A NEW FUZZY-CHAOTIC MODELLING PROPOSAL FOR MEDICAL DIAGNOSTIC PROCESSES

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TİMUR BEYAN

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Approval of the Graduate School of Informatics.

Assoc. Prof.Dr. Nazife BAYKAL
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Onur DEMİRÖRS
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Information Systems.

Assoc. Prof.Dr. Nazife BAYKAL
Supervisor

Examining Committee Members

Assist. Prof.Dr. Erkan MUMCUOĞLU	(METU, Informatics Ins.)	
Assoc. Prof.Dr. Nazife BAYKAL	(METU, Informatics Ins.)	
Dr. Ali ARİFOĞLU	(METU, Informatics Ins.)	
Dr. Aydın KOLAT	(MNG Bilgisayar A.Ş.)	
Zeki SAGAY	(MNG Bilgisayar A.Ş.)	

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Timur BEYAN

ABSTRACT

A NEW FUZZY-CHAOTIC MODELLING PROPOSAL FOR MEDICAL DIAGNOSTIC PROCESSES

Beyan, Timur

M.S., Department of Information Systems
Supervisor: Assoc. Prof. Dr. Nazife Baykal

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Main reason of this study is to set forth the internal paradox of the basic approach of the artificial intelligence in the medical field to by discussing on the theoretical and application levels and to suggest solutions in theory and practice against that. In order to rule out the internal paradox in the medical decision support systematic, a new medical model is suggested and based on this, concepts such as disease, health, etiology, diagnosis and treatment are questioned. Meanwhile, with the current scientific data, a simple application sample based on how a decision making system which was set up by fuzzy logic and which is based on the perception of human as a complex adaptive system has been explained. Finally, results of the research about accuracy and validity of this application, current improvements based on the current model and the location on the artificial intelligence theory is discussed.

Keywords: Medical model, Fuzzy Logic, Complex Adaptive Systems, Chaos Theory, Artifical Intelligence, Clinical Decision Support Systems

ÖZ

TIBBİ TANISAL SÜREÇLER İÇİN YENİ BİR BULANIK-KAOTİK TIBBİ MODELLEME ÖNERİSİ

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Bu çalışmanın temel amacı, yapay zekanın tıp alanındaki temel yaklaşımının içsel çelişkisini teori ve uygulama düzeyinde tartışılarak ortaya koymak ve buna karşı teorik ve pratik düzeyde çözümler önermektedir. Tıbbi karar destek sistematiğindeki içsel çelişkinin ortadan kaldırılması için yeni bir tıbbi model önerisinde bulunulmakta, buna dayanarak hastalık, sağlık, etiyoloji, tanı, tedavi gibi kavramlar sorgulanmaktadır. Bu arada mevcut bilimsel bilgi ile, karmaşık adaptif bir sistem olarak insanın algılanması temeline dayanan ve bulanık mantıkla kurgulanmış bir karar verici sistemin nasıl geliştirilebileceği basit bir uygulama örneği ile de açıklanmaktadır. Son olarak, bu uygulamanın doğruluk ve geçerliliğinin araştırma sonuçları, mevcut modele dayanan olası açılımlar ve bunun yapay zeka teorisindeki yeri tartışılmaktadır.

Anahtar Kelimeler: Tıbbi Model, Bulanık Mantık, Kompleks Adaptif Sistemler, Kaos Teorisi, Yapay Zeka, Klinik Karar Destek Sistemleri.

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LIST OF ABBREVATIONS AND ACRONYMS

ATHENA	:	Assessment and Treatment of Hypertension: Evidence based Automation
CDC	:	Centers for Disease Control and Prevention
CDSS	:	Clinical Decision Support System
CEMS	:	Clinical Evaluation and Monitoring System
CWP	:	Computing with Words and Perceptions
ERA	:	The Early Referrals Applications
HIS	:	Hospital Information System
HIV	:	Human Immunodeficiency Virus
ICD-10	:	International Classification of Diseases-10
IOM	:	Institute of Medicine
IPR_{OB}	:	Intelligent Patient Record for Obstetrics
ISM	:	Integrated Science Model
LISA	:	Leukemia Information System and Advice
MAX	:	Maximum operator
MIN	:	Minimum operator
OPPASS	:	Out Patient Preassesment System for Windows
PAIRS	:	Physician Assistant Artificial Intelligente System
QMR	:	Quick Medical Reference
WHO	:	World Health Organization

CHAPTER-1

INTRODUCTION

1.1. SCIENTIFIC MODELING AND ITS EVOLUTION

Science, in order to be able to realize certain aims regarding the outside reality such as prediction, control, deals with the reduction of the perceived/measured dimensions of this reality to an acceptable level and its modeling. There are several phases in establishing a scientific model [Kuhn 1970, Demir 2000].

First, problem area should be perceived and defined. An experiment and observation-based approach is used in scientific methodology in obtaining the data regarding the perception and definition of the reality [Chalmers, 1978].

Scientist interprets the data she/he has obtained with experiment and observation in a certain view and understanding and develops a model. During this process, various concepts and terms defining the relevant area are discussed. Scientist, during this effort, puts forward his/her model in line with a specific perspective (paradigm) formed by his/her own values and acknowledgements and by using a (mostly Aristotle's) logical inference [Kuhn 1970, Chalmers, 1978].

Afterwards, she/he develops with current methods several practices aimed at intended goals. These practices developed for the solution of the problems in the related area will never reach a perfect conclusion because the model developed by the scientist at the very beginning is in fact just a reduction of the actual problem area. In time, when the balance between the benefit from the practices and the problems that occurred, come to an unaccepted level, new searches begin. In this case, generally adapted approach is to develop new practices. Sometimes, to develop new practices, new methods and approaches born out of different disciplines are applied to the present model [Kuhn 1970, Demir 2000].

However, if the desired success can still not be achieved, the model (that is, the theoretical structure such as definitions, concepts, and terms) is questioned. The model is revised by adding to the model the newly perceived parts of the reality or that parts whose importance has just been recognized. Sometimes, this is also considered inadequate and a new model is established after current model is completely demolished. This is called paradigm shift [Kuhn 1970]. These phases can be generally defined as epistemological level, modeling level (paradigm level) and implementation level (Figure 1.1).

Scientific methodology has adopted the experiment and observation as the source of knowledge. Therefore, almost all the scientific studies have been based on experiment and observation. Scientific debates, where questioning on such level that can be called epistemological level, takes place can cause severe cracks in the wholeness of the science. The most obvious example for this is the quantum theory. It caused a serious crack in scientific epistemology by defending the impact of the observant in the observation process and the principle of uncertainty and its agreement with the classical Newton physics was made possible only by assuming it was valid only in a specific dimension of the universe [Demir 2000].

Second level is the modeling level. Scientist, during modeling, (generally) has various subjective restrictions she/he herself/himself is not aware of. His/her senses, values and acknowledgements, formal education and prejudices are the main elements forming this perspective. Scientist, with this subjective perspective she/he owns, defines the problem area and other concepts related to the problem. One of the main characteristics of this perspective is that outside reality is defined as objects (concept, object, category, group etc.) and the relations among them. There are two sub-phases on modeling level: making definitions and developing (or implementing) the methods. After making the definitions, obtained data are integrated by using logical inferences as a whole. On the other hand, the ground is set for the technological production by applying the current methods to the models [Kuhn 1970, Demir 2000].

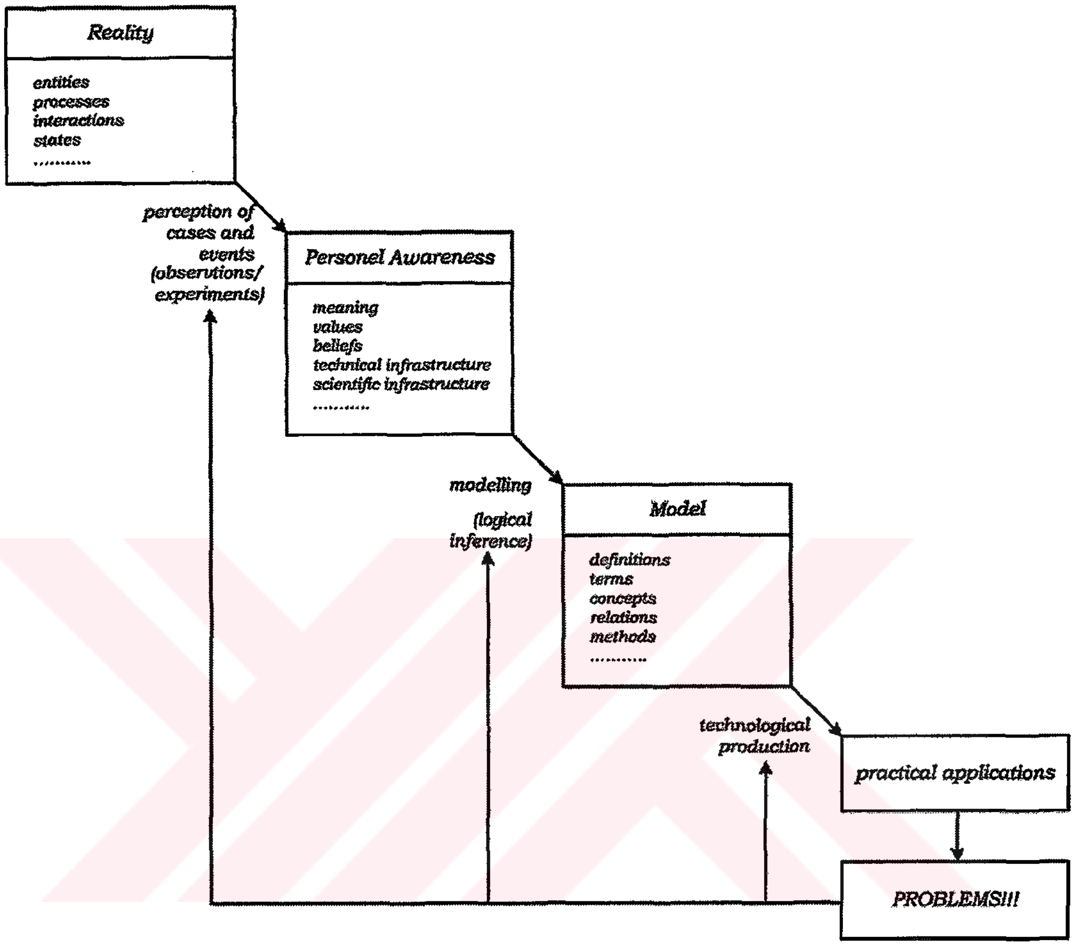


Figure 1.1. *Levels of scientific methodology (revised from [Kuhn 1970, Dodig-Crnkovic 2002])*

Third level is the implementation level. The model obtained at the end will never be perfect since it is just a reduced indicator of the reality due to the nature of the scientific knowledge. In time, problems will arise in practice and practices and solutions will be sought for these problems first in methods and then definition. From time to time, methods used in different disciplines will be adapted or the problem will be tried to be solved by revising the model set at the beginning. Medicine has undergone this whole process and still does [Demir 2000].

