \exp(-\frac{||x_i - x_j||^2}{2\gamma^2}) \qquad (6.2)$$

γ value is set to 0.5 and x_i= ($x1$, $x2$, $x3$, $x4$, $x5$, $x6$, $x7$, $x8$) for liver disorders in ILPD and α_i is Lagrange Multipliers and these values are calculated in Wolfram Mathematica programming. For calculation of Lagrange Multipliers, Radial Bases Function was written in f(x) and it was obtained

$$f(x) = \sum \alpha_i y_i \exp(-\frac{\left|\left|x_i - x_j\right|\right|^2}{2\gamma^2})$$

$$L_D = \sum_{i=1}^{70} \alpha_i - \frac{1}{2} \sum_{i=1}^{70} \sum_{j=1}^{70} \alpha_i \alpha_j y_i y_j \exp(-\frac{\left|\left|x_i - x_j\right|\right|^2}{2\gamma^2}), \quad \alpha_i \geq 0\,, \quad \forall i,$$

L_D function was solved in Wolfram Mathematica 10.0 by using followings

$$\boldsymbol{\alpha} = \{\boldsymbol{\alpha_1}, \boldsymbol{\alpha_2}, \boldsymbol{\alpha_3}, \ldots, \boldsymbol{\alpha_{68}}, \boldsymbol{\alpha_{69}}, \boldsymbol{\alpha_{70}}\},$$

$$\boldsymbol{\gamma} = 0.5,$$

y={1,1,1,1,1,-1,1,1,1,-1,1,1,1,1,1,1,-1,-1,1,1,1,-1,1,-1,1,1,-1,1,-1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,-1,-1,1,1,1,-1,1,1,1,1,1,1,1,-1,1,-1,1,-1,-1,1,-1,-1,-1},

x={0.6, 0.1, 862, 76, 180, 6.3, 2.7, 0.75}, {0.6, 0.1, 186, 25, 22, 6.8,3.4, 1}, {0.6, 0.2, 137, 15, 16, 4.8, 2.6, 1.1}, … ,{0.8, 0.2, 215, 24, 17, 6.3, 3, 0.9}, {1, 0.3, 195, 22, 28, 5.8, 2.6, 0.8}, {1, 0.3, 90, 18,108, 6.8, 3.1, 0.8}},

and it is obtained like in following Figure 6.2

$$L[\alpha, y, x, \gamma] = \sum_{i=1}^{70} \alpha[[i]] - 1/2 * \left(\sum_{i=1}^{70} \sum_{j=1}^{70} \alpha[[i]]\, \alpha[[j]]\, y[[i]]\, y[[j]]\, \left(e^{((-1)*(\text{Norm}[x[[i]]-x[[j]]])/2*\gamma^2)} \right) \right)$$

$$= \alpha1 + \alpha10 + \alpha11 + \alpha12 + \alpha13 + \alpha14 + \alpha15 + \alpha16 + \alpha17 + \alpha18 + \alpha19 + \alpha2 + \alpha20 +$$
$$\alpha21 + \alpha22 + \alpha23 + \alpha24 + \alpha25 + \alpha26 + \alpha27 + \alpha28 + \alpha29 + \alpha3 + \alpha30 + \alpha31 + \alpha32 +$$
$$\alpha33 + \alpha34 + \alpha35 + \alpha36 + \alpha37 + \alpha38 + \alpha39 + \alpha4 + \alpha40 + \alpha41 + \alpha42 + \alpha43 +$$
$$\alpha44 + \alpha45 + \alpha46 + \alpha47 + \alpha48 + \alpha49 + \alpha5 + \alpha50 + \alpha51 + \alpha52 + \alpha53 + \alpha54 + \alpha55 +$$
$$\alpha56 + \alpha57 + \alpha58 + \alpha59 + \alpha6 + \alpha60 + \alpha61 + \alpha62 + \alpha63 + \alpha64 + \alpha65 + \alpha66 + \alpha67 +$$
$$\alpha68 + \alpha69 + \alpha7 + \alpha70 + \alpha8 + \alpha9 + \frac{1}{2} \left(-1.\, \alpha1^2 + 5.94562 \times 10^{-42}\, \alpha1\, \alpha10 - 1.\, \alpha10^2 - \right.$$
$$1.31287 \times 10^{-21}\, \alpha1\, \alpha11 + 5.84426 \times 10^{-22}\, \alpha10\, \alpha11 - 1.\, \alpha11^2 - 5.25566 \times 10^{-40}\, \alpha1\, \alpha12 +$$
$$1.51261 \times 10^{-6}\, \alpha10\, \alpha12 - 2.08595 \times 10^{-19}\, \alpha11\, \alpha12 - 1.\, \alpha12^2 - 4.88725 \times 10^{-22}\, \alpha1\, \alpha13 +$$
$$6.75753 \times 10^{-12}\, \alpha10\, \alpha13 - 1.61655 \times 10^{-13}\, \alpha11\, \alpha13 - 2.9785 \times 10^{-13}\, \alpha12\, \alpha13 - 1.\, \alpha13^2 -$$
$$+ \ldots +$$
$$4.8298 \times 10^{-7}\, \alpha54\, \alpha9 - 3.19198 \times 10^{-15}\, \alpha55\, \alpha9 - 0.0000114558\, \alpha56\, \alpha9 -$$
$$2.50212 \times 10^{-16}\, \alpha57\, \alpha9 - 4.8789 \times 10^{-58}\, \alpha58\, \alpha9 - 0.00451897\, \alpha59\, \alpha9 + 1.93189 \times 10^{-7}\, \alpha6\, \alpha9 -$$
$$2.1158 \times 10^{-13}\, \alpha60\, \alpha9 + 0.0000328554\, \alpha61\, \alpha9 - 0.00161706\, \alpha62\, \alpha9 + 1.9314 \times 10^{-7}\, \alpha63\, \alpha9 -$$
$$0.331605\, \alpha64\, \alpha9 + 5.05924 \times 10^{-9}\, \alpha65\, \alpha9 + 0.0000201362\, \alpha66\, \alpha9 - 0.0000390915\, \alpha67\, \alpha9 +$$
$$0.000166816\, \alpha68\, \alpha9 + 0.0000133391\, \alpha69\, \alpha9 - 0.0000674901\, \alpha7\, \alpha9 + 2.83684 \times 10^{-12}\, \alpha70\, \alpha9$$
$$\left. - 7.45352 \times 10^{-10}\, \alpha8\, \alpha9 - 1.\, \alpha9^2 \right)$$

Figure 6.2 : Objective function based on Lagrange Multipliers for ILPD (It is obtained from Wolfram Mathematica 10.)

Now, it only contains unknown α Lagrange values. After that,

$$\frac{\partial L_D}{\partial \alpha_1} = 0, \quad \frac{\partial L_D}{\partial \alpha_2} = 0, \quad \frac{\partial L_D}{\partial \alpha_3} = 0, \quad \ldots \frac{\partial L_D}{\partial \alpha_{69}} = 0, \quad \frac{\partial L_D}{\partial \alpha_{70}} = 0$$

was applied and α is obtained as following values in Figure 6.3:

$$\boldsymbol{\alpha} = \{1.,\ 1.08819,\ 1.28516,\ 1.67134,\ 0.966033,\ 1.6263,\ 0.714004,\ 0.82617,\ 0.699122,$$
$$0.994144,\ 0.997538,\ 1.05737,\ 0.999995,\ 1.58232,\ 0.861271,\ 0.870871,\ 1.24172,$$
$$2.08013,\ 0.722522,\ 0.3651,\ 0.997001,\ 1.33531,\ 0.756865,\ 1.1268,\ 0.519903,$$
$$0.835958,\ 1.10797,\ 0.983371,\ 1.21279,\ 1.11644,\ 1.,\ 0.933415,\ 1.10445,\ 2.17806,$$
$$0.99479,\ 1.00298,\ 1.0301,\ 0.966467,\ 1.,\ 0.999985,\ 1.28973,\ 0.453985,\ 1.33915,$$
$$1.,\ 0.991028,\ 1.28282,\ 0.917457,\ 0.965764,\ 1.,\ 1.,\ 0.985631,\ 0.998521,\ 1.,$$
$$0.997933,\ 1.00001,\ 0.996109,\ 1.00001,\ 1.,\ 0.901323,\ 0.999986,\ 1.29501,\ 1.37315,$$
$$1.00271,\ 0.697871,\ 0.962646,\ 1.42087,\ 0.679796,\ 1.73386,\ 1.47507,\ 0.993855\}$$

Figure 6.3 : Lagrange Multipliers Values for ILPD (It is obtained from Wolfram Mathematica 10.)

Later, α values were written in

$$f(x) = \sum \alpha_i y_i \exp(-\frac{\left||x_i - x_j|\right|^2}{2\gamma^2}) \qquad (6.3)$$

The objective function is defined for all X=(X1,X2,X3,X4,X5,X6,X7,X8) as following Figure 6.4.

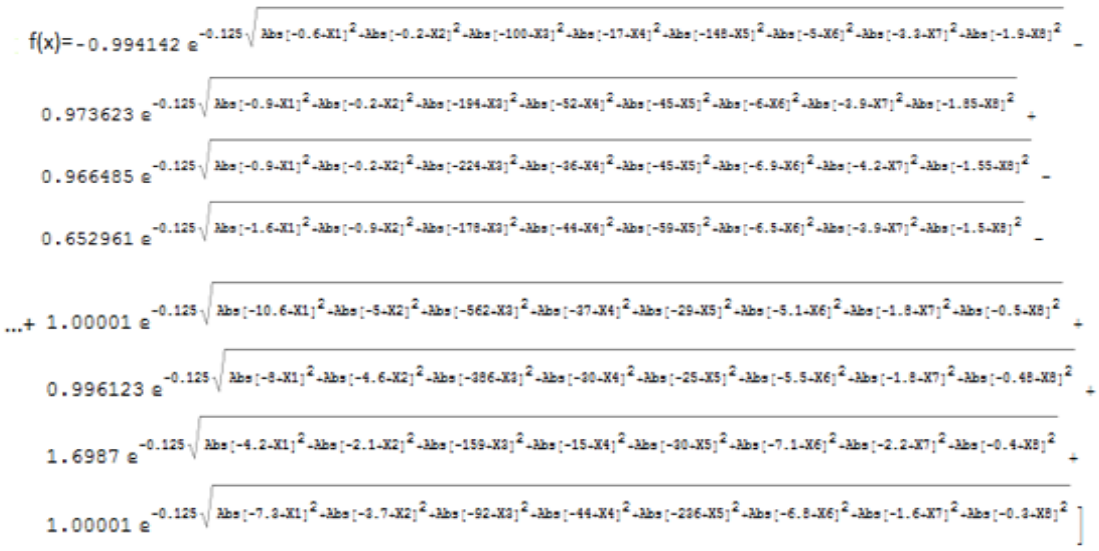


Figure 6.4 : Objective function of Purposed System based on FA and SVM for ILPD (It is obtained from Wolfram Mathematica 10.).

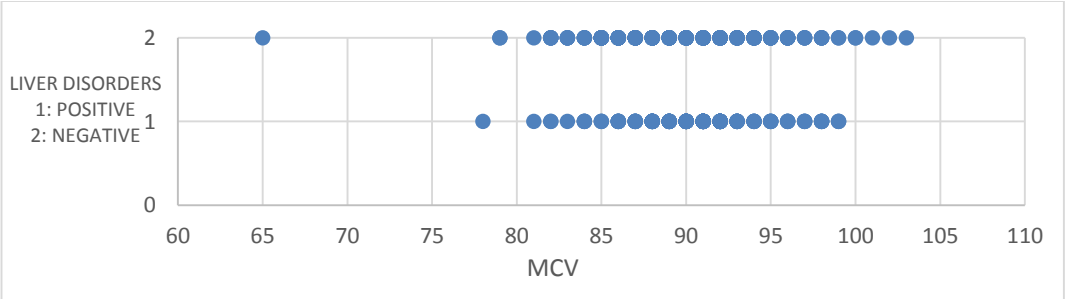
6.2 Expert System for BUPA Dataset

In the proposed expert system, Firefly Algorithm and support vector machine algorithm were used for the diagnosis of liver disorders by using data in BUPA dataset and was designed in C# programming language. For initial population, 90 data values were used for training set in liver disorder and some of them are given in Table 6.2.

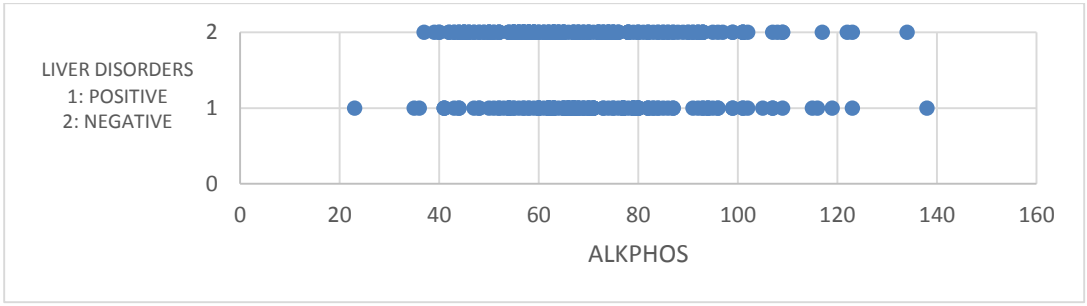
Table 6.2 Some of the training set in liver disorder in proposed system for BUPA Dataset.

MCV	ALKHAPOS	SGPT	SGOT	GAMMAGT	DRINKS NUMBER	DIAGNOSIS
85	92	45	27	31	0.0	1
85	64	59	32	23	0.0	2
86	54	33	16	54	0.0	2
91	78	34	24	36	0.0	2
87	70	12	28	10	0.0	2
98	55	13	17	17	0.0	2
88	62	20	17	9	0,5	1
88	67	21	11	11	0,5	1
92	54	22	20	7	0,5	1
90	60	25	19	5	0,5	1
89	52	13	24	15	0,5	1
82	62	17	17	15	0,5	1
90	64	61	32	13	0,5	1
86	77	25	19	18	0,5	1
96	67	29	20	11	0,5	1
91	78	20	31	18	0,5	1

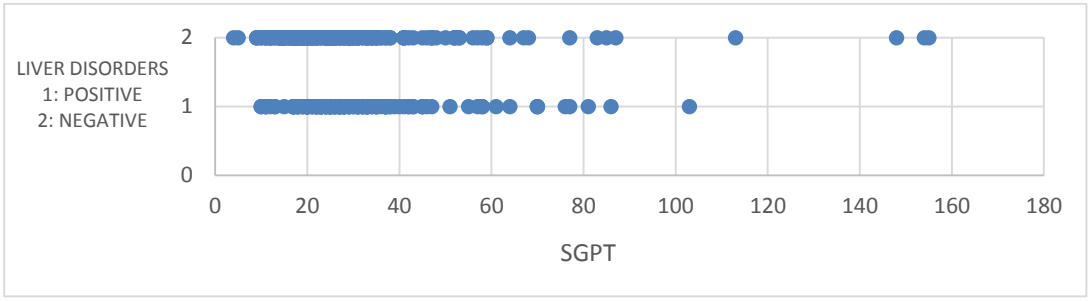
The same situations, which are in attributes of ILPD, are true for attributes in BUPA dataset. Following graphics show relations between attributes of BUPA and results of Liver disorders in BUPA dataset. These graphics proof that problem of diagnosis of liver disorders.



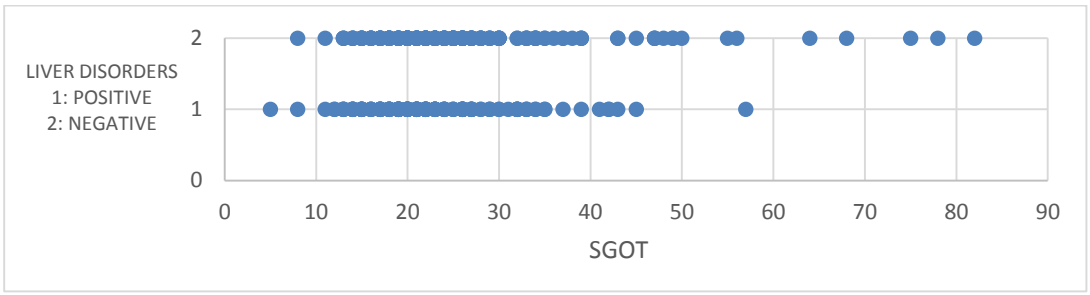
(a)


LIVER DISORDERS
1: POSITIVE
2: NEGATIVE
2
1
0
0
20
40
60
80
100
120
140
160
ALKPHOS

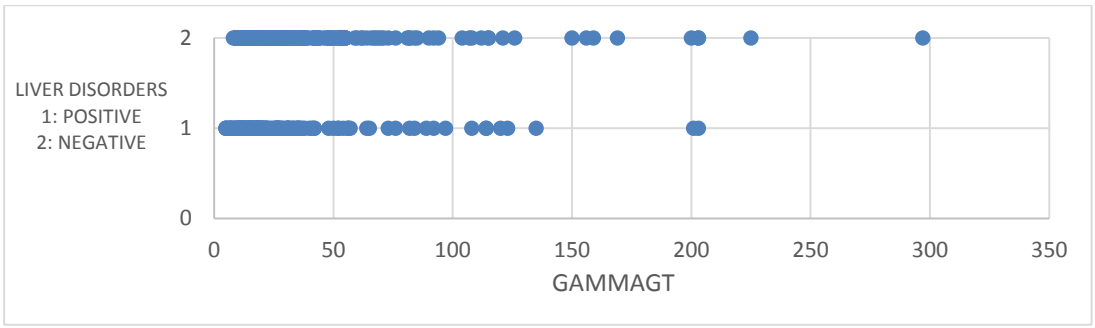
(b)


LIVER DISORDERS
1: POSITIVE
2: NEGATIVE
2
1
0
0
20
40
60
80
100
120
140
160
180
SGPT

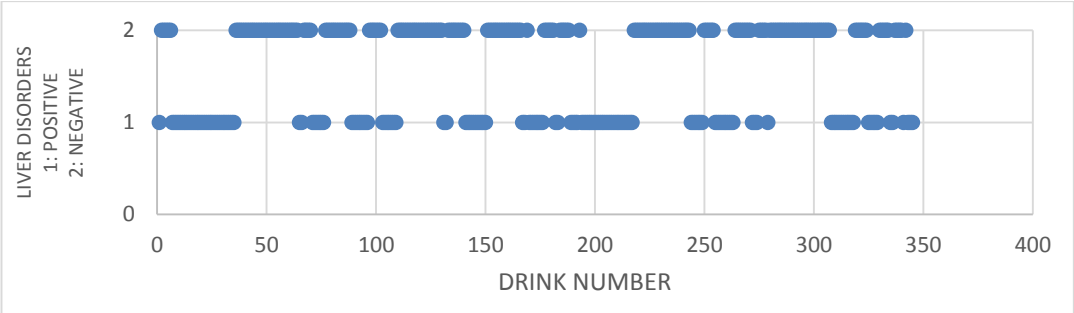
(c)


LIVER DISORDERS
1: POSITIVE
2: NEGATIVE
2
1
0
0
10
20
30
40
50
60
70
80
90
SGOT

(d)


LIVER DISORDERS
1: POSITIVE
2: NEGATIVE
2
1
0
0
50
100
150
200
250
300
350
GAMMAGT

(e)



(f)

Figure 6.5 : Comparison between attributes of BUPA Dataset and diagnosis result of BUPA Dataset

The given problem in BUPA Dataset is non-linear too and so objective functions are defined as following:

$$f(x) = \sum \alpha_i y_i K(x_{i,} x_j)$$

(xi,) is the Kernel function and in application it was chosen Radial Bases function is determined as follows :

$$K(x_{i,} x_j) = \exp(-\frac{\left|\left|x_i - x_j\right|\right|^2}{2\gamma^2})$$

γ value is set to 0.5 and x_i= ($x1$, $x2$, $x3$, $x4$, $x5$, $x6$) for liver disorders in ILPD and α_i is Lagrange Multipliers and these values are calculated in Wolfram Mathematica programming. For calculation of Lagrange Multipliers, Radial Bases Function was written in f(x) and it was obtained

$$f(x) = \sum \alpha_i y_i \exp(-\frac{\left|\left|x_i - x_j\right|\right|^2}{2\gamma^2})$$

$$L_D = \sum_{i=1}^{90} \alpha_i - \frac{1}{2} \sum_{i=1}^{90} \sum_{j=1}^{90} \alpha_i \alpha_j y_i y_j \exp(-\frac{\left|\left|x_i - x_j\right|\right|^2}{2\gamma^2}), \quad \alpha_i \geq 0\,, \quad \forall i,$$

L_D function was solved in Wolfram Mathematica 10.0 by using followings

$\boldsymbol{\alpha} = \{\boldsymbol{\alpha_1}, \boldsymbol{\alpha_2}, \boldsymbol{\alpha_3}, \ldots, \boldsymbol{\alpha_{88}}, \boldsymbol{\alpha_{89}}, \boldsymbol{\alpha_{90}}\}$,

$\boldsymbol{\gamma}$ = 0.5,

y = {1, -1, -1, -1, -1, -1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1,