1.2. SCIENCE AND MEDICINE AS PRACTICE

Medicine is a science when its part using the scientific method is concerned and a "craft" when its generally accepted practices are concerned. The subject matter of the medicine is bringing the changes that are called "anomaly" in the complex body of the human being to the normal values and establishing a complete state of wellness in its every aspect [Sadegh-Zadeh 1999].

It was the biomedical model that had been first developed when an approach of scientific medicine was appearing in line with the atomistic Descartes-Newton perspective. No matter how well-structured it was, there are several areas where medicine has failed in daily life as every scientific activity do. While some of these failed areas stem from individual and institutional mistakes, some part is due to the grounds of the area and its internal structure. For eliminating these defects in internal structure, biomedical model has been restructured so that it encompasses psychological and social perspective. It is still hard to say that these models are widely accepted in practice [Sadegh-Zadeh 1999].

Human being is a multi-layered and multi-dimensional whole of complex relations so it is impossible to make a simple distinction between the states of illness and health. The process that we mostly call illness displays a blurred bordered, dynamic and variable structure. Medical staff aims to understand the "real" meaning and importance of this process by the help of the arguments such as complaint, symptom and finding, which are reflections of this structure that consists of multi-level interactions and which they are a part of and they aim to interfere with this process if a deviation is in question [Demir 2000].

With information systems have been developed, a lot of decision support systems have been produced for supporting the "medical decision-making" of the medical professions. Yet, these decision support systems aren't on the desired level in terms of both scope and effect. The foremost reason for this is that various types of uncertainty have come out due to the complex and adaptive structure of the human being. Different approaches have been defended for coping with these uncertainties within the framework of both classical and flexible methods. However, while all these being done, a major problem area has been ignored. The main reason underlying the inadequacy or failure of the current medical decision support systems is caused by the faulty and subjective acknowledgements regarding the offering of the medical knowledge, expression of the process of medical decision-making, and basic medical concepts. In short, a new medical model is needed for minimizing the number of problems. This can only achieved with the theory of fuzzy logic and chaos that offers different opportunities on the level of method developing with regards to epistemology, modeling and practice.

1.3. FUZZY LOGIC, CHAOS THEORY AND THEIR CONTRIBUTIONS TO MEDICINE

Chaos Theory (science of complex systems) is a determinist science but with a subject matter that examines unforeseeable nonlinear behavior, that behavior existing in the most systems in the nature [Baykal and Beyan 2004-1, 2004-2].

Fuzzy logic was first put forward in 1965 by L. Zadeh. Basically an extension of the classical Aristotle's logic, fuzzy logic is used on many different levels ranging from group theories to inference, from model approximation to probability theory and to the calculation with words and perceptions [Baykal and Beyan 2004-1, 2004-2].

Fuzzy logic can also be used in to develop of different methods and devices that can be useful in practice. We can cite the fuzzy medical decision support systems and fuzzy medical control systems as examples. On a higher level, that is, on the level of structuring concepts, terms and definitions, fuzzy logic can be used for developing a new medical model. Via fuzzy logic, basic definitions such as disease, health, factor and treatment, relations among terms and hence medical decision-making process can be redefined. There is a limited number of studies regarding this issue [Baykal and Beyan 2004-1, 2004-2].

As for the epistemological level, in terms of obtaining the knowledge and its characteristics, *fuzzy logic represents* an alternative to the recent concept of perception-based calculation and to the concept of "measurement" that has been widely accepted until now as the criterion of the scientific feature and offers new implications to approximate modeling [Baykal and Beyan 2004-1, 2004-2].

Human body is a complex and adaptive system continually maintaining a dynamic balance (homeodynamic). Uncertainty and fuzziness are the basic potential and internal property of the human health as the same in every complex adaptive system. It should be kept in mind that every scientific approach dealing with human being is a complex and adaptive structure [Baykal and Beyan 2004-1, 2004-2].

In the area of medicine, observing the behavioral changes of this adaptive structure at the closest point, symptoms and findings which are the basic elements of the decision-making is generally expressed in words. Besides, it is meaningless in practice to define the limits of normal/anomaly for the measurable data because same values belonging to the one parameter can change from people to people and can even be the indicators of both normal/abnormal from time to time. Here, we see "*gradual membership to a group (fuzzy membership)*. The most effective method in calculating the verbal expressions and assessing the concept of gradual membership is fuzzy logic. So, a modeling approach based on fuzzy logic and chaos theory seems to be and ideal *methodology* [Baykal and Beyan 2004-1, 2004-2].

1.4. PROPOSALS AND CONTRIBUTIONS

One of the most prioritized aims of this thesis is the restructuring of the current model, one of the main sources of the internal uncertainty in medicine, by using *fuzzy logic and complex adaptive systems*. Within this scope, a new fuzzy-chaotic model is defined. Afterwards, disease, health, causes (etiology) and process of the disease, diagnostic methods and medical decision-making processes are redescribed from this point of view. This model is still developing.

In the 5th chapter, a system that is based on the verbal modeling technique of the fuzzy logic and subjective complaints of the individuals, that takes into account the state of "wellness" which is the criterion for the adaptive ability of the society and individuals, that determines the possible diseases and their emergency degrees by using fuzzy verbal expressions have been described.

This system which is based on newly developed medical model has two phases: In the first phase, following the patient's complaints, data obtained by questioning individual (age, gender, medical properties etc.), risk factors and possible etiological agents are combined with the approach of fuzzy logic and most probable diseases are determined.

In the second phase, the individual's biological and psychological characteristics are questioned, his/her response ability to the disease process is determined, and with this value, person-specific urgency degree is set. At the end, individual is guided by utilizing the information obtained after these two phases. It is concluded that such effort sets the ground for developing some concepts and approaches regarding the establishment of the intuitional model of the clinical diagnosis process that is planned to be made in the future.

This study has respectively been structured as follows:

In ***Chapter 1,*** general structure of the study is defined; brief information about the perspective used in the study is given and the contributions made by the study are summarized.

In ***Chapter 2,*** current definitions of health, disease and illness and current medical models are discussed; generally accepted process of medical decision-making is summarized; medical mistakes, their prevalence and importance are described; information about studies of artificial intelligence and decision support systems is given together with the sources of uncertainty in medicine.

In ***Chapter 3,*** for the purpose of setting the ground for a new model, information about the theory of fuzzy logic and complex systems is given.

In ***Chapter 4,*** using the theory of fuzzy logic and chaos, a new model is developed for defining the concept of human being; within this framework, the concepts of disease, health and illness are defined; possible implications of the processes of clinical assessment and treatment are mentioned.

In ***Chapter 5,*** in line with the newly proposed model, as an example to the use of the information provided to us by the current medical paradigms, a system that starts from the subjective complaints of the individuals, that determines the possible diseases and their emergency degrees by assessing the individual's general wellness, risk factors and protective factors is developed. The research about "from complaints to disease" approach is defined and methodology is explained.

In ***Chapter 6***, conclusions of this research are assessed, potential effects and feasibility of the general model is discussed and its possible implications are evaluated.

The principal thesis in this study;
-that source of the uncertainty in medicine is in the essence of the human being that is a complex and adaptive system and it is not completely foreseeable,
-that information systems and artificial intelligence practices that have been generated for increasing the quality of the healthcare and reducing the cost can have a limited positive contribution to the present chaos,
- that it is necessary to define a new medical model by using the theory of fuzzy logic and complex systems, which defines the reality more appropriately and to base the medical education and service on this model.

In the 5th chapter, an implementation that will reveal the possible adaptation of the medical knowledge that has been institutionalized within the framework of the present medical model to the newly proposed model. In the 6th chapter, the results of this approach and possible directions are discussed.

CHAPTER-2

CURRENT MEDICAL SYSTEM, PROBLEMS AND APPROACHES

In this chapter, general information about the foundations of the current medical model is given and problems in the current structure, new approaches put forward against these problems, sources of the uncertainty in the medicine and practices of artificial intelligence in medicine are summarized.

In so doing, answers for the questions below are given:

1. What do the concepts of health, disease and illness mean according to the current medical understanding?

2. What are the current medical models and their alternatives?

3. What is the foundation of the clinical diagnostic process and decision-making in medicine?

4. What is the achievement of the medical system? What are the medical mistakes and their results?

5. What are the practices of artificial intelligence and their results?

2.1 CONCEPTS OF HEALTH, DISEASE, ILLNESS AND SICKNESS

In this section, concepts of health, disease, illness and sickness are defined, and various approaches to these concepts originated from medical philosophy are briefly summarized.

In its broadest sense, health is defined today as the "lack of disease or illness". World Health Organization (WHO) defines health as "the state of biological, social and mental well-being. [Sahler and Carr, 2003].

According to the etiology, ***disease*** is defined as an environmental trauma, biological functional disorder or a process developed due to an identifiable agent or substance. Diseases may cause a structural defect or a functional disorder. ***Sickness*** is the uncomfortable feeling of sick person with no identifiable disease existing. A person may not feel himself sick even though s/he is sick. ***Illness*** is the combination of how the patient feels about the disease and his/her perception of the disease and the reaction of the surrounding and his/her family against the disease. Illness is affected by the society or the person's family. Disease, illness and sickness do not necessarily exist in the same patient at the same time [Sahler and Carr, 2003].

However, it is sometimes the case that concepts of illness and sickness can be replaced each other. There may be implications of the concept of health in modern sense on three levels such as individual, social context and their interactions. Medical convention (especially biological model) has been concentrated on the individual for a long time. Thanks to the increase in the medical knowledge, a significant amount of knowledge has been achieved regarding the physiological and psychological body of the human being. Views of Thomas McKeown are more related with the social context. McKeown emphasizes the importance of the environment and presents the crucialness of correcting the environmental factors in the phenomenon of health as the case. According to this approach, most effective factors on health are the social and economic environment. A third view focuses on the interaction between the individual and his/her surroundings. The studies of

Talcott Parsons express that people's health conditions are closely related to their work and social environments [Glouberman, 2001]

People's perceptions of health and illness vary from culture to culture and it is concept-specific, dynamic and variable. Sociologists, anthropologists and historians have described the social foundations of the concepts of health and illness [Bilton, Bonnett, Jones, Lawson, Skinner, Stanworth, Webster, 2002].

There is no agreed definition of the concept of disease in Medical Philosophy; various approaches regarding the concept and categorization of disease such as normativism, descriptivism, naive normativism, metaphorism and Philistinism are expressed [Sadegh-Zadeh.1999]

Normativism sampled by H. Tristram Engelhardt Jr. defends that an independent distinction between health and disease is not possible. Members of this school emphasize that during the course of the history, several conditions (homosexuality, masturbation, free thought) change into normal states from being called disease because of the value and meaning that we attribute to certain concepts. Therefore, they express that there can not be an objective fact or meaning determining whether the organism is healthy or sick. According to the members of this school, as our knowledge about the biological conditions expands, our analyses as to the concept of disease will also change [Sadegh-Zadeh, 1999; Holm, 2002].

Descriptivism or ***naturalism*** is just in the opposite direction of the normativism. According to the realistic or functional analysis of the disease concept mentioned by Christopher Boorse in classical terms, disease appears as an objective deviation in the functions of the organism. Other functionalist philosophers have included social functions as well or they have been alienated from the statistical normality of Boorse. Yet, their basic analyses are the same at the root. The main advantage of this approach is that it aims to eliminate the subjective values attributed to the diseases. According to this, disease is a type of statistical below-normal biological body functions and health is the nonexistence of disease. Here, phenomena of health and disease are considered as objective issues without any value required [Sadegh-Zadeh, 1999; Holm, 2002].