-1, -1, -1, -1, -1, -1, 1, 1, -1, -1, -1, -1, 1, 1, 1, 1, 1, 1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, -1, 1, 1, 1}

x = {{85, 92, 45, 27, 31, 0.0}, {85, 64, 59, 32, 23, 0.0}, {86, 54, 33, 16, 54, 0.0}, {91, 78, 34, 24, 36, 0.0}, {87, 70, 12, 28, 10, 0.0}, … ,{92, 60, 30, 27, 297, 2.0}, {88, 47, 33, 26, 29, 2.0}, {92, 65, 17, 25, 9, 2.0}, {92, 79, 22, 20, 11, 3.0}, {84, 83, 20, 25, 7, 3.0}, {88, 68, 27, 21, 26, 3.0}}

and it is obtained like

$$L[\alpha, y, x, \gamma] = \sum_{i=1}^{90} \alpha[[i]] - 1/2 * \left(\sum_{i=1}^{90} \sum_{j=1}^{90} \alpha[[i]]\, \alpha[[j]]\, y[[i]]\, y[[j]]\, \left(e^{((-1)*(\text{Norm}[x[[i]]-x[[j]]])/2*\gamma^2)} \right) \right)$$

$$= \alpha 1 + \alpha 10 + \alpha 11 + \alpha 12 + \alpha 13 + \alpha 14 + \alpha 15 + \alpha 16 + \alpha 17 + \alpha 18 + \alpha 19 + \alpha 2 + \alpha 20 + \alpha 21 + \alpha 22 + \alpha 23 + \alpha 24 + \alpha 25 + \alpha 26 + \alpha 27 + \alpha 28 + \alpha 29 + \alpha 3 + \alpha 30 + \alpha 31 + \alpha 32 + \alpha 33 + \alpha 34 + \alpha 35 + \alpha 36 + \alpha 37 + \alpha 38 + \alpha 39 + \alpha 4 + \alpha 40 + \alpha 41 + \alpha 42 + \alpha 43 + \alpha 44 + \alpha 45 + \alpha 46 + \alpha 47 + \alpha 48 + \alpha 49 + \alpha 5 + \alpha 50 + \alpha 51 + \alpha 52 + \alpha 53 + \alpha 54 + \alpha 55 + \alpha 56 + \alpha 57 + \alpha 58 + \alpha 59 + \alpha 6 + \alpha 60 + \alpha 61 + \alpha 62 + \alpha 63 + \alpha 64 + \alpha 65 + \alpha 66 + \alpha 67 + \alpha 68 + \alpha 69 + \alpha 7 + \alpha 70 + \alpha 71 + \alpha 72 + \alpha 73 + \alpha 74 + \alpha 75 + \alpha 76 + \alpha 77 + \alpha 78 + \alpha 79 + \alpha 8 + \alpha 80 + \alpha 81 + \alpha 82 + \alpha 83 + \alpha 84 + \alpha 85 + \alpha 86 + \alpha 87 + \alpha 88 + \alpha 89 + \alpha 9 + \alpha 90 +$$

$$\frac{1}{2} \left(-1.\, \alpha 1^2 - 0.00576742\, \alpha 1\, \alpha 10 - 1.\, \alpha 10^2 - 0.0023711\, \alpha 1\, \alpha 11 - 0.203658\, \alpha 10\, \alpha 11 - 1.\, \alpha 11^2 - 0.00697493\, \alpha 1\, \alpha 12 - 0.29313\, \alpha 10\, \alpha 12 - 0.321279\, \alpha 11\, \alpha 12 - 1.\, \alpha 12^2 - 0.0181757\, \alpha 1\, \alpha 13 - 0.0146962\, \alpha 10\, \alpha 13 - 0.00377987\, \alpha 11\, \alpha 13 - 0.0054416\, \alpha 12\, \alpha 13 \right.$$

$$- \ldots -$$

$$\left. 0.16611\, \alpha 7\, \alpha 90 + 0.23115\, \alpha 70\, \alpha 90 - 0.0384759\, \alpha 71\, \alpha 90 - 0.421856\, \alpha 72\, \alpha 90 - 0.232833\, \alpha 73\, \alpha 90 - 0.591436\, \alpha 74\, \alpha 90 - 0.192938\, \alpha 75\, \alpha 90 - 0.116274\, \alpha 76\, \alpha 90 + 1.20358 \times 10^{-7}\, \alpha 77\, \alpha 90 + 0.565927\, \alpha 78\, \alpha 90 + 0.0892051\, \alpha 79\, \alpha 90 - 0.181666\, \alpha 8\, \alpha 90 + 0.370391\, \alpha 80\, \alpha 90 + 0.00309508\, \alpha 81\, \alpha 90 + 0.0406008\, \alpha 82\, \alpha 90 + 0.0174177\, \alpha 83\, \alpha 90 + 0.370391\, \alpha 84\, \alpha 90 + 3.77302 \times 10^{-15}\, \alpha 85\, \alpha 90 + 0.118211\, \alpha 86\, \alpha 90 + 0.149282\, \alpha 87\, \alpha 90 - 0.170492\, \alpha 88\, \alpha 90 - 0.0792502\, \alpha 89\, \alpha 90 - 0.0923581\, \alpha 9\, \alpha 90 - 1.\, \alpha 90^2 \right)$$

Figure 6.6 : Objective function based on Lagrange Multipliers for BUPA (It is obtained from Wolfram Mathematica 10.)

Now, it only contains unknown α Lagrange values. After that,

$$\frac{\partial L_D}{\partial \alpha_1} = 0, \quad \frac{\partial L_D}{\partial \alpha_2} = 0, \quad \frac{\partial L_D}{\partial \alpha_3} = 0, \quad \ldots \frac{\partial L_D}{\partial \alpha_{89}} = 0, \quad \frac{\partial L_D}{\partial \alpha_{90}} = 0$$

was applied and α is obtained as following values.

α= {1.15396, 1.21904, 1.04401, 1.31779, 0.683385, 0.567487, 1.0022, 0.801547,
1.14469, 0.0489638, 3.17315, 1.95576, 1.33686, 1.12646, 0.578099, 1.94502,
0.153374, 2.28094, 1.00914, 1.07889, 0.790458, 1.00006, 1.22422, 2.01791,
1.02714, 1.12775, 1.05969, 2.50525, 1.23401, 0.978477, 0.549801, 1.99099,
1.45247, 1.03218, 0.71366, 0.999992, 0.888726, 1.09936, 1.08906, 1.15302,
1.01136, 0.821928, 1.31019, 1.86555, 2.24063, 1.96935, 1.01863, 0.967419,
2.74002, 0.665635, 1.68445, 2.80093, 1.01924, 0.739878, 0.407805, 0.716459,
1.71457, 1.70321, 0.595012, 1.00012, 0.597054, 1.70097, 0.728057, 1.94964,
0.372826, 0.61744, 0.566139, 0.721822, 1.16027, 0.743598, 1.35837, 1.22786,
1.595, 0.441816, 2.25792, 1.13991, 1.00048, 1.93231, 1.21329, 0.961857,
1.11885, 0.90817, 1.10213, 0.74712, 1., 0.560415, 1.33624, 1.56121,1.26617,
1.60519}

Figure 6.7 : Lagrange Multipliers for BUPA (It is obtained from Wolfram Mathematica 10.)

Later, α values were written in

$$f(x) = \sum \alpha_i y_i \exp(-\frac{\left|\left|x_i - x_j\right|\right|^2}{2\gamma^2})$$

The objective function is as following:

f(x)= 1.60519 $e^{-0.125\sqrt{\text{Abs}[-88+X1]^2+\text{Abs}[-68+X2]^2+\text{Abs}[-27+X3]^2+\text{Abs}[-21+X4]^2+\text{Abs}[-26+X5]^2+\text{Abs}[-3.+X6]^2}}$ +

1.56121 $e^{-0.125\sqrt{\text{Abs}[-92+X1]^2+\text{Abs}[-79+X2]^2+\text{Abs}[-22+X3]^2+\text{Abs}[-20+X4]^2+\text{Abs}[-11+X5]^2+\text{Abs}[-3.+X6]^2}}$ +

1.26617 $e^{-0.125\sqrt{\text{Abs}[-84+X1]^2+\text{Abs}[-83+X2]^2+\text{Abs}[-20+X3]^2+\text{Abs}[-25+X4]^2+\text{Abs}[-7+X5]^2+\text{Abs}[-3.+X6]^2}}$ -

1. $e^{-0.125\sqrt{\text{Abs}[-92+X1]^2+\text{Abs}[-60+X2]^2+\text{Abs}[-30+X3]^2+\text{Abs}[-27+X4]^2+\text{Abs}[-297+X5]^2+\text{Abs}[-2.+X6]^2}}$ -

1.00048 $e^{-0.125\sqrt{\text{Abs}[-87+X1]^2+\text{Abs}[-90+X2]^2+\text{Abs}[-43+X3]^2+\text{Abs}[-28+X4]^2+\text{Abs}[-156+X5]^2+\text{Abs}[-2.+X6]^2}}$ -

1.11885 $e^{-0.125\sqrt{\text{Abs}[-92+X1]^2+\text{Abs}[-101+X2]^2+\text{Abs}[-34+X3]^2+\text{Abs}[-30+X4]^2+\text{Abs}[-64+X5]^2+\text{Abs}[-2.+X6]^2}}$

+ ... -

1.21904 $e^{-0.125\sqrt{\text{Abs}[-85+X1]^2+\text{Abs}[-64+X2]^2+\text{Abs}[-59+X3]^2+\text{Abs}[-32+X4]^2+\text{Abs}[-23+X5]^2+\text{Abs}[0.+X6]^2}}$ -

0.567487 $e^{-0.125\sqrt{\text{Abs}[-98+X1]^2+\text{Abs}[-55+X2]^2+\text{Abs}[-13+X3]^2+\text{Abs}[-17+X4]^2+\text{Abs}[-17+X5]^2+\text{Abs}[0.+X6]^2}}$ -

0.683385 $e^{-0.125\sqrt{\text{Abs}[-87+X1]^2+\text{Abs}[-70+X2]^2+\text{Abs}[-12+X3]^2+\text{Abs}[-28+X4]^2+\text{Abs}[-10+X5]^2+\text{Abs}[0.+X6]^2}}$

Figure 6.8 : Objective function of Purposed System based on FA and SVM for ILPD (It is obtained from Wolfram Mathematica 10.)

and now for new $\forall x_i = (x_1, x_2, x_3, x_4, x_5, x_6)$ it can be find a solution.

In FA, I(x) = f(x**)** can be determined. In equation (1), ϒ is set to value of 0.01 and **ε** is set to value of 0.2 according to general impression. Max generation is chosen 100.

7. SIMULATION RESULTS AND EVALUATIONS

In the proposed system Firefly Algorithm and Support Vector Machine is used for diagnosis of liver disorders. In implementation, it was used C# programming language.