According to the ***naive normalism*** dominant in the medical education, health is a normal condition while disease is an abnormal one. Here, normal and abnormal are not distinctively separated. ***Metaphorism*** approach of Thomas Szasz is limited to psychiatrics and defends that mental illness is just a myth. ***Philistinism***, expressed by Germund Hesslow, says that disease, health and illness are unnecessary and irrelevant concepts in medicine [Sadegh-Zadeh, 1999].

2.2 MEDICAL MODELS

In this part, several historical models of medicine and their characteristics are evaluated.

Though it is claimed that history of the medical practice dates back to 30.000 years ago, systematic records about the human body and healthcare belong to Babylonians 6000 years ago. In 1500 – 500 B.C, Chinese, Ayurveda and Greek medicine was developed [Sahler and Carr, 2003]. Towards the 17th century, developments in natural sciences gave way to a significant number of studies on the physical, mechanical and chemical functions of the human body. Towards the end of the 19th century, when medicine began to gain a scientific ground, clinical techniques were also developed and became to be disease-specific [Sahler and Carr, 2003].

2.2.1 Biomedical Model

Medicine in modern sense was established at the end of the 19th century. Darwin's thesis "Origin of Species" where he explained the theory of evolution was printed in 1856. In biomedical model evolved from this theory, human is defined like the other biological entities in the nature [Ogden, 2004].

Biomedical model, based on the basic biological sciences and scientific methodology was put forward in the Flexner report which was published in 1910 and demanded higher standards in the USA for the medical education [Sahler and Carr, 2003].

Biomedical can be explained in brief as follows [Ogden, 2004; Bilton et. al., 2002]:

What are the reasons for the diseases? According to the biomedical model, reason for the disease is either the factors occupying the body from outside the body and causing a physical change or internal involuntary changes. We can cite the chemical imbalances, bacteria, virus and genetic susceptibility as examples for these factors.

Who is responsible for the illness? Since diseases depend on uncontrolled factors, individuals aren't responsible for the diseases. Patients are considered as victims to the external factors causing internal changes.

How should treat? Biomedical model defends such treatments as vaccination, surgical treatment, chemotherapy and radio therapy that aim to change the physical condition in the body.

Who is responsible for the treatment? Medical professionals are responsible for the treatment.

What is the correlation between the health and illness? In biomedical model, health and disease are considered different in quality. Person is either ill or not. There is no continuity between the two.

What is the correlation between the mind and the body? According to the biomedical model, these two are independent from each other. This is because of the conventional distinction between mind and the body. According to this, mind being an abstract phenomenon, is about the feelings and thoughts. Body is a physical substance. Hence, mind can not affect the physical substance and mind and body are completely different phenomena.

What is the role of the psychology in the phenomena of health and illness?
According to the conventional biomedical model, diseases may have many psychological results but may not have psychological reasons.

During the 20th century, many evidences were observed against the many claims of the biomedical model. But, whether several different medical models conflicts with each others in scientific and practical areas in modern era, the dominant medical paradigm is, unfortunately, the biomedical model.

2.2.2 Psychosomatic Medicine

Inadequacy of the biopsychosocial model became evident during the Second World War with the soldiers suffering from the post traumatic stress disorder. The importance of the psychosocial factors on the disease perception of the patient and the results of the treatment came clear [Sahler and Carr, 2003].

This situation gave way to the development of different understandings such as psychosomatic medicine, behavioral health, behavioral medicine and in recent times, health psychology and to the improvement of the models of psychological and sociocultural health care as alternatives to the pure biomedicine model [Sahler and Carr 2003; Ogden 2004].

Psychosomatic medicine is the first challenge to the biomedical model. It first appeared at the beginning of the 20th century with Freud's relation analysis between mental and physical illness. When commenting about a disease called hysterical paralysis, Freud defended that an interaction existed between the mind and the body and that psychological factors might also be the reason for the disease as well as the result [Ogden, 2004].

2.2.3 Biopsychosocial Model

In 1970s, a broader health care model was needed. George Engel, an internal specialist in Rochester University, in his article "The Need for a New Medical Model:

A Challenge for Biomedicine" published in 1977 in "Science", proposed a new approach called biopsychosocial model. Engel, in this model, defends there are lots of determiners in the development of the disease and depended illnesses, hierarchical structure of the biological and social system has impact on the disease and illness experience. According to him, every system is a subsystem of a more abstract system and all the systems are closely related to each other. Any change in one system will affect the other. Engel, moreover, expresses that psychological and social sciences are also important for understanding the determiners of the illness as well as the natural sciences [Sahler and Carr, 2003].

In his criticism of the biomedical model, Engel claims that there are different reasons for the illness on the molecular, individual and social levels. Besides, it is of concern that psychosocial factors affect the biological treatment (placebo effect) also on treatment level [Borrell-Carrió, Suchman, Epstein, 2004].

Engel emphasizes that clinicians should assess the biological, psychological and social factors together in understanding the illness adequately and showing the necessary reaction [Borrell-Carrió et. al., 2004]. In biopsychosocial model, biological factors are genetics, viruses, bacteria, structural defects; psychological factors are cognitive (such as health expectation), emotional (such as fear of treatment) and behavioral (such as smoking, diet, exercise, alcohol consumption) dimensions of the concepts of health and illness and social factors are concepts such as behaviors, social norms, pressure for behavioral change, health-related social values, social class and ethnicity [Ogden, 2004].

Today, biopsychosocial model is of importance with respect to both clinical care philosophy and practical clinical guide. Philosophically, this model enables to define the diseases and illnesses affected by the multiple levels of the organization from the society to molecular level. In practice, it emphasizes the contribution of the subjective experience of the patients to the correct diagnosis, health results and humanitarian care [Borrell-Carrió et. al., 2004].

2.2.4 Behavioral Medicine

In the following studies in time, many data supporting the Engel's proposals were obtained. In the studies done, effects of the elements such as cognition, learning, society, culture and environment on the phenomena of disease and health were revealed; the area of the behavioral medicine that tried to relate the behaviors to biomedical sciences experimentally emerged [Sahler and Carr, 2003].

Behavioral medicine, which is one of the approaches challenging the biomedical medicine in health, was first announced by Schwartz and Weiss (1977). This approach combines the concepts taken from some disciplines related with behavioral sciences (psychology, sociology, health education) with respect to health care, treatment and prevention. Behavioral medicine defined by Pomerlau and Brady (1979), by including methods rooted in experimental behavioral analyses such as behavioral medicine, behavior treatment and modification of behavior, encompasses assessment, treatment and prevention of physical diseases and physical functional disorders. Behavioral medicine defies the conventional mind-body discrimination [Ogden, 2004].

2.2.5 Health Psychology

This approach defies the conventional mind-body discrimination in the reasons and treatments of the diseases, too. This approach can be summarized as follows [Ogden,2004]:

What are the reasons for the diseases? According to this model, people may be considered as complex systems and diseases develop depending on not just one factor but on multiple variables. The approach of health psychology differs from the simple linear model in that combination of the biological, psychological and social reasons cause the diseases. This approach is like the biopsychosocial health and disease model that has first been defended by Engel.

Who is responsible for the illness? In this approach, patient isn't a passive victim and individual responsibility is included in health and disease.

How should treat? According to this model, the person should be treated as a whole. This behavioral change may include such dimensions as acknowledgements and values.

Who is responsible for the treatment? Since the patient isn't considered as a passive victim to disease, s/he shares the responsibility of his/her treatment.

What is the correlation between the health and illness? Health and disease aren't different in quality. There is continuity between them. People are at some point between health and disease continuity, not either ill or healthy.

What is the correlation between the mind and the body? Helath psychology accepts that there is an interaction between the mind and the body. Though there is a difference between them, there is a continual interaction.

What is the role of the psychology in the phenomena of health and illness?
Health psychology expresses that psychological factors are influential not only on the result but also directly or indirectly on the reasons for the diseases.
Health psychology is developing in United Kingdom, Europe, Australia and New Zealand.

2.2.6 Integrated Sciences Model (ISM)

ISM, in line with the universal principles, emphasizes that biological and psychological phenomena are related to each other and enables the assessment of the effects of various scientific disciplines on health care [Sahler and Carr, 2003].

According to this model, every patient is a complex but integrated system consisting of many variables and can be organized in five areas. These areas are biological, behavioral, cognitive, sociocultural and environmental. Each area equals to an information category significant for assessing the patient. Variables in each area are in ongoing interaction with each other. Human is in an effort to maintain an optimal balance as the other systems do and a single area will not achieve this. So, the concept of homeostasis can be applied to the psychosocial phenomena as well as biological phenomena [Sahler and Carr, 2003].

Every factor affecting homeostasis can be called stress. Stress isn't a completely negative phenomenon. Overstressing has an adverse effect on performance and motivation. Mid-level stress ensures an optimal motivation. There are factors in patients destabilizing the whole system. System responds to this with a multi-variable answer in all areas. The system has an evolutionary quality and changes continually in an adaptive way. In this way, the individual encountering stress in any area develops a response in other areas as well. This complex interaction among the areas happens in all periods and contributes to the health state of the individual. The factors of individual such as diet, physical activity, alcohol consumption, smoking, drug use and sexual behaviors are behaviors and habits directly affecting the health. For this reason, it is necessary to gain "healthy life patterns" in early periods life and to keep these in order to maintain the health in later periods of the life [Sahler and Carr, 2003].

The variables in these five areas result in an adaptive experience by interacting during lifetime. A correct assessment of the biological, behavioral, cognitive, cultural and environmental risk factors and different contributions of the etiological areas are the basic factor in determining the most effective treatment. Every patient should be comprehensively assessed with respect to the variables in these five areas. In this way, patient's problem should be handled not only according to the symptoms and etiology but also to the environmental (where did it happen?), behavioral (what did the patient do?), cognitive (what did the patient think? How did s/he interpret?), psychosocial (With whom, under which circumstances did s/he share and what was the result?), dimensions. In this way, a more effective treatment and help can be achieved. ISM model reveals that single area or treatment means the failure while the diseases appear as the interaction of the complex factors [Sahler and Carr, 2003].

In explaining the specific diseases situations, genetic, neuroendocrin, biological, behavioral, cognitive, sociocultural or environmental models have been proposed.

ISM, beyond these, defends the handling of all the possible variables affecting the course and treatment of the disease [Sahler and Carr, 2003].

2.2.7 Evaluation of the modern medical models

In the early periods of the modern age, concepts of disease and health were defined with a wholly mechanistic (Descartes-Newton dualistic perspective) perspective; the concept of disease was related to external effects, treatment was bound to the elimination of existing symptoms, signs and factors. Accordingly, several methods and standards were developed for diagnosing "absolute"-limited tables called "disease" and several methods were proposed for their treatments [Sadegh-Zadeh, 1999].

In time, as the defects of the current model became known, first, the accuracy of the approaches and standards regarding the diagnosis and treatment were questioned and at the same time, several additions and expansions were made to the concepts of disease and health. The point reached today, adoption of the evidence-based model for achieving the expected process of medical follow-up and treatment; developing and implementing models that also assess the interactions outside the human being's biological level.