Some terms and formulas of terminology and obtainment from a confusion matrix are given as following:

- ✓ **True positive (TP):** Sick people are accurately defined as sick,
- ✓ **False positive (FP):** Healthy people are inaccurately defined as sick,
- ✓ **True negative (TN):** Healthy people are accurately defined as healthy,
- ✓ **False negative (FN):** Sick people are inaccurately defined as healthy [37].

Table 7.1 Some formulas of evaluation terminology

$\text{Accuracy} = \frac{TN + TP}{TN + TP + FN + FP}$
$\text{Negative predictive Value} = \frac{TN}{TN + FN}$
$\text{Positive predictive Value} = \frac{TP}{TP + FP}$
$\text{Specificity} = \frac{TN}{TN + FP}$
$\text{Sensitivity} = \frac{TP}{TP + FN}$
$\text{Precision} = \frac{TP}{TP + FP}$
$\text{F\_Measure} = 2\,x\frac{precision\ x\ sensitivity}{precision + sensitivity}$

7.1 Simulation Results and Evaluations of Liver Disorder Expert System Based on Firefly Algorithm in ILPD

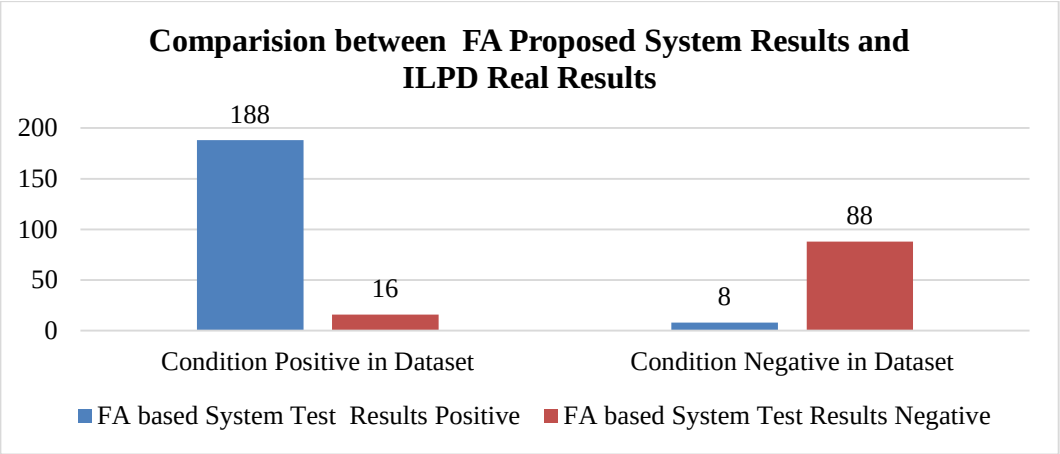
In this study, 300 numbers of patient data were used to evaluate the system and to equilibrate the numbers of liver and non-liver patients. While number of positive liver disorder patient is 204, negative liver patient is 96.

In Table 7.2, Liver Disorder Laboratory Test results can be seen according to the system based on Firefly Algorithm. As it can be obtained from Table 7.2, the system predicted accurately liver disorder test results of 188 number of patients, which had liver disorders; it predicted inaccurately liver disorders test results of 16 number of patients. It could also be seen from the table that the system predicted accurately liver disorders test results of 88 number of patients, which did not have liver disorders, it predicted inaccurately liver disorders test results of 8 number of them.

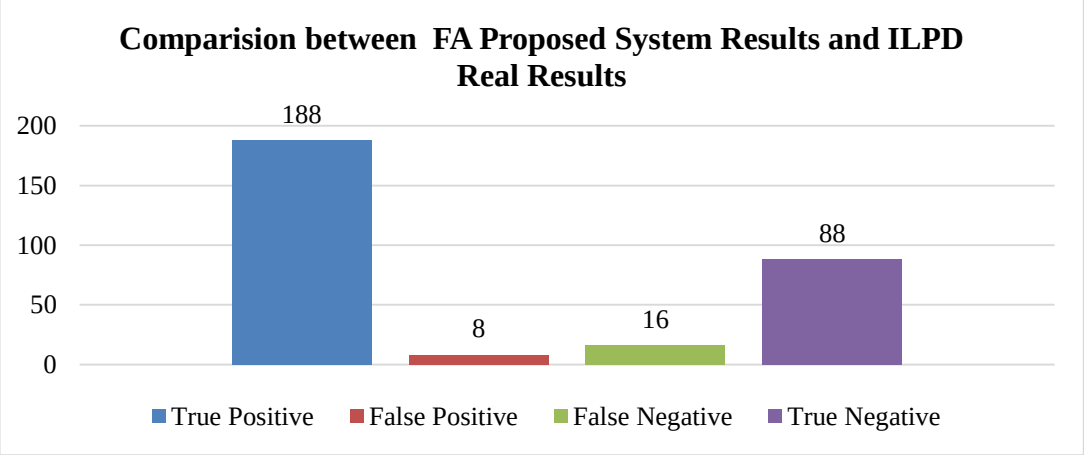
Table 7.2 Liver Disorder Laboratory Test results according to the system based on FA.

Liver Disorders Laboratory Test Results of the FA Based System	**Condition Positive in Dataset**	**Condition Negative in Dataset**
FA based System Test Results Positive	**True Positive (TP) = 188**	**False Positive (FP) = 8**
FA based System Test Results Negative	**False Negative (FN) = 16**	**True Negative (TN) = 88**

In Figure 7.1, it is shown graphical interpretation of the Table 7.2.



(a)



(b)

Figure 7.1 (a) Comparison between FA Proposed System Results and ILPD Real Results (b) Comparison between FA Proposed System Results and ILPD Real Results

As it is shown in Table 7.3, Negative predictive value is achieved 83.01%, Positive predictive value is achieved 95.91%, Sensitivity is achieved 92%, Specificity is achieved 84.16% and Accuracy (ACC) is achieved 92%. Precision is 95.91 and F-Measure is 93.91. Positive predictive value 95.1% is significant because it gives a high confidence that its positive result is true. If sum of the sensitivity and specificity is higher than 170, it can be accepted that the system is useful and helpful as clinical investigation. In this study, the system determines condition as follows:

$$\text{Sensitivity} + \text{Specificity} = 92 + 84.16 = 176.16 > 170$$

Table 7.3 Simulation Results and Evaluations of Liver Disorder Expert System according to FA.

Negative Predictive Value (%)	Positive Predictive Value (%)	Specificity (%)	Sensitivity (%)	Precision (%)	F_Measure (%)	Accuracy
83.01	95.91	84.61	92	95.91	93.91	92

In Figure 7.2, it is shown in graphical interpretation of Table 7.3.

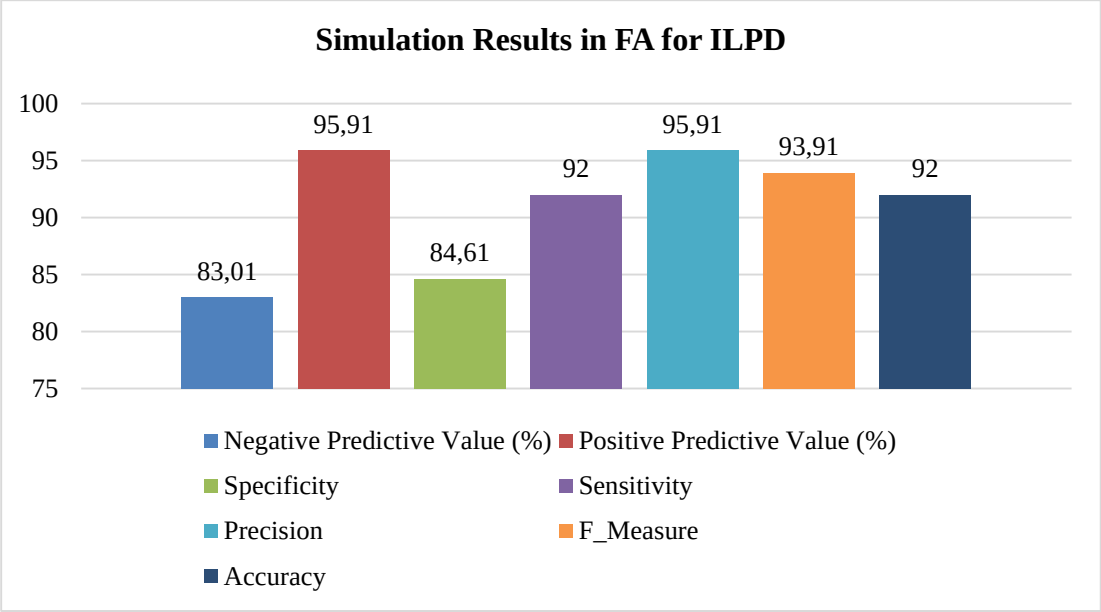


Figure 7.2 Simulation Results in FA for ILPD

Figure 7.3 compares the values of real negative liver disorder and proposed system's negative liver disorder values in ILPD. As it can be seen from the figure, the system achieves highly accurate predictions of Non-Liver Patients' Test Results values.

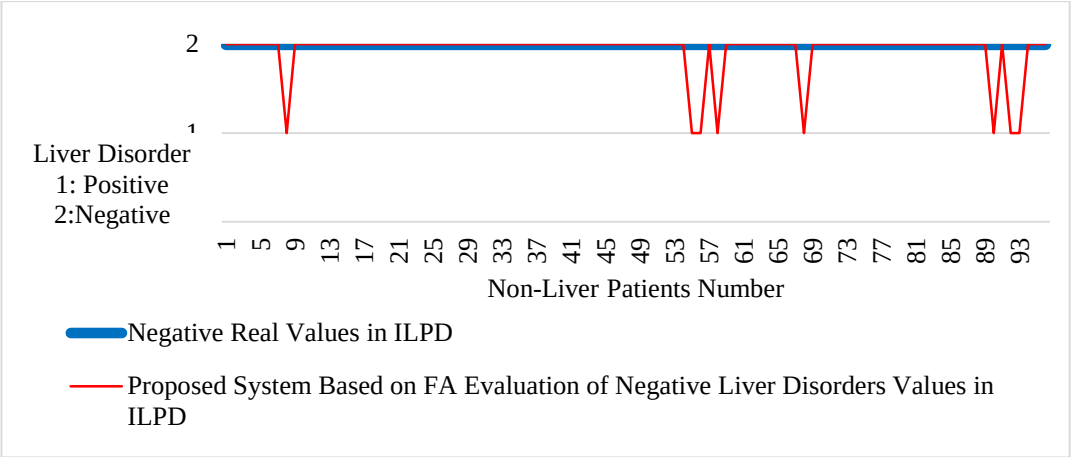


Figure 7.3 Comparison of real negative liver disorder values in dataset and proposed System based on FA negative liver disorders values in ILPD

Figure 7.4 compares real positive liver disorders values in ILPD and proposed system's positive liver disorders values. It can be obtained from the simulation results that the system achieves highly accurate predictions of Liver Patients' Test Results values.

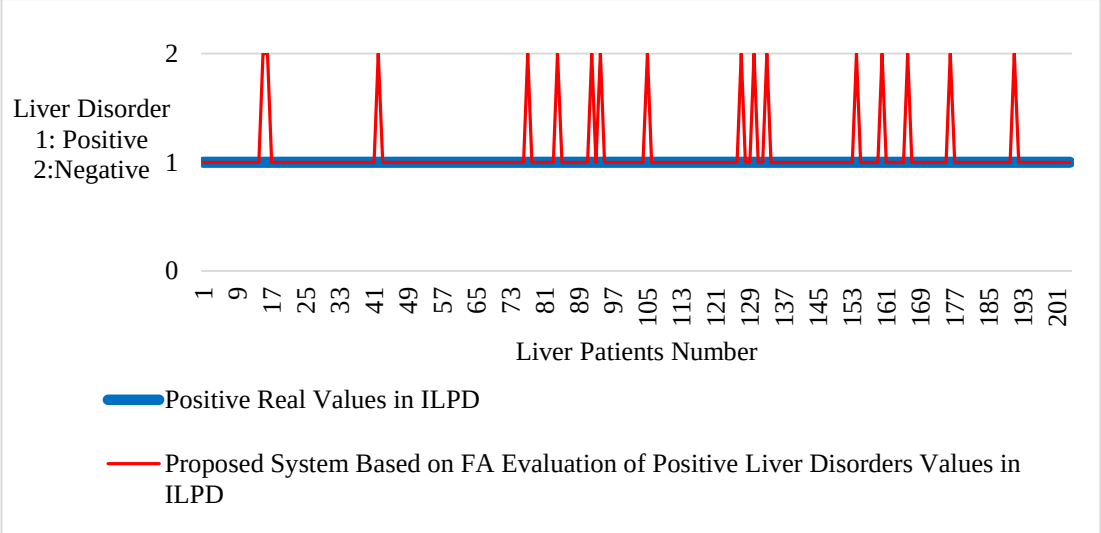


Figure 7.4 Comparison of real positive liver disorders value in ILPD and proposed system based on FA of positive liver disorders values.

7.2 Simulation Results and Evaluations of Liver Disorder Expert System Based on Support Vector Machine in ILPD

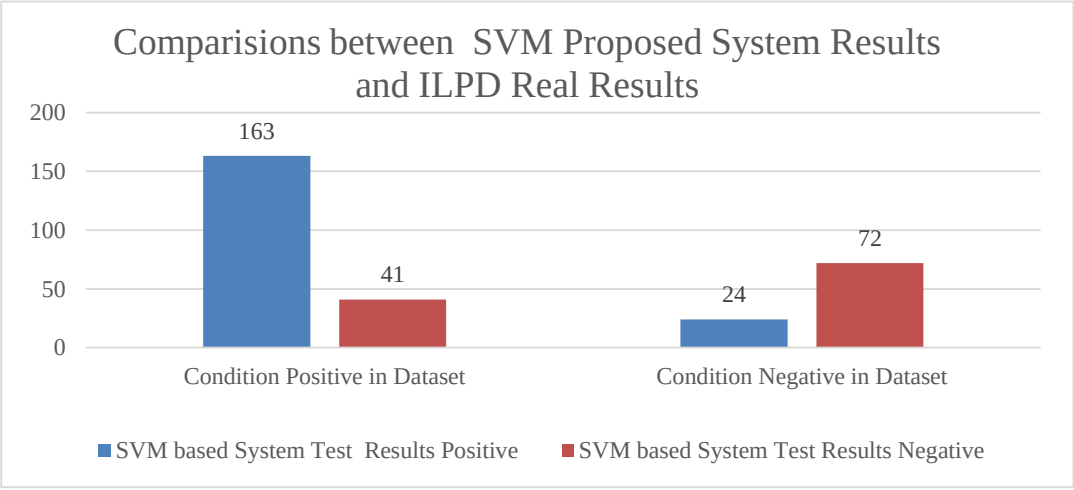
In Table 7.4, Liver Disorder Laboratory Test results could be seen according to the system based on SVM. As it could be obtained from Table 7.4, the system predicted accurately liver disorder test results of 163 number of patients, which had liver

disorders; it predicted inaccurately liver disorders test results of 42 number of patients. It could also be seen from the table that the system predicted accurately liver disorders test results of 72 number of patients, which did not have liver disorders; it predicted inaccurately liver disorders test results of 24 number of them.

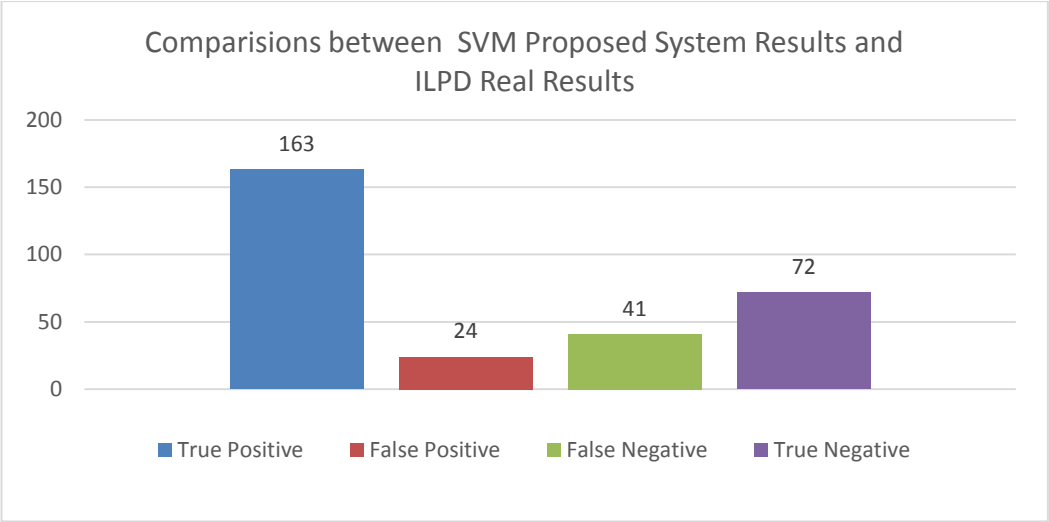
Table 7.4 Liver Disorder Laboratory Test results according to the system based on Support Vector Machine

Liver Disorders Laboratory Test Results of the SVM Based System	**Condition Positive in Dataset**	**Condition Negative in Dataset**
SVM based System Test Results Positive	**True Positive (TP) = 163**	**False Positive (FP) = 24**
SVM based System Test Results Negative	**False Negative (FN) = 41**	**True Negative (TN) = 72**

In Figure 7.5, it is shown graphical interpretation of the Table 7.4.



(a)



(b)

Figure 7.5 (a) Comparison between SVM Proposed System Results and ILPD Real Results (b) Comparison between SVM Proposed System Results and ILPD Real Results

As it is shown in Table 7.5, Negative predictive value is achieved 63.71%, Positive predictive value is achieved 87.16 %, Sensitivity is achieved 79.9 %, Specificity is achieved 75% and Accuracy (ACC) is achieved 78.33%. Precision is 87.16 % and F-Measure is 83.37. Positive predictive value 87.16 % is significant because it gives a high confidence that its positive result is true. If sum of the sensitivity and specificity is higher than 170, it can be accepted that the system is useful and helpful as clinical investigation. In this study, the system determines condition as follows:

$$\text{Sensitivity} + \text{Specificity} = 79.9 + 75 = 156.9 < 170$$

Table 7.5 Simulation Results and Evaluations of Liver Disorder Expert System

Negative Predictive Value (%)	**Positive Predictive Value (%)**	**Specificity (%)**	**Sensitivity (%)**	**Precision (%)**	**F_Measure (%)**	**Accuracy (%)**
63.71	87.16	75	79.9	87.16	83.37	78.33

In Figure 7.6, it is shown in graphical interpretation of Table 7.5.

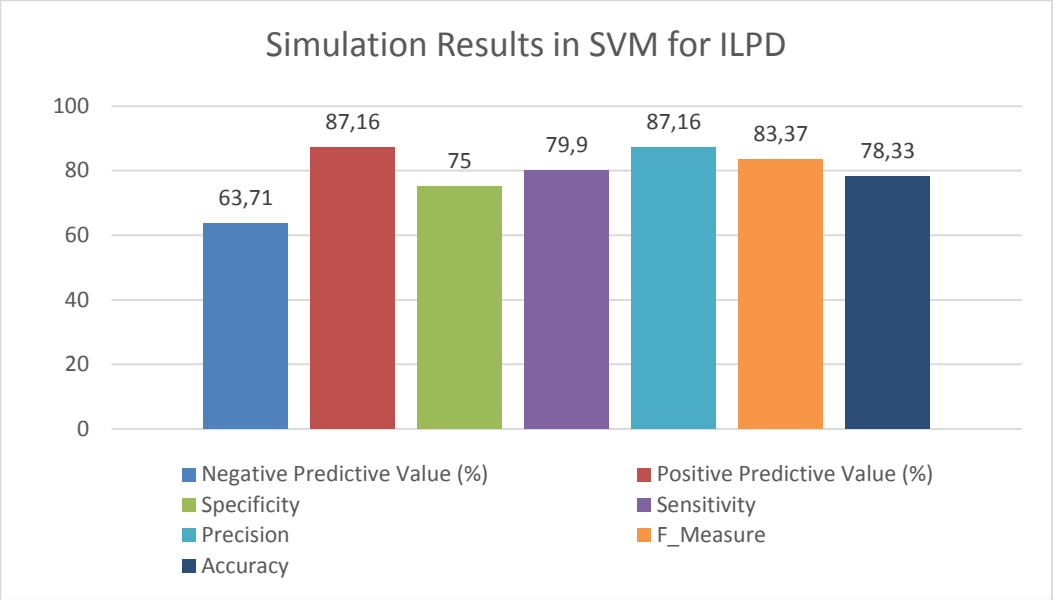


Figure 7.6 Simulation Results in SVM for ILPD

Figure 7.7 compares the values of real negative liver disorder and proposed system's negative liver disorder values in ILPD. As it can be seen from the figure, the system achieves highly accurate predictions of Non-Liver Patients' Test Results values.