2.3 DECISION-MAKING IN MEDICINE

Profession of medicine is based on decision-making in medicine. Therefore, most of the computer systems used in health care have direct or indirect impact on the quality of the health care service In this section, kinds of diagnostic decision making are explained.

There are several ways of diagnostic decision-making. Diagnosis is analyzing the obtained data in order to have a pathophysiological explanation for the symptoms of the patient. In diagnostic process, not only the condition of the patient but the method of obtaining the data for determining this condition is also assessed. When diagnosis is put, depending on the knowledge and experience of the doctor,

phenomena management comes to the agenda [Shortliffe, Perrault, Wiederhold, 2001].
Three factors are important for a good decision-making: accurate data, valid information and appropriate problem-solving techniques. There has to be enough data for the decision-making for the phenomenon. These data should not be too many. This situation may hinder a reasonable and fast decision. Besides, the quality of the obtained data is also important. Clinical data must frequently be verified

Decision maker must have general knowledge about medicine, specialty in his/her field, access to additional information when necessary. The information of the decision-maker must be correct, s/he must have an understanding regarding the blurred topics and s/he must differentiate his/her own preferences in dogmatic areas. Decision-makers' knowledge should be updated as well.

They should have problem-solving abilities. They should determine the appropriate targets, know how to realize them, establish cost/benefit balance in diagnosis or treatment.

After several researches, several definitions have been made regarding the clinical diagnostic process. Understanding this process well helps develop decision support systems [Shortliffe et al., 2001].

Differential diagnosis, using the possible explanations of the patient's complaints, symptoms and signs, is forming possible cases explaining them. The process of Differential diagnosis forming hasn't been explained yet. This process depends on the structure of the phenomenon, doctor's general and phenomenological experience. Several approaches to decision-making have been studied. These are pattern recognition, algorithmic method, causal reasoning, probabilistic reasoning, and hypothetic-deductive reasoning [Shortliffe et al., 2001].

Doctors develop a systematic of ***pattern recognition*** mostly for the issues they have experience about. These patterns are internal and may not be easily identified. This approach requires a familiarity about the issue and doctor's high level of knowledge and experience.

Algorithmic method uses proved decision strategies. Doctor makes his/her decision by following the decision tree. When developed well, these tools may help, they may be used effectively in increasing the quality of the health care service, may provide better service for less cost. However, many medical problems are quite complicated and such effective algorithms haven't been developed.

Causal reasoning is based on cause-effect relation among clinical variables. As opposed to the diagnostic inference process, it may be considered as effect-cause.
Another approach for decision-making is ***probabilistic reasoning***. During the process of medical diagnosis and interpretation, several uncertainties that can be presented as the probabilistic relation among clinical variables may appear. Probabilistic reasoning focuses on defining such uncertainties with statistical methods. The disadvantage of this method is that it requires golden standards regarding absolute identifications, disease identifications and frequency of a specific disease in the society.

The often-used method in the process of diagnostic reasoning is the ***hypothetic-deductive reasoning***. In this process, disease, syndrome or general information about various situations are applied to a certain phenomenon. According to the obtained data, a list of diagnostic hypotheses that expresses possible diagnoses is obtained. Afterwards, the list is narrowed down as much as possible by testing these diagnostic hypotheses in an iterative way.

There are two approaches in data collection; ***scanning*** and ***searching***. In scanning process, information is obtained by asking questions. This is done generally without any focus. Searching process supports the iterative hypothesis testing. The search is focused on questions [Shortliffe et al., 2001].

There is a faulty prejudice in medical diagnosis. This is the understanding that diagnosis for the problem from which the patients suffer objectively can be put and the reason can be found. However, diagnostic process should be considered as a social practice. Diagnosing process is determining the anomalies determined by the medical-scientific community with the same methods again they have determined.

Moreover, studies on classification and naming are also the same. For this reason, diagnosing process is a social product stemming from certain social processes. The phenomenon of diagnosis is just a complex social-historical process. Diagnostic processes should happen by several technological operation and devices that diagnosing person should use. Hence, this process is also a technological building process [Sadegh-Zadeh, 2000].

2.4 PROBLEMS IN HEALTH CARE

2.4.1 Medical mistakes and their importance

Medical mistakes are quite frequent. Though accurate figures are not known, it is assumed that every year 2.5 million people in the USA die due to the medical mistakes [NPSF, 1997].

According to the several researches, 42% of the people believe that they are exposed to medical failures during health service. According to the information given in the report of the Institute of Medicine (IOM) (1999) by referring to two studies, every year 44.000 – 98.000 people die because of the medical mistakes.

Table 2.1. According to the CDC report, reasons for death in the USA in 1999 [CDC, 2001]

549,838	Cancers
124,181	chronic lower respiratory infections
68,399	Diabetics
44,536	Alzheimer disease
30,680	septicemias
725,192	heart diseases
167,366	stroke or other cerebrovascular diseases
97,860	incidents
63,730	influenza and pneumonia
35,525	some kidney diseases
484,092	other reasons

According to CDC – 1999 reports, almost 2.4 million people die in the USA every year (Table 2.1). Accordingly, 1.8 – 4.0 % of this proportion is due to the medical mistakes [IOM, 2000] [CDC, 2001].

Medical mistakes, according to the findings of the research, correspond to a point between 5 and 9 in this ranking. When it is considered that this study has been done according to the hospital records and deaths due to medical mistakes in examination room haven't been included, it is obvious that death rate due to medical mistakes will be much higher.

The reports above have been written by evaluating the hospital applicants died because of the side effects. If it is assumed that a 2.9 – 3.7% side effect exists in applications to the hospital and that 33.6 million people have applied to the hospitals in the USA in 1997, it will be revealed that almost half of the side effects (58 – 53%) are due to the mistakes. IOM report expresses that 7391 death cases in 1993 were due to the drug treatment (medication), anesthesia-related deaths, 2 in 10,000 in early 1980s are now down to 1 in 200,000 – 300,000 [IOM, 2000].

It is claimed that every year 225,000 people die in the USA due to the medical mistakes, 106,000 of which is because of the drug side effects without any medical mistake. According to this ratio, the third frequent death reason in the USA is iatrogenic reasons after heart diseases and cancer. In 1999, 2.4 million US citizens died and 9.3% of this figure died of iatrogenic reasons.

Yet, it will be wrong to say that all these people died because of mistakes. Some of them may have died because of the side effects of the treatment with no mistake made. According to one view, 1,000,000 patients are harmed every year due to the drug treatment and side effects and 106,000 of these people are mostly dying from side effect of the treatment [Holland and Degruy, 1997].

Starfield expresses in his report that 12,000 people die from unnecessary treatment, 7000 people die from treatment mistakes in the hospital and 20,000 people from reasons other than treatment [Starfield, 2000].

Nosocomial infections, though there is no specific mistake of the medical staff, occur during the stay in hospital. Annual ratio for this is 2,000,000/year or 10% of the patients in the hospital and 20,000 – 88,000 people every year are assumed to die for this reason. The financial cost is $4,5 billion per year. 2,9-3,7% of the patients in hospital cope with side effects. 7391 death cases have been reported for drug mistakes.

2.4.2 Sources of the medical mistakes

There are lots of reasons for the medical mistakes. Medical mistakes may be because of health staff, specialist, hospital management, nurses, pharmacist, pathologist and laboratory assistant, drug companies and lots of other elements. The patient may also make mistakes. All these make the ratio of the medical mistakes much higher. There several types of medical mistakes. Most frequent medical mistakes are wrong diagnoses, treatment mistakes, surgical mistakes, nosocomial infections (infections caught at the hospital), laboratory testing mistakes and managerial mistakes. Reasons for the medical mistakes are inattentiveness, lack of training and education, communication problems, wrong diagnosis, overload work, pharmacist's mistake or misreading the text [IOM, 2000].

Various studies indicate that wrong diagnosis has a ratio of 8-42%. Wrong diagnosis is the most frequent mistake type. There are several types of wrong diagnosis. Wrong diagnosis may vary from completely wrong diagnosis to partially wrong diagnosis (wrong subtype, wrong perception of the underlying reason, treatment reasons, conditions or complications) [NPSF, 1997].

According to the Patient Safety Incidents done by HealthGrades, every 155 patients of 1,000 patients (%15,5) staying in hospital have been diagnosed wrong and they can't be treated in time. The rate of wrong diagnosis in intensive care or emergency units can change between 20-40% [HealthGrades, 2004].

Davenport (2000) expresses that most frequent malpractice conditions are respectively myocardial infarction, breast cancer, appendicitis, lung cancer and colon cancer. For almost all of these, wrong diagnosis or wrongly requested tests cause the treatment to be late [Davenport, 2000].

In various studies, it's been found that wrongly diagnosed cases of acute MI, stroke, pulmonary emboli, meningitis, appendicitis in emergency units are quite frequent. In cases of sample hear attack, untypical like young and woman, correct diagnosis is seldom placed. Moreover, the possibility of heart attack is not eliminated even the EKG tests that doctors rely much upon are normal. Appendicitis is another wrongly diagnosed case frequent in emergency units. Preliminary wrong diagnosis ratio is 28-57% among children below 12 and almost 100% in infants [Rothrock and Pagane, 2000].

In the autopsy studies, it's been claimed that ratio of wrong diagnosis is 40% in intensive care units. This is a very high ratio. One of the reasons for this is the multifactor nature of the severe intensive care phenomena. There are many reasons for the wrong diagnosis. It has many dimensions depending on the patient, doctor, specialist or test. The patient may not express everything completely and accurately during medical questioning or may not do the requested tests correctly and completely. Different situations apply for the doctors. There are over 20,000 disease diagnoses in medicine. Doctors know only the most frequent ones. Besides, every doctor does not have equal talent. They also have different prejudices. That is, a frequent disease is the first considered case in diagnosis, to give an example. This tendency also exists in treatment. While one suggests surgery, the other suggests internal pills. Moreover, every test brings a financial cost. Especially this may cause wrong diagnosis. Lack of time and difficulty of analyzing behavioral/mental symptoms are also reasons for mistakes.

There also mistakes in laboratory and pathology tests. Though tests are useful for the diagnosis, they can't be perfect. Human mistakes during testing are also parts of wrong diagnosis. Again, in tests, wrong positive and negative cases are in question. Also, some tests may give wrong results because of the specific properties of the individuals [Kronz, Westra, Epstein, 1999].

Some diseases are hard to be diagnosed as well. Especially children's diseases and psychiatric diseases are difficult to be diagnosed. Since the symptoms of the digestive system diseases are vague and the patients refrain from complaining because of embarrassment, there may be confusion [WD, 2005].

It is also hard to diagnose when symptoms are not clear. Differential diagnoses of some conditions (such as lupus, multiple sclerosis, fibromyalgia, chronic fatigue syndrome, Lyme disease, hypothyroidism that can cause symptoms such as general malaise, fatigue, and other vague neurological symptoms) is very hard [WD, 2005].

Some diseases are more frequently used in diagnosis. That is, doctors may call these diseases as diagnosis by mistake even for different conditions. To give example: lack of attention and hyperactivity syndrome, irritable intestinal syndrome, middle ear infections, sinusitis, Lyme disease, Alzheimer's disease [WD, 2005].