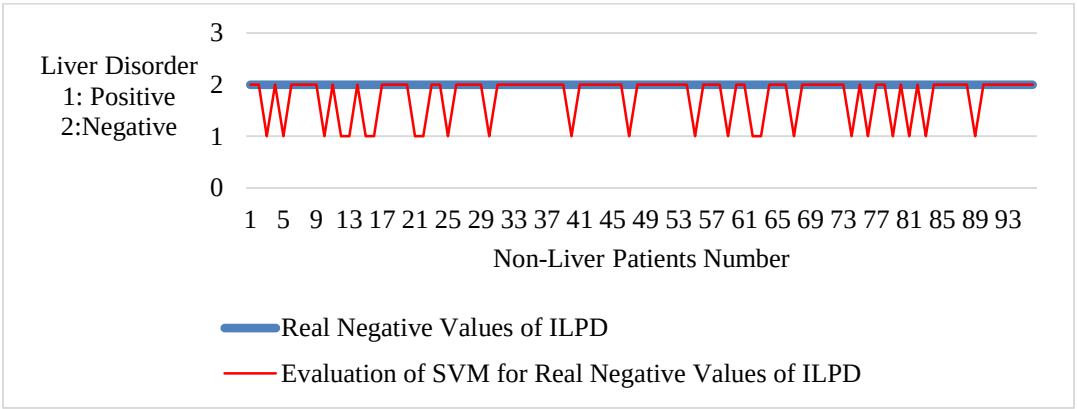


Figure 7.7 Comparison of real negative liver disorder values in dataset and proposed System based on SVM negative liver disorders values in ILPD.

Figure 7.8 compares real positive liver disorder values in ILPD and proposed system's positive liver disorders values. It can be obtained from the simulation results that the system achieves highly accurate predictions of Liver Patients' Test Results values.

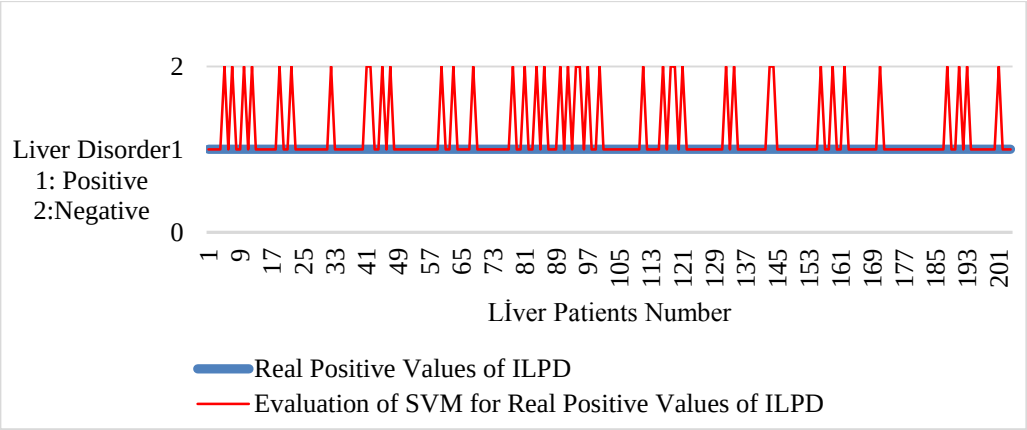


Figure 7.8 Comparison of real positive liver disorders value in ILPD and proposed System Based on SVM of positive liver disorders values.

In Figure 7.9, it is shown that comparison of evaluation of FA and evaluation of SVM for ILPD.

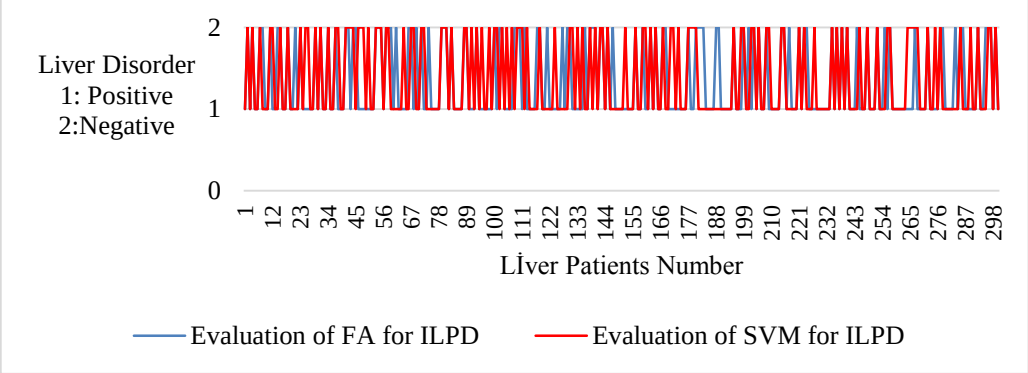


Figure 7.9 Comparison of Evaluation of FA and Evaluation of SVM for ILPD

7. 3 Simulation Results and Evaluations of Liver Disorder Expert System Based on Firefly Algorithm in BUPA Dataset

In this study, 250 numbers of patient data are used to evaluate the system and to equilibrate the numbers of liver and non-liver patients. While number of positive liver disorder patient is 100, negative liver patient is 150.

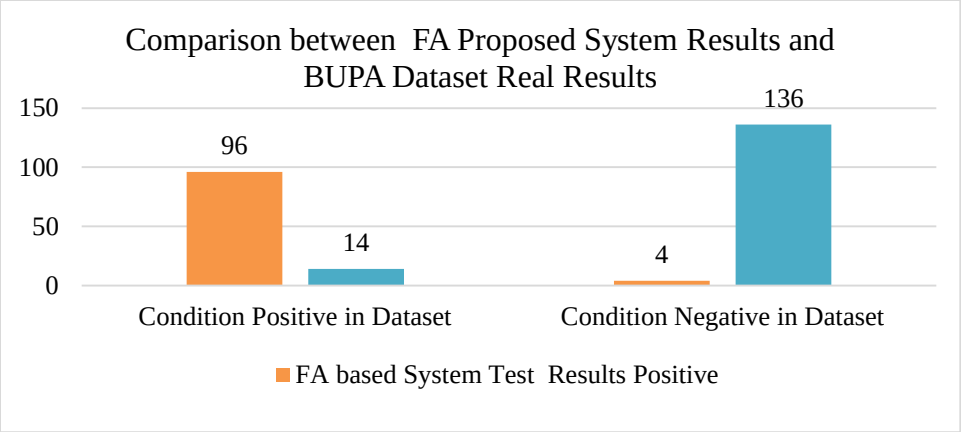
In Table 7.6, Liver Disorder Laboratory Test results can be seen according to the system based on Firefly Algorithm. As it can be obtained from Table 7.6, the system predicts accurately liver disorder test results of 96 number of patients, which have liver disorders; it predicts inaccurately liver disorders test results of 4 number of patients.

It can also be seen from the table that the system predicts accurately liver disorders test results of 136 number of patients, which do not have liver disorders, it predicts inaccurately liver disorders test results of 14 number of them.

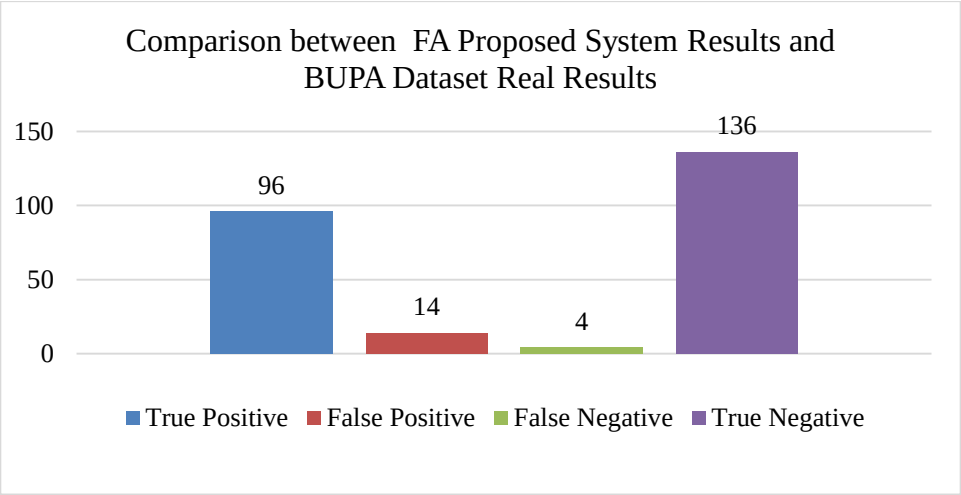
Table 7.6 Liver Disorder Laboratory Test results according to the system based on FA

Liver Disorders Laboratory Test Results of the FA Based System	**Condition Positive in Dataset**	**Condition Negative in Dataset**
FA based System Test Results Positive	**True Positive (TP) = 96**	**False Positive (FP) = 14**
FA based System Test Results Negative	**False Negative (FN) = 4**	**True Negative (TN) = 136**

In Figure 7.10, it is shown graphical interpretation of the Table 7.6..



(a)



(b)

Figure 7.10 (a) Comparison between FA Proposed System Results and BUPA Dataset Real Results (b) Comparison between FA Proposed System Results and BUPA Dataset Real Results

As it is shown in Table 7.7, Negative predictive value is achieved 97.14%, Positive predictive value is achieved 87.27%, Sensitivity is achieved 96%, Specificity is achieved 90.66% and Accuracy (ACC) is achieved 92.8%. Precision is 87.27 and F-Measure is 92.8. Positive predictive value 87.27 % is significant because it gives a high confidence that its positive result is true. If sum of the sensitivity and specificity is higher than 170, it can be accepted that the system is useful and helpful as clinical investigation. In this study, the system determines condition as follows:

$$\text{Sensitivity} + \text{Specificity} = 96 + 90.66 = 186.66 > 170$$

Table 7.7 Simulation Results and Evaluations of Liver Disorder Expert System according to FA in BUPA dataset

Negative Predictive Value (%)	**Positive Predictive Value (%)**	**Specificity (%)**	**Sensitivity (%)**	**Precision (%)**	**F_Measure (%)**	**Accuracy %**
97,14	87,27	90,66	96	87,27	91,42	92,8

In Figure 7.11, it is shown in graphical interpretation of Table 7.7.