It is also common that vague tables or symptom-less cases are not expressed as diagnoses. Because of the vagueness or lack of symptoms, wrong diagnosis may be put for the diseases of type II diabetics and impaired glucose intolerance, high cholesterol, hypertension, osteoporosis, sexually transmitted diseases, hemochromatosis, chronic kidney disease, Hashimoto's disease, glocom. In some cases, diagnosis can't be put because it is hard to identify the conditions: depression, infectious diarrhea, fecal incontinence, lactose intolerance, polycystic ovary syndrome, flat foot, lack of attention and hyperactivity disorder, sleeping disorders and sleep apnea, asthma. Relatively seldom cases like bipolar disorders, celiac disease and whooping cough may also be wrongly diagnosed (Table 2.2) [WD, 2005].

At the same time, wrong diagnoses are also seen in cases where the patient has more than one disease. For example, heart diseases, hypertension, high cholesterol, diabetics and overweight can be related with each other. Moreover, autoimmune diseases may co exist with lupus, type I diabetics, multiple sclerosis, psoriasis and nearly 100 tables [WD, 2005].

Table 2.2. Silent conditions and its rates in US. [Reader's Digest, 2004]

Condition	Percent	Rate	US People
Toxoplasmosis	22.06%	1 in 4	60 million
Sleep disorders	14.71%	1 in 6	40 million
Otosclerosis	10.00%	1 in 10	27.2 million
Osteoporosis	6.62%	1 in 15	18 million
Hypertension	5.51%	1 in 18	15 million
Chronic lower respiratory diseases	5.51%	1 in 18	15 million
Chronic Obstructive Pulmonary Disease	5.51%	1 in 18	15 million
Migraine	5.15%	1 in 19	14 million
Thyroid disorders	4.78%	1 in 20	13 million
Latent tuberculosis	3.68%	1 in 27	10 million
Obstructive sleep apnea	3.68%	1 in 27	10 million
Diabetes	2.10%	1 in 47	5.7 million
Sleep apnea	2.00%	1 in 50	5.4 million
Chlamydia	1.25%	1 in 80	3.4 million
Parkinson's Disease	1.10%	1 in 90	3 million
Age-related macular degeneration	0.83%	1 in 120	2.3 million
Sjogren's Syndrome	0.74%	1 in 136	2 million
Aneurysm	0.74%	1 in 136	2 million
Hemochromatosis	0.55%	1 in 181	1.5 million
Salmonella food poisoning	0.51%	1 in 194	1.4 million
Breast Cancer	0.37%	1 in 272	1 million
Glaucoma	0.37%	1 in 272	1 million
Celiac Disease	0.37%	1 in 272	1 million
Von Willebrand disease	0.37%	1 in 272	1 million
Open-angle glaucoma	0.37%	1 in 272	1 million
Cryptosporiosis	0.18%	1 in 544	500,000
Gonorrhea	0.15%	1 in 679	400,000
HIV/AIDS	0.08%	1 in 1,208	225,000
Narcolepsy	0.06%	1 in 1,813	150,000

Despite the developments in biomedical sciences and technology, the ratio of wrong diagnosis is 40%. One of the basic reasons for this ratio is the outmoded models and perspectives regarding the clinical information and reasoning [Sadegh-Zadeh,1999].

These approaches have influence even on many medical standards that are wide spread and considered basic for standardization. Health professionals like doctors, clinicians, and pathologists do not make enough effort for developing models and a better language because the formal education they have been given may prevent health professionals from understanding such a necessity. When different theses of philosophers, theologians and medical historians are added to the situation, it gets much worse [Sadegh-Zadeh,1999].

Healthcare-oriented clinical guides, decision trees and similar systems are important and they save many lives without any doubt. However, such approaches are only suitable for the fully understood problems. In practice, intuition and imagination have to be used for a first time problem. These two are away even from computers. Complex real world is producing complicated, vague, unique and over context-bound problems [Fraser and Greenhalgh, 2001].

2.5 CLINICAL DECISION SUPPORT SYSTEMS

2.5.1 General information about the decision support systems

Clinical decision support systems (CDSS) are in the form of software parts that obtain information about the clinical situation and produce inferences as output, help the doctor in decision-making processes and are considered as intelligent by the users of the program [Coiera, 2003].

Sometimes, the term ***knowledge-based system*** is used as the synonym of the CDSS and defined as the system that operates in the patient data base, that has inference mechanism and information base [Baykal and Beyan 2004-2].

CDSS are the devices that eliminate many problems such as the information load doctors' encounter, over specialization, lack of the coordination among the specialties, mistakes in the health care systems.

In another perspective, there are two issues with the medical data. One is the exchange of a certain patient's data among hospitals. Other is fast production of new information in medical sciences and ensuring this information is conveyed from the researchers to the doctors in hospitals. CDSSs may be divided into various types according to four criteria (Table 2.3).

Table 2.3. CDSS types

Criteria	Categories	Explanation
Target domain	Large scale	General internal medicine
	Focused	One disease only
Purpose	Overall	All the purposes in one system
	Adverse Drug Effects	For managing ADE
	Drug Dosing	For drug dosing, some focused CDSS
Architecture	Stand alone	Free from HIS
	DS component	(component in HIS)
Target users	Physician	Primary+Secondary care physician
	Nonphysician	Nurses, patients, etc.

According to their goals, CDSSs may be divided into several categories (Table 2.4)

Table 2.4. Division of health care systems according to their purposes

Hospital Information Systems	Drug therapy systems
Notification systems	Quality assurance and administration systems
Acute Care Systems	Educational systems
Laboratory Systems	Research systems

Though different systems were developed for every different task in the past, today, there is a tendency for more integrated systems encompassing all the functions mentioned in the table above. All the focused CDSSs have an issue called critical mass problem. If a doctor needs a dozen practices even for a simple procedure, the use of the system will not be easy. Various systems and establishing an integrated environment for the CDSS components will enable the doctors to conduct their daily works comfortably. Another point is that component based CDSSs offer more flexibility [Coiera, 2003].

The history of CDSSs begins with MYCIN in 1970s. First big scale CDSSs (Internist-1, QMR, and DxPlain) appeared in 1980 and first medical terminologies were completed. HELP system is the first component-based system achieved in 1990s with the formation of Arden syntax and other standards. EON/Protégé approach represents the second generation CDSSs. Component based systems have more flexibility with their ease regarding updating and renewing information capabilities. While older systems were established according to the first approach historically, passive approach is considered more appropriate by the doctors [Coiera, 2003].

2.5.2 Uncertainty in Medicine and Its Sources

The real world is uncertain. In the daily experience, absolute true and wrong in Aristotelian sense is very seldom. In 1927, Heisenberg published the "*Uncertainty Principle*" of the famous quantum mechanics. According to this principle, there is a limit between the position of an object and its momentum that prevents it from being correctly known synchronously. In mathematical terms, where Δx is the uncertainty in the position, Δp_x is the uncertainty in momentum and h is Planck's constant ($\approx 6.626 \times 10^{-34}$Js)

$$\Delta x \Delta p_x \geq \frac{h}{4\pi} \qquad (2.1)$$

The principle emphasizes that the momentum of an object will be known with less accuracy when the position of the object is measured more precisely [Garibaldi, 1997].

This striking conclusion is independent from the used measuring devices. It is an irrevocable fact of the quantum nature of the universe. It isn't possible to rule out Heisenberg's "Uncertainty Principle" as long as a measuring device is used and there is always uncertainty in the real world. Though this theoretical uncertainty is quite little, it doesn't lessen the universal importance of the uncertainty. Moreover, as a result of the chaos theory, it's been revealed that small changes in the universe may cause under suitable conditions such results that can affect the system on a large scale. This is the butterfly effect [Baykal and Beyan 2004-2].

People, despite the uncertainty, try for managing the reasons and making decisions. For this reason, imprecise reasoning should be imitated in expert systems in order to imitate the human reasoning in certain areas. There are lots of sources of this uncertainty. Main sources of uncertainty in the dimension of expert systems;

- Unreliable sources of data and information
- Abundance of unrelated information
- Imprecision of the sensory devices
- Error measurement equipment
- Imprecision of the natural language
- Conflicting and complementary sources of the facts
- Hidden variables that cause randomness

Although precision, accuracy and reliability replace each other in daily language, they are technically very different [Garibaldi, 1997];

Precision is the expression of how close the measurement is to the reality, how precise it is. Precision can be considered as the decimal of the measurement.

Accuracy is how well measurement reflects the real world.

Reliability is how stable the measurement remains in time, how valid it is.

All these explain the uncertainty of the data. Uncertainty is a combination of the imprecision, inaccuracy and unreliability.

There is also uncertainty of the knowledge. There may be uncertainty in the rules and facts of an expert system. Vague rules are often parts of human reasoning. Besides, knowledge base may not be complete. Rules may encompass all the problem area or there may be exceptions. Rules may be contradictory, there may be evidences that make us think of different diagnoses at the same time. It may be difficult to correctly formulate these rule sets. One set of variable input may lead to different conclusions.

In an expert system, it is very important to synthesize and to implement the performance of an expert in a specific area in controlling the uncertainty. Many techniques are used for tackling with the uncertainty. The appropriate method depends on the context [Garibaldi, 1997].

2.5.3 Mechanisms of Reasoning

In this process, there are several methods configured according to the evaluation of these data by the computer. These methods are: deterministic (rule based) reasoning, causal reasoning, probabilistic reasoning, decision theoretic reasoning, possibilistic reasoning (fuzzy logic), commonsense reasoning (default reasoning) and case based reasoning [Shortliffe et all, 2001].

In ***deterministic (rule based) reasoning***, information is gathered as facts. Yet, there is a problem of locality in medicine. Under normal conditions, if the expression "IF A, THEN B" is known as true and "if A is true, B is supposed to be true". However there are many examples in medicine that do not apply to this rule. Three factors have been put forward as the reason for the fact that such a proposition does not apply in medicine: laziness, theoretical ignorance, practical ignorance. These are considered as the reasons for uncertainties in medicine. Several measures have been taken for this. As an example, the concept ***certainty factors*** are used in the MYCIN system. This concept is based on the preferences of the field expert instead of epidemiological data. Its value is between 0 and 1.

Differing from MYCIN, Leeds abdominal pain system is based on the simple Bayesian computation. Yet, early Bayes systems were problematic because a great number of probability estimates were needed for them to function. New evidences were causing to re-computation of all the valid probability estimates. One of the requirements of the first period Bayesian systems was the concept "conditional independence". Failure to achieve conditional independence caused the Bayesian reasoning system to lose status in eyes of the expert systems developers. While these systems contribute to the problems in their own areas, reasoning systems have been inadequate for the big scale problems.

Causal reasoning is the use of the area information in decision-making. CASNET is the first medical decision support system that is based on this approach. One of the interesting aspects of the CASNET is its hierarchic organization in the data base. Sign, symptom and tests are at the bottom; pathophysiological states are in the middle; disease categories are at the top. Disadvantages of this system are that many disease mechanisms haven't been clearly understood yet, detail level and time-related presentation in causal networks.

Probabilistic reasoning (Bayesian reasoning) systems are becoming less popular since mid 1970s since they develop a significant number of probability tables and require lots of operation.