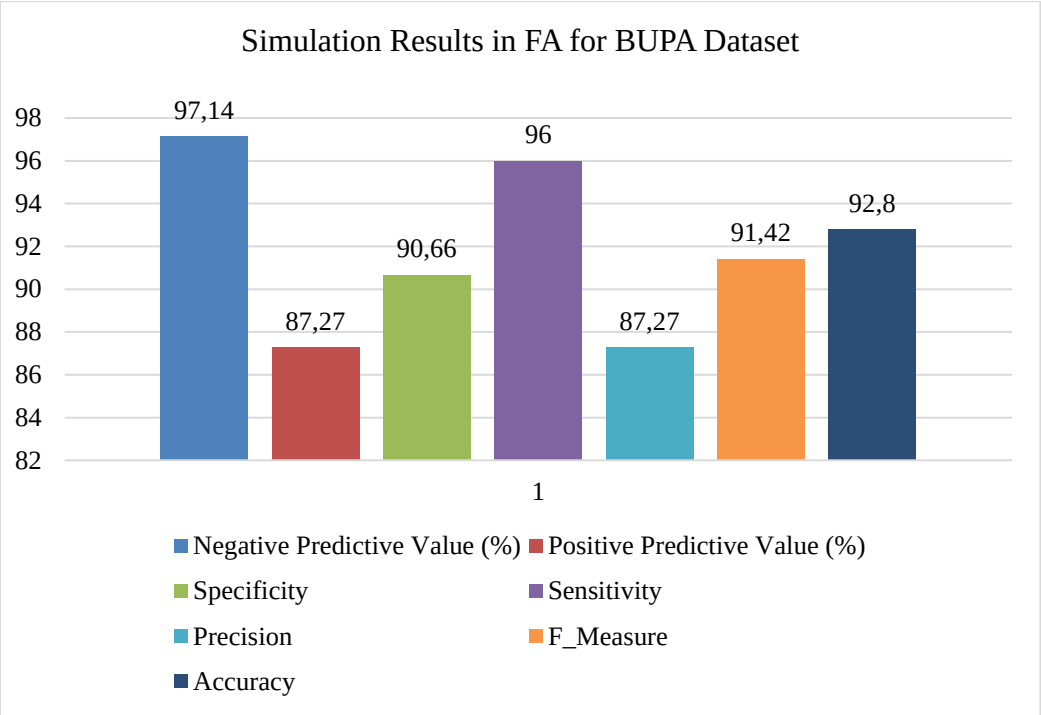


Figure 7.11 Simulation Results in FA for BUPA Dataset

Figure 7.12 compares the values of real negative liver disorder and proposed system's negative liver disorder values in dataset. As it can be seen from the figure, the system achieves highly accurate predictions of Non-Liver Patients' Test Results values.

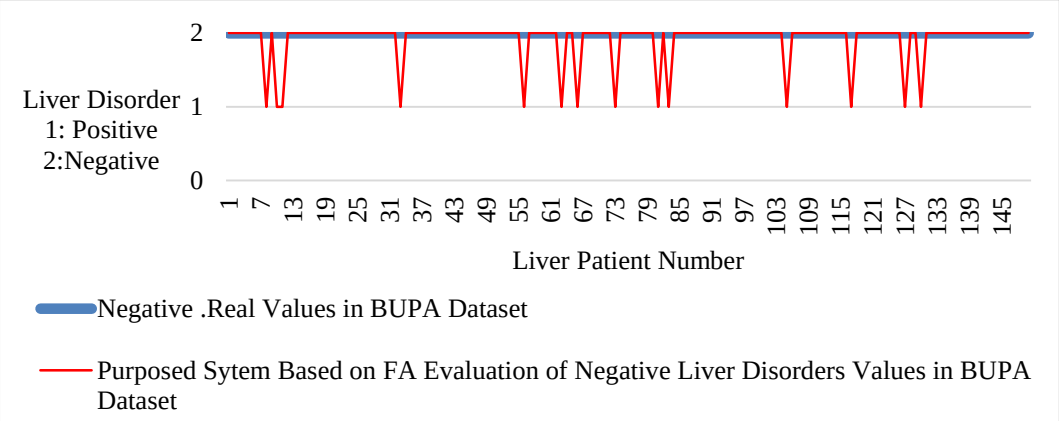


Figure 7.12 Comparison of real negative liver disorder values in dataset and proposed System based on FA negative liver disorders values in BUPA dataset

Figure 7.13 compares real positive liver disorder values in BUPA dataset and proposed system's positive liver disorders values. It can be obtained from the simulation results that the system achieves highly accurate predictions of Liver Patients' Test Results values.

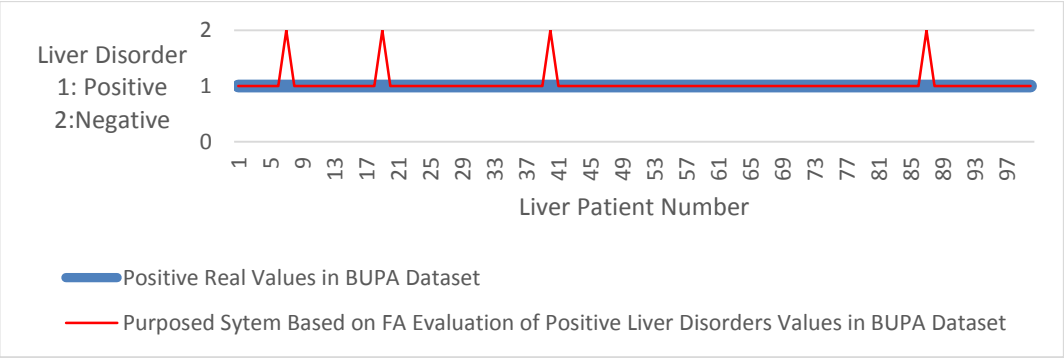


Figure 7.13 Comparison of real positive liver disorders value in BUPA dataset and proposed System Based on FA of positive liver disorders values.

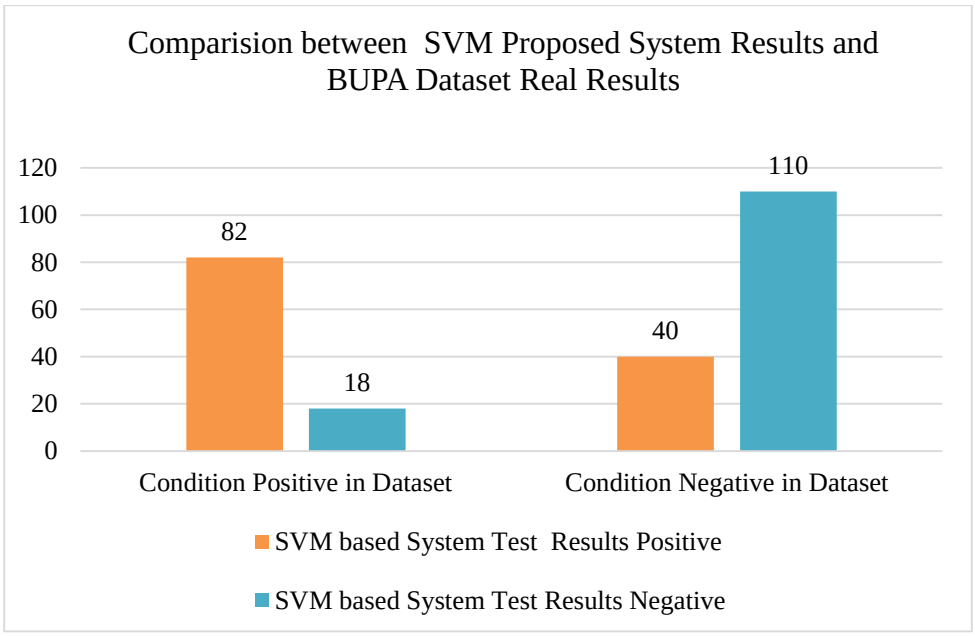
7.4 Simulation Results and Evaluations of Liver Disorder Expert System Based on Support Vector Machine in BUPA dataset

In Table 7.8, Liver Disorder Laboratory Test results can be seen according to the system based on SVM. As it can be obtained from Table 7.8, the system predicts accurately liver disorder test results of 82 number of patients which have liver disorders; it predicts inaccurately liver disorders test results of 18 number of patients. It can also be seen from the table that the system predicts accurately liver disorders test results of 110 number of patients which do not have liver disorders, it predicts inaccurately liver disorders test results of 40 number of them.

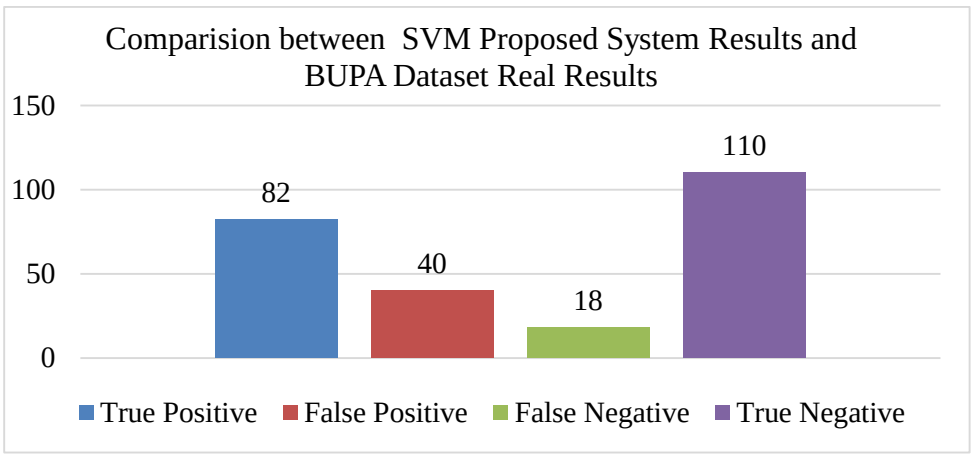
Table 7.8 Liver Disorder Laboratory Test results according to the system based on SVM

Liver Disorders Laboratory Test Results of the SVM Based System	**Condition Positive in Dataset**	**Condition Negative in Dataset**
SVM based System Test Results Positive	**True Positive (TP) = 82**	**False Positive (FP) = 40**
SVM based System Test Results Negative	**False Negative (FN) = 18**	**True Negative (TN) = 110**

In Figure 7.14, it is shown in graphical interpretation of Table 7.8.