Decision theoretic reasoning is a design style that is based on using the decision theory in reasoning processes. Decision theory is based on the utility concept. The disadvantage/advantage that patient may encounter after the decision is used here.

Possibilistic reasoning (fuzzy logic) is the use of imprecision in explaining findings or factors. Fuzzy logic offers methods for computing vague propositions.

Common sense (default) reasoning is based on assumptions. It is based on mental manipulation of the objects depending on their general properties and their classification in groups accordingly. New realities about objects, which are presented as updated in data base, should be conciliated with the old ones.

Case based reasoning is based on the "case" concept. Case is defined as the presentation of the experience from which the reasoner can draw lessons in reaching his/her targets as a part of information related with the context. Case based data bases consist of two parts as the case itself and index that is used for effective context based retrieval. Case based systems gain information by solving problems. Cases are stored as the information reflecting past experiences in problem solving. Each case has three parts depending on the problem as explanation, solution and result. In this approach, each case is controlled with an index. The key to problem solving in case based systems is the compliance of the problem at hand with the past experiences and searching for the said experience by using index. In these systems that are more successful and faster in solving problems that are based on pen-ended and incompletely defined concepts when compared to the conventional systems, there may be problems about indexation level, designing a general roof for the index content and design of the case retrieval algorithm.

2.5.4 Various Medical Decision Support Systems

There are very different and many artificial intelligence system used in medicine, most known ones are shown in the table (Table 2.5).

These systems are systems developed for helping clinical decision support systems, acute care systems, training, and management and laboratory services. Systems developed to be used as a support in clinical decision support systems can either be specific to a certain area or suitable for a much wider use. Below are there general information about these systems and criticisms published in literature about them [Coiera, 2003].

Table2.5. Several Decision Support Systems in Medicine [Coiera, 2003, (OCA, 2005)]			
Name	**Type**	**Commiss'd**	**Status**
Acute care			
ACORN	Coronary care admission	1987	decommissioned
Automedon	Ventilator manager	2001	routine use
NéoGanesh	Ventilator manager	1992	decommissioned
POEMS	Post-operative care	1992	
SETH	Clinical toxicology	1992	
VentEx	Ventilator manager		
VIE-PNN	Neo-natal parentral nutrition	1993	In use
CDSS			
ATHENA	DSS for the management of hypertension in primary care	2002	routine use
CEMS	Mental health decision support system	1993	routine use
DXplain	Clinical decision support	1987	routine use
Epileptologists' Assistant	Nurse progress note assistant	1989	decommissioned
ERA	Web-enabled electronic decision support and referrals system for cancer	2001	in clinical use / under evaluation
GIDEON	Support for the diagnosis and treatment of infectious diseases	1994	Commercial product
HELP	Knowledge-based HIS	1975	routine use
HepatoConsult	Diagnosic knowledge-based system for liver and biliary tract disease	1994	In clinical use
Iliad	Clinical decision support		routine use
IPROB	Intelligent Patient Record for Obstetrics	1995	routine use
Isabel	Web-based paediatric diagnosis reminder and knowledge mobilising system	2002	routine use
Jeremiah	Orthodontic treatment planner	1992	
LISA	Decision support for treatment of childhood acute lymphoblastic leukaemia	2003	enters routine use summer 2003
MDDB	Diagnosis of dysmorphic syndromes	1988	
Orthoplanner	Orthodontic treatment planner	1994	
PAIRS	Diagnostic decision-support system for difficult cases	2001	in clinical use
QMR	Diagnostic decision-support system for internists	1972	routine use
RaPiD	Designs removable partial dentures	1994	
RetroGram	Decision support for drug regimens for HIV-infected patients	1999	routine use
Therapy Edge	Web-enabled decision support system for the treatment of HIV	2001	routine use
TheraSim CS-HIV	Clinical simulation, decision support, continuing medical education technology for the management of HIV	2002	in clinical practice
TxDENT	Screeing dental patients	1997	

Table 2.5. Several Decision Suppport Systems in Medicine [Coiera, 2003, (OCA, 2005)] (cont'd)			
Name	**Type**	**Commiss'd**	**Status**
Educational Systems			
Cancer, Me?	Patient cancer advice	1989	
Diabetes In Action	NIDDM training aid	1991	decommissioned
TheraSim CS-HIV	Clinical simulation, decision support, continuing medical education technology for the management of HIV	2002	in clinical practice
Laboratory Systems			
Becton Dickinson Systems	Haematology, microbiology	1995	routine use
Coulter® FACULTYTM	Haematology	1995	
DoseChecker	Drug dose checker	1994	routine use
GermAlert	Infection control	1993	
GermWatcher	Infection Control surveillance	1993	routine use
Hepaxpert I, II, III	Hepatitis serology	1989	routine use
Interpretation of acid-base disorders	acid-base disorders	1989	
Liporap	Dyslipoproteinaemia phenotyping	1987	
Microbiology/ Pharmacy Expert System	Drug sensitivity	1991	
PEIRS	Pathology reports	1991	decommissioned
Pro M.D.	CSF interpretation		
PUFF	Pulmonary function tests	1979	
SahmAlert	Drug sensitivity	1995	
Medical Imaging			
Perfex	Cardiac SPECT interpretation		
Phoenix	Radiology consultant		decommissioned
Thallium Diagnostic Workstation	Thallium myocardial scintigraphy		decommissioned
Quality Assurance and Administration			
ADE Monitor	Adverse Drug Events	1995	
Clinical Event Monitor	Clinical alerts	1992	
Colorado Medicaid Utilization Review System	Prescription quality review	1990	
Geriatric Discharge Planning System	Patient discharge planning	1990	
IPROB	Intelligent Patient Record for Obstetrics	1995	routine use
Managed Second Surgical Opinion System	Managed care	1989	
Reportable Diseases Monitor	Monitoring and reporting infectious diseases	1995	routine use

Assessment and Treatment of Hypertension: Evidence Based Automation (ATHENA)

Athena decision support system is the system doing the hypertension management by using component-based architecture. It makes suggestions about the medication according to the accompanying disease by checking the blood pressure. Data base including suitability criteria, risk situation, blood pressure targets, accompanying diseases, drug suggestions, clinical messages can be easily changed. In this way, it is possible to add new and proved information to the system. Together with the database mediator Athenaeum, it can be integrated to various electronic patient recording systems independent from the physical and logical data type of the computed patient recording systems [Chan, Coleman, Martins, Advani, Musen, Bosworth, Oddone, Shlipak, Hoffman, Goldstein 2004; Goldstein, Hoffman, Coleman, 2000, Goldstein Hoffman, Coleman, Tu, Shankar, O'Connor, Martins, Advani, Musen, 2001, Shankar, Martins, Tu, Goldstein Musen, 2001; Advani, Tu, O'Connor, Coleman, Goldstein, Musen 1999].

DXplain

Dxplain is a clinical decision support system that uses the set of clinical signs (sign, symptom, and laboratory data), defines them and makes a possible diagnosis list. Dxplain does not offer a precise clinical consultation and not replace the decision-making position of the clinician.

Over 4500 clinical patterns caused by more than 2000 diseases exist in a large data base according to their approximate frequency. The system uses modified Bayesian approach. Dxplain is used in many hospitals and medical school for the purpose of clinical training and consultation.

Dxplain bears the characteristics of electronic medical books and medical reference systems. It gives information about the symptoms, signs, etiology, pathology and prognosis of more than 2000 diseases [Barnett, Famiglietti, Kim, Hoffer, Feldman, 1998; Elhanan, Socratous, Cimino, 1996].

Epileptologists' Assistant

Epileptologists' Assistant is an expert system designed for the purpose of cost-effective health care in clinical monitoring of the epilepsy. The system with object oriented architecture is divided into modules that include rules and data [Ruchelman, Krishnamurthy, Hostetler, Peterson, Jungmann, Doller, 1992]

The Early Referrals Application (ERA)

It is an interactive decision support system developed for evaluating cancer-suspected patients [Coiera, 2003].

GIDEON

The system, relying on the information such as system, sign, symptom, laboratory tests, area, incubation period and by using the Bayesian sequence, supports the diagnosis for all the infection diseases in all areas. Including 327 diseases, 205 countries, 806 bacteria clusters and 185 antibacterial agents, GIDEON consists of diagnosis, epidemiology, treatment and microbiology modules [Berger, 2000].

HELP

HELP, is a full data-based hospital information system. In addition to the routine operations of an hospital information system, it also supports such operations as data input, pharmaceutics, radiology, nursing documentation, ICU monitoring and gives a strong decision support. Decision support system has been added effectively to the routine operations of hospital information systems. Decision support offers warning, reminder, data interpretation, patient diagnosis, suggestions about patient management and support in clinical protocol. HELP system supports an integrated database that eases the decision support operations [Gardner, Golubjatnikov, Laub, Jacobson, Evans, 1990; Gardner et al, 1999, Haug, Gardner, Tate, Evans, East, Kuperman, Pryor, Huff, Warner, 1994, Haug, Rocha, Evans, 2003; Aronsky and Haug, 1999; Larsen et al., 1989]

HepatoConsult

It is a data based system designed for helping the diseases of liver and biliary tract. It's been set up by using the diagnostic expert system shell called D3 (Assist) [Puppe, 1998, Buscher, Engler, Fuhrer, Kirschke, Puppe, 2002].

Iliad

It is a system using the Bayesian reasoning for reaching a diagnostic result from the clinical signs of the given case. The system, basically developed for internal diseases, gives support to the diagnosis of nearly 1500 diseases by evaluating thousands of signs [Lincoln, Turner, Haug 1991].

Intelligent Patient Record for Obstetrics (IPR_{OB})

IPR_{OB}, which is claimed to be the first wholly integrated clinical management system developed for the obstetricians, is designed to boost the quality of the risk management and care from the prenatal period till postpartum period [OCA, 2005].

ISABEL

It is a web-based diagnostic decision support system developed to help Differential diagnosis. The system is focused on pediatric patients [Ramnarayan and Britto, 2002; Ramnarayan, Tomlinson, Rao, Coren, Winrow, Britto, 2003].

JEREMIAH

It is a system that gives decision support to the dentists in orthodontic treatments and that is developed on the basis of fuzzy logic [OCA, 2005].

Leukemia Information System and Advice (LISA)

It is a web-based patient data and decision support system designed for drug dosage decisions in treatment of child time acute lymphoblastic leukemia [Bury, Hurt, Roy, 2004].

MDDB

It is a system developed for the diagnosis of dimorphic syndromes by using case based reasoning. There are nearly 1000 types of dimorphic syndrome and only the seldom cases may be overlooked. This decision support system helps identify these. New cases are continually added to the data base [OCA, 2005].

Out Patient Pre-assessment System for Windows (OPPASS)

OPPASS is a decision support system that helps evaluate the patient's condition for the purpose of reducing the risk in pre-planned (elective) and general anesthesia-included operations [OCA, 2005].

Orthoplanner

Being a system developed for helping the orthodontists, Orthoplanner is offers the orthodontic information as based on the fuzzy logic [OCA, 2005].

Physician Assistant Artificial Intelligence System (PAIRS)

PAIRS is a system developed for helping the cases where the diagnosis is difficult to be put. PAIRS system is based on using variational method in order to make an effective inference in large-scale probabilistic models. It includes in its large data base 30,000 diseases and characteristics and 620 internal diseases [OCA, 2005].

Quick Medical Reference (QMR)

QMR, developed from Internist-I, help doctors for the diagnosis of adult diseases. Offering electronic access to more than 750 diseases, OMR includes in its data base more than 5000 characteristics that define the signs of the diseases. Findings include medical story, symptoms, physical signs and laboratory test results. Laboratory test results are divided into three categories according to the prevalence and cost. QMR is used in hospital and examination room [Lemaire et al., 1999].

RaPiD

It is a data based system used in design of partial false teeth [OCA, 2005].

RetroGram

RetroGram, in HIV-1 resistance, correlates the clinical suitability of the anti-retroviral drugs to the complex genomic information. RetroGram lists the expected clinical impact of the FDA approved drugs for a specific patient according to the suitability rank. What makes it unique is that it achieves expert experience and preference in algorithms that evaluate the impact of the specific genotypic changes. It's been supported by a multi-central clinical practice in Spain [OCA, 2005].

Therapy Edge

TherapyEdge-HIV is a HIV-specific system of patient recording, decision support, monitoring and reporting. It can be combined with the ViroScore Sequence data base and can become a strong clinical monitoring and research system. Besides patient records related with the governments, it's been used by NGOs in more than 36 clinics in 32 countries to reduce the costs.

TherapyEdge monitors the clinical data (medical conditions, drugs, genetic tests for drug resistance, drug effectiveness and toxicity) of the HIVTM patient graphically and processes automatically. The system monitors the current condition of the patient and includes patient-specific optimal treatment options. Real-time, intelligent alarm system of this system controls the drug interactions, medical conditions or side effects automatically) [OCA, 2005].

TheraSim CS-HIV

TheraSim CS (Clinical Simulator) is a clinical simulation technology supporting doctors, nurses, medical students and pharmacists in diagnosis and treatment of the chronic and infectious diseases. TheraSim CS-HIV is the technology developed in relation with the HIV diagnosis and management of the TheraSim CS. There also technologies that are tried to be developed for diabetics, malaria, TBc, NBC, cardiovascular and neurological diseases [OCA, 2005].

TxDENT

TxDENT is an expert system produced for several functions from clinical observation in oral health to expert suggestions in the treatment of clinical problems. The system evaluates a detailed treatment list and its costs. It's been developed to scan the treatment requirements of the dental clinics, to store the clinical data regarding clinical monitoring and treatment results. The system uses the model of decision tree [OCA, 2005].

2.5.5 Support systems criticisms

In a medical environment, uncertainty is a serious problem since it can't be determined effectively. The information CDSS based on should be evidence-based and verified by experimental researches. Uncertainty in the statistical evidence obtained from such researches to be used in CDSS is a basic source of uncertainty. If the accuracy of a disease is emphasized with a specific percentage, it means that, another certain percentage is overlooked. Besides, when system is configured by using a logic based on true/false values, enough accuracy on individual level cannot be achieved. As long as text book cases do not happen, mostly do not, Differential diagnostic operations that are seldom but do not ignore the significant properties, that enable reasoning with inadequate information and that lead to a diagnosis should be developed [OCA, 2005].

In several medical decision support systems conducted up until now, it's been acknowledged that there are some numerical or linguistic expression clusters forming the categories basically called disease and that these should be evaluated by classical methods or flexible computation. Ignoring on which health/disease level the symptoms are, fuzzy table of every disease is handled by considering a certain accuracy or probability degree. Such approach, by its very nature, can not avoid vagueness and makes it necessary to use only one method for every kind of uncertainty.

CHAPTER-3

NEED TO FINDING A WAY OUT: FUZZY LOGIC AND COMPLEX SYSTEMS THEORY

In this chapter, various perspectives of scientific approaches are evaluated and brief information about fuzzy chaotic medical model to be explained in 4rd Chapter, is given. This chapter is summarized from [Baykal and Beyan, 2004-1 and 2004-2]

This evaluation will be made under the frame of the following sub-issues;

1. What are the basic principals of scientific approach and their connection to medical model?: Diseases according to scientific literature, are certain limited categories that were structured by experiment-observation methods, atomistic approaches and Aristotelian logic. Any cases out of these categories are defined as health according to scientific literature. Contemporary scientific knowledge accumulation has caused the foundation of new theories which emphasizes human being as complex and adaptive system for their individual and social dimensions. Thus via this, ineffectiveness of absolute atomistic point of view has been revealed more clearly. Also different opinions are generated via bringing forward the ineffectiveness of Aristotle logic on logical inference level. Particularly with the help of works on the artificial intelligence, fuzzy logic which is basically an extension of the classical Aristotle's' logic and also soft computing methods that are tightly depended upon with these principles, are generated.

2. Are there different logical approaches? Fuzzy logic by excluding the two principles of classical Aristotle's' logic may provide a more appropriate modeling opportunity. In this way, more effective modeling tools are provided especially for biological and human sciences.

3. Complex adaptive systems and chaos theory: Complex adaptive systems are the systems where chaotic behaviors can be observed and has the capacity of self-organization. Chaotic behavior in these systems especially has become in the foreground currently and which is the most outstanding feature, distinguishing these types of systems from classical mechanical systems.

3.1. BASIC PRINCIPLES OF SCIENTIFIC APPROACH AND THEIR CONNECTION TO MEDICAL MODEL

3.1.1. Contemporary scientific methodology

Science is one of the institutions of social environment, generated by an individual. Scientific methodology by being processing way of science and that is mostly based upon principles of Western culture includes three basic elements. These are; obtaining data related to external reality from experiments and observations, perceiving them within the scope of atomistic point of view and gathering them via using the principals of Aristotelian logic inference system for model production.

Criticism on experiments and observations and different opinions are out of the boundaries of this research. Therefore only the atomistic point of view and Aristotle's' logic levels are evaluated.

In ancient Greece, the atomistic point of view, triggered by some philosophers such as Parmenides, Leucippus, Zenon, Democritus, Anaxagoras and Empedocles has been developed and continued in modern era by Descartes, Gassendi, and Newton. Atomistic point of view is an approach which grants objects as the principal of objective reality and process as its second attribute.

Classical Aristoteles logic is based upon three basic principals. These are respectively ***static identity, non-contradiction*** and ***excluded middle*** principals. When it is combined with atomist point of view, Aristotle's logic anticipates the external reality as formed by certain limited and clearly defined categories and also the process to be defined as the relationship of these categories. While doing all these, it uses mathematical methods in a widespread way.

This approach beside its approximately 2500-year sovereignty in Western world has become one of the principals of modern scientific methodology. However apart from this, there are approaching possibilities.

3.1.2. A Social phenomenon: Modern medical institution

A modern medical paradigm that defines the efficiency of scientific methods and individuals' health and illness conditions and categorizing them via scientific methods and finding solutions accordingly. It is one of the most advanced practices of atomistic scientific methodology.

Basically, concept of disease is the category and hypothesis, formed by scientific community under the light of scientific methodology and historical accumulation rather than an objective category.

Modern medical institution, being one of the productions of modern culture, tries to define certain limited disease categories as a result of atomist approach. It is believed that these categories can be well defined and afterwards certain reasons, lead to them, are defined and treatment can be provided by abolishing all these factors. When this completely point of view combines with scientific methodology there appears a modern medical approach.

During modeling process, this point of view acts toward defining "basic principal" objects. According to this, various objects such as atom, cell, molecule, organ are defined and some certain and limited functions are given to them. Current researches have shown that even interactions on the lowest level are extremely sophisticated and crowded.

3.1.3. Other approach possibilities

Universal reality is a multi-layered and multi-dimensional phenomenon. Scientific methodologies, no matter which principals they are based upon, can not claim to explain the entire as universal reality can not surround it.

Therefore, different methodologies can be developed according to the features of every cultural structure's perceiving way of universal reality. The most "appropriate" one among these is directly related to what is desired. Absolute reality is not the purpose and target of scientific endeavor.

Generally, in the statement of universal reality, two basic approaches are stood out throughout the history. These approaches are both object and process approaches. Atomist approach is an object approach. In contrast with this, there had been some philosophers and scientists who were defending either process or movement. There are representatives of this idea in Far East and Near East whose origin dated back to Heraclites (Pante Rei). During modern era, Duhem, Planck, Boatman, Einstein, were the representatives of this idea. Especially the results of various research fields such as quantum theory, system dynamics, chaos theory, complex systems theory are the thesis that strengthens process oriented approach.

Once upon a time, concept of uncertainty which was sacrificed into reduction understanding of mechanist point of view is no longer perceived as a threat but an opportunity and reasons in their origins have been investigated. While doing this, modification endeavor on different levels of scientific epistemology, have been discussed. Process oriented approach, brought forward different logic types in order to allow better interpretation of interactions. One of this is the non-linear dynamics approach as being dialectic logic. This logical approach brought forward an understanding based upon the principals of dynamic identity union of opposites and junction of opposites [Sabelli, 1995].

There are also various logical systems that are formed by refusing some principals of Aristotelian logic. ***Intuitionist logic*** refuses excluded middle principal and

paraconsistent logic refuses non-contradiction principal. ***Fuzzy logic*** refuses either of these principals.

Although identity principle currently exists, fuzzy logic emphasizes that attributes of objects can not be categorized as certain limited. And that unavoidably makes it necessary to form a point of view based upon process rather than objects. Fuzzy logic with its feature establishes an ideal frame for evaluating modern scientific accumulation and struggling against uncertainties.

There are some various approaches such as fuzziology that have been developed by applying fuzzy ontology for fuzzy logic [Dimitrov, 2002].

3.2. FUZZY LOGIC AND SOFT COMPUTING METHODS

3.2.1. Soft computing methods

Lotfi Zadeh (1921-), named all of the approaches such as artificial neural network, fuzzy logic, evolutionary computation, chaotic modeling as soft computing methods. Soft computing methods are the user friendly approaches that exist in the sphere of interest of many scientific disciplines within the scope of analysis, interpretation, reasoning, theory generating, scientific explanation, prediction and modeling. These methods, generally, are applied into the computer system. Apart from hard computing systems, soft computing systems are more appropriate for imprecise and uncertainty sovereign fields. Via soft computing methodology, more adaptive, trustworthy and cost-effective systems can be developed. Under some circumstances term of adaptive or intelligent systems are used for the systems, based on soft computing methods.

Quantitative models have disadvantages. Generally logical/mathematical and statistical models include sophisticated formulas and thus from their users' point of view- if they do not have a bend for advanced mathematic- they are perceived as almost black or grey box. As these models require advanced mathematical capacities and notation, they are boring from computation and information technology's side.

As daily life is very sophisticated, non-linear methods for solving the problems are used. If a model is simplified by using linear-models then one can encounter with unreliable and unsatisfactory results.

Furthermore, computers for instance still run hardware, based on two valued logic and certain models can be either paradoxical or cause extremely heavy burden. For this reason engineering sciences use soft computing methodology if designers have a bend for these methods.

In qualitative methods, indefinite, ambiguous, uncertain, non-numeric objects are used. In addition to this most of the results are based on intuition, interpretation, abstraction and approximate reasoning.

Other feature of the soft computing methods is their being successful for solving the problems such as classification, pattern recognition, control, global optimization and other sophisticated ones. Soft computing methods are closely related to both artificial intelligence and cognitive sciences. Nowadays, the most interesting artificial intelligence paradigms are fuzzy logic, neural network and genetic algorithms. During the last few years, production of approaches in which all of these three methods are used in order to increase performance much better, started to arouse people's interest.

Basically, soft computing methods include fuzzy systems, artificial neural network, probabilistic reasoning and evolutionary computation. Currently, some fields such as chaos theory, artificial life, learning theory are added to this scope. These methods either with each other or classical mathematical methods are used in a way by forming a hybrid system. Also some fields such as medicine, anthropology, social sciences and behavioral sciences are the fields where soft computing methods can be used as effectively and comfortably.

On the computer system, these elements deal with imprecise, learning, uncertainty and optimization. The main target of soft computing programming is to imitate people's linguistic inference process by using computers. Apart from certain methods including artificial intelligence, soft computing methodology must have a high-level machine IQ. Therefore, other meaning of soft computing methodology is the methods such as information granulation theories, processing and computation via words whose origin based upon fuzzy logic. The major advantage of soft computing methods is to be able to include both quantitative and qualitative methods.

Fuzzy logic is the essence of soft computing methodology. The basic feature of fuzzy logic is to grow out of reliability of reasoning mechanism. As fuzzy logic in soft computing methodology has the function of a springboard where every theory can be generalized, has a special role. Fuzzy logic in soft computing field deals with uncertain conditions and approximate reasoning, artificial neural network, learning, probabilistic reasoning, belief propagation and uncertainty, evolutionary computation, general optimization and search, and chaotic modeling deals with non-linear dynamics. From a general point of view, it can be said that all of these methods are not competing but integrating methods with each other. Hybrid intelligent systems can be generated by usage of these methods related to each other.

3.2.2. Fuzzy logic concept

Fuzzy logic focuses on approximate reasoning rather than certain reasoning. In two valued logic, everything is either correct or false. In multi-valued logic, correctness is a gradation problem. But in fuzzy logic, everything included correctness or everything allowed is a gradation problem. The basic principals of fuzzy logic and its influence on fundamental sciences especially on mathematical and physical sciences become more obvious day by day. But still there are many false evaluations about the purpose of fuzzy logic and its strong or weak sides.

One of them is about the definition of fuzzy logic. There are two meanings of fuzzy logic. In fact fuzzy logic with its narrow meaning is a logical system that intends to shape approximate reasoning. In this context, although fuzzy logic is an extension of multi-valued logic, it is completely different from multi-valued systems whose agenda is classical.

Fuzzy logic with its broad meaning includes fuzzy set theory and with its narrow meaning it includes fuzzy logic. Nowadays when fuzzy logic is denominated then what understood is fuzzy logic with its broad meaning.

Other important point is any of these X sets that include crisp sets are to be altered with fuzzy sets and able to be made fuzzy. That is to say by fuzziness, arithmetic might be generalized with fuzzy arithmetic, topology might be generalized with fuzzy topology and control theory might be generalized with fuzzy control theory. From this point of view, classical meaning of fuzzy rules, fuzzy graph and fuzzy probability is to connote the generalization of rule, graph and possibilities. All of these have a central role on fuzzy applications.

Fuzzy graph on the account of fuzzy graph can be defined as disjunction of Cartesian multiplication of fuzzy sets. Actually fuzzy graph can be perceived as a squeezing representation of functional and related dependence. Fuzzy graph calculation is the subset of fuzzy logic.

Possibilities on the account of fuzzy probability are stated by using fuzzy numbers rather than certain number values. Possibility dispersion can be shown as fuzzy graph. The basic target of fuzzy probability computation is to provide a framework for linguistic decision analysis. Linguistic decision analysis is a qualitative analysis type and in the presentation of probability and utilization, fuzzy numbers and fuzzy graphs are used.

Fuzzy rule, fuzzy graph and fuzzy probability methodology are suitable for the conditions where uncertainty and indefiniteness is common and where certainty and definiteness bring cost. Consequently basic purpose of these methods is to provide compatibility, reliability and cost effectiveness via using tolerance against for the uncertainty and imprecision.

Fuzzy logic has four principal ways. These are respectively its logical, set theory, relational and epistemic ways. Logical was as mentioned above, deals with logical systems where correctness is graded. Set theory way is directly related to fuzzy set theory. Most of the mathematical literature that is related to fuzzy logic, deals with fuzzy set theory. Relational way focuses on fuzzy dependence, granulation, linguistic variables and fuzzy rule sets. Most of the applications connected with fuzzy logic, are related to relational way. Basically epistemic way is related to knowledge representation, natural languages, semantics and expert systems. Probabilistic and possibilistic way of thinking is the part of logical and relational way as much as t is the part of this way.

One of the strongest ways of fuzzy logic is to be able to provide computing. Actually explanation power of words is higher than numbers. Linguistic variable concept has a central role on fuzzy logic and applications. Development of fuzzy logic in the field of principal, theory and application has shown a tendency towards a different dimension lately. This field is defined as computing with words and perceptions (CWP).

Although succession of fuzzy logic, it has not found a universal acceptance yet. From the beginning, even the name of fuzzy logic has become a discussion subject. And more important, fuzzy logic emphasizes incompetence of classical methodology and challenges orthodox scientific understanding. Scientific revolutions are always depressed and they require the accumulation of complaints and incompetence, generated for current methodology and theories. On the other hand, it is a clear fact that scientific transaction and development establish their new tendency for scientific understanding and knowledge on the conceptual ground of fuzzy logic.

3.2.3. Fuzzy sets and membership function

Set term, used in conventional set theory is based upon two optional logics whether an object or a set has an element or not. In the middle of 1960's Zadeh recommended the definition of fuzzy sets that were stated as gradual membership function rather than crisp sets in which attributions were stated as double membership function.

In fuzzy set theory, a kind of multi-valued set theory, every individual in the set is considered as a member to some degree rather than not a member or member as it is in classical double valued set theory. Also fuzzy set is a community which has many elements at various gradual memberships.

Transition between membership gradations in fuzzy set must be in a soft and continuous way. Elements belong to fuzzy set in a partial degree. Characteristic function in crisp sets $\mu_A : E \rightarrow \{0,1\}$ replaces by membership function, shown as $\mu_A : E \rightarrow [0,1]$ function, in fuzzy sets.

Generally a curve which differs from set members and their values is called ***membership function.*** On the membership function graph while axis shows members, y axis shows membership gradation. Although there are many memberships function types, more common ones are triangle, trapezoid, bell-shaped curve, Gaussian and sigmoid functions. A triangle membership function is defined as a_1, a_2 and a_3 by three parameters.

$$\mu_A(x;a_1,a_2,a_3)=\begin{cases} a_1 \leq x \leq a_2;\ \text{if } (x-a_1)/(a_2-a_1) \\ a_2 \leq x \leq a_3\ ;\ \text{if}(a_3-x)/(a_3-a_2) \\ x>a_3 \text{ or } x<a_1\ ;\ \text{if } 0 \end{cases} \qquad (3.1)$$

A trapezoid membership function is defined as a_1, a_2, a_3 and a_4 by four parameters. Actually triangle membership function is the special situation of the trapezoid membership function.

$$\mu_A(x;a_1,a_2,a_3,a_4)=\begin{cases} a_1 \leq x \leq a_2,\ \text{if } (x-a_1)/(a_2-a_1) \\ a_2 \leq x \leq a_3,\ \text{if}1 \\ a_3 \leq x \leq a_4,\ \text{if } (a_4-x)/(a_4-a_3) \\ x>a_4 \text{ or } x<a_1;\ \text{if } 0 \end{cases} \qquad (3.2)$$

3.2.4. Fuzzy logic and linguistic variables

The underlying basic principal idea of fuzzy logic is either values in a set which contains correctness of the hypothesis and hypothesis of infinite numbers of accuracy values between certain wrongs and accurate or acceptance of a function, related to interval of real numbers [0,1] numerically.

Fuzzy logic is the logic of approximate reasoning. Its being expressed via various attribute gradation as linguistic (or existing between [0,1] interval of real numbers numerically) and its having inference rules whose accuracy values and validity is not certain but approximate .

The important features that distinguish fuzzy logic from other logic systems are excluded middle principle and also the principle known as non-contradiction in which two features, very important for the classical logic, are not valid. It can not be said that "a hypothesis can not be both true and false at the same time" in fuzzy logic. This situation is derived from correctness being too valuable and the meaning that "AND" connective conveys. Fuzziness is derived from the uncertainty between a hypothesis and its negation.

The prior one between two situations in which fuzzy logic is the most effective, opposes of considering people's point of views and value judgments in a condition when the analyzed event becomes too sophisticated and enough information about this does not exist. The second one is the condition that requires peoples' cognitions and judgments. Although uncertainty is not numerical on peoples' mind, it is still beneficial source of information. Thus principals of fuzzy logic would assist to use these kinds of source of information in an original way for analyzing the events. Via fuzzy logic, one may have the chance of benefiting from linguistic uncertainties used in daily language for modeling and computation. People understand each other by talking with linguistic information. The major field in which fuzzy logic to be evaluated is to find out how to think for analyzing in a condition when these kinds of information is gathered. It has been strived for approximate modeling of any problems and controlling it by not sophisticated mathematical solution methods via fuzzy logic.

Fuzzy set, fuzzy logic and fuzzy system principals are used for scoping out completely by processing linguistic information achieved from experts. Every linguistic information corresponds to fuzzy sets. In fuzzy sets, gradual membership functions can be decided by making subjective preferences. Hence; fuzzy sets help for modeling a dialogue between individuals.

Fuzzy logic distinguishes from classical Aristotle's logic, objective logics and other logic systems such as logics that have set-value of accuracy values obviously. Accuracy graphs and inference rules of fuzzy logic contain uncertainty. Accuracy gradation depends upon quantitative used for strengthening or weakening these meanings as much as the meaning conveying by true or false.

In fuzzy expressions, some processors such as negation ($\sim$, $\neg$), conjunction (and, $\wedge$), disjunction (or,$\vee$) and implication (conditional state, if,$\Rightarrow$) are used. In addition to this there are different definitions which explain the meaning of these processors. Generally variables convey numerical values. If a linguistic term is given to a variable then it is called ***linguistic variable.***

Fuzzy linguistic variables are formed by two parts, known as fuzzy predicate and fuzzy attributes. ***Fuzzy predicate*** is a primary term. ***Fuzzy attributes*** features them and are words such as very, possible, almost impossible, extremely, not possible. Attributes are used for changing the meaning of antecedent and categorized into two groups. Some parts of attributes are defined as ***fuzzy featuring accuracy*** and ***fuzzy accuracy value***. Words such as definitely correct, very correct, extremely correct or less correct can be given as an example. Fuzzy featuring consists of the words like very, few, almost, all, generally.

If a set that features the predicate is a fuzzy set then it is called fuzzy predicate When a fuzzy predicate is given as "x is P " then it can be interpreted in two ways;

1. P(x); is a fuzzy set. Gradual membership of x in P set $\mu_{P(x)}$ is defined by membership functions.

2. $\mu_{P(x)}$; P is fulfilling gradation of its features. Thus accuracy value of fuzzy predicate is defined