(a)



(b)

Figure 7.14 (a) Comparision between SVM Proposed System Results and BUPA Dataset Real Results (b) Comparision between SVM Proposed System Results and BUPA Dataset Real Results

As it is shown in Table 7.9, Negative predictive value is achieved 85.93%, Positive predictive value is achieved 67.21 %, Sensitivity is achieved 82 %, Specificity is achieved 73.33% and Accuracy (ACC) is achieved 76.8%. Precision is 67.21 % and F- Measure is 73.87. Positive predictive value 87.16 % is significant because it gives a high confidence that its positive result is true. If sum of the sensitivity and specificity is higher than 170, it can be accepted that the system is useful and helpful as clinical investigation. In this study, the system determines condition as follows:

Sensitivity + Specificity= 82+73.33= 155.33 <170

Table 7.9 Simulation Results and Evaluations of Liver Disorder Expert System

Negative Predictive Value (%)	Positive Predictive Value (%)	Specificity (%)	Sensitivity (%)	Precision (%)	F_Measure (%)	Accuracy
85,93	67,21	73,33	82	67,21	73,87	76,8

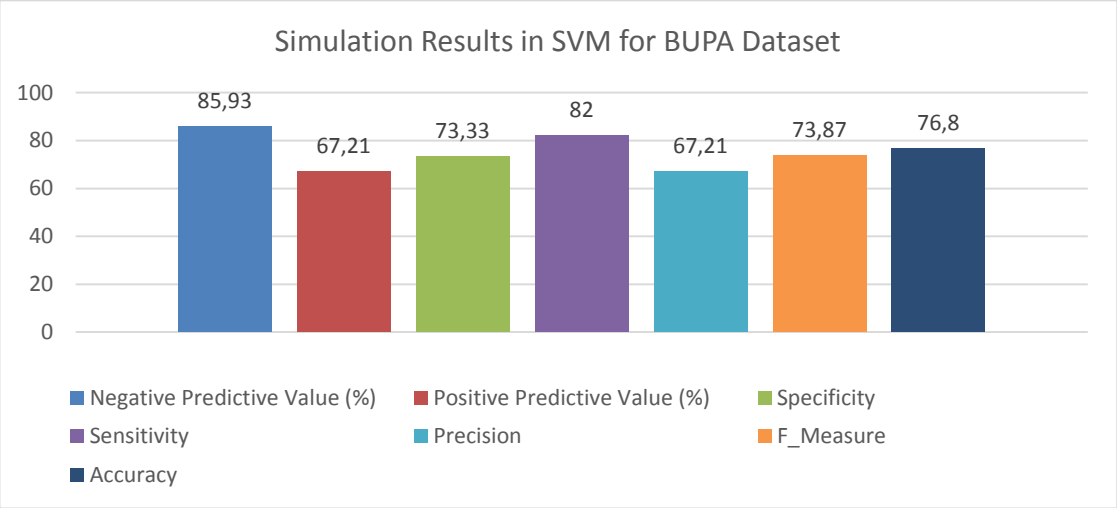


Figure 7.15 Simulation Results in SVM for BUPA Dataset

Figure 7.16 compares the values of real negative liver disorder and proposed system's negative liver disorder values in dataset. As it can be seen from the figure, the system achieves highly accurate predictions of Non-Liver Patients' Test Results values.

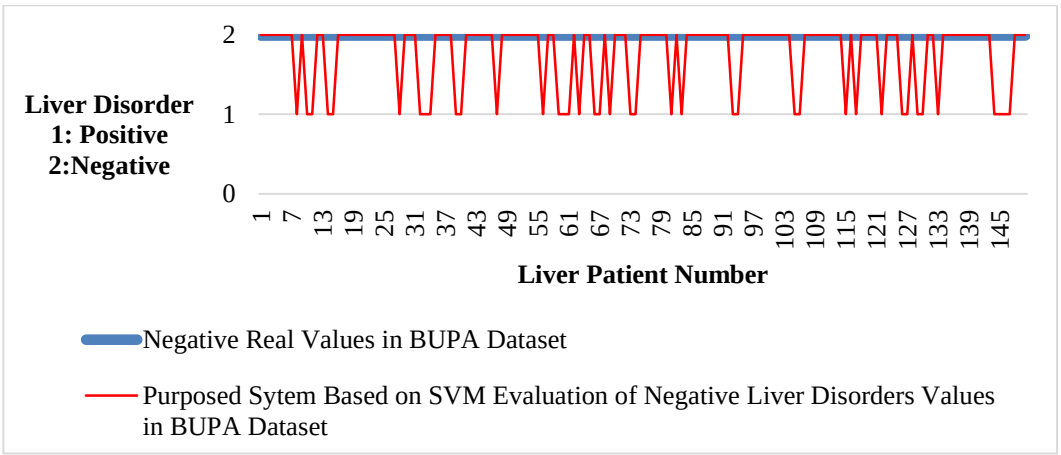


Figure 7.16 Comparison of real negative liver disorder values in dataset and proposed System based on SVM negative liver disorders values in BUPA dataset.

Figure 7.17 compares real positive liver disorder values in dataset and proposed system's positive liver disorders values. It can be obtained from the simulation results that the system achieves highly accurate predictions of Liver Patients' Test Results values.

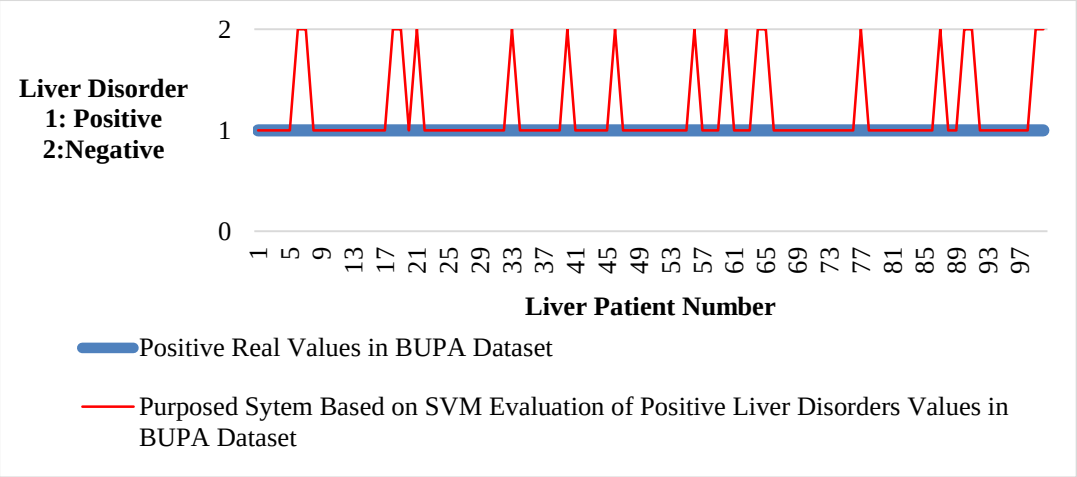


Figure 7.17 Comparison of real positive liver disorders value in dataset and proposed System Based on SVM of positive liver disorders values.

In Figure 7.18 shows that comparisons between evaluation of proposed system based on FA and evaluation of proposed system based on SVM for BUPA dataset.

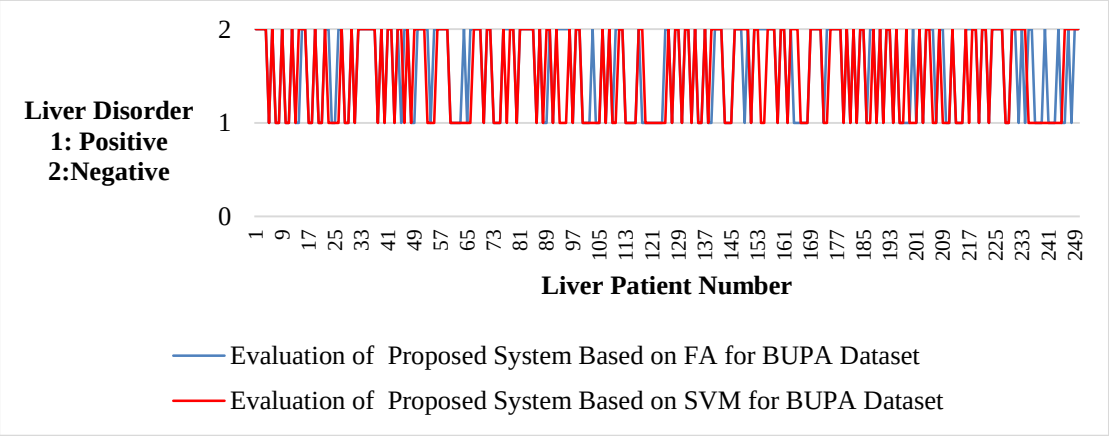


Figure 7.18 Comparisons between Evaluation of Proposed System Based on FA and Evaluation of Proposed System Based on SVM for BUPA Dataset

8. CONCLUSION AND DISSCUSSION

In this thesis study, an Expert System based on Firefly Algorithm (FA), which is one of new applications in AI, and Support Vector Machine (SVM) were generated by using two datasets, ILPD (Indian Liver Patient Dataset) and BUPA Dataset (Liver Disorder Dataset) for diagnosis of liver disorders and new medical expert systems based on AI were obtained.

Algorithms, intelligence systems, artificial intelligence and expert systems were given obviously and thoroughly. Liver and liver diseases and laboratory tests using for diagnosis of liver disorders were introduced clearly. FA and SVM algorithm was introduced and a comprehensive literature review about FA, SVM and diagnosis systems used AI. It was given information of datasets be used in the applications and it is done analyses of between attributes of datasets. These analyses were presented as graphical interpretations and obtaining results from analyses of datasets were used to generate objective function for two algorithms. It was shown of solutions of Lagrange multipliers and objective function designing was clearly exhibited.

Analyses, which were obtained from applications, were presented by using comparisons between FA and SVM for both ILPD and BUPA dataset. These comparisons consisted of graphics and tables, which were obtained from statistical evaluations, Accuracy, Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value, Precision and F-Measure.

This study showed that FA gave more effective results than SVM to diagnose liver disorders. In the recent paper which was presented in 2015 by Jenn-Long Liu and Chung-Chih Li, it was studied a Non-Symmetrical Weighted K-Means (NSWKM) algorithm, Rank-Based Artificial Bee Colony Algorithm, and these two algorithm has been combined and it has been obtained NSWKM-RABC algorithm. NSWKM-RABC has been applied to ILPD and other four dataset for diagnosis. After the results, which were obtained from NSWKM-RABC, algorithm has been compared with Naive Bayes, C4.5 and K-means algorithms [57]. Additionally, we compared FA and SVM

with these algorithms in Table 8.1 showed that these algorithms and FA and SVM results. FA gaved the best accuracy value with 92% and SVM had second-best accuracy result. So it is seen that FA very efficient result for diagnosis of liver disorders.

Table 8.1 Performance Parameters of Liver Disease according to the algorithms. For ILPD [57].

Parameter	Naïve Bayes	C4.5	K-Means	NSWKM-RABC	SVM	FA
Accuracy	55,78%	68.05%	64.25%	72.37%	78.33%	92%
Sensitivity	95.15%	86.71%	91.79%	93.24%	79.9%	92%
Specificity	40.09%	21.21%	29.70%	20.00%	75 %	84.61%

This thesis study can be developed by changing and adding some values and applications. For instance,

- In objective function designing, it can be used different Kernel functions or training set can be chosen more effective by trying different combinations.
- In FA, it can be studied by choosing different distance calculation formulas such as Manhattan distance and Minkowski distance formulas and can be shown that will be obtained more or less effective result.

Because medical diagnosis is very important, such studies will be continued. It is hoped that the generated systems will contribute to in researches of expert systems based on artificial intelligent.

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List of Publications

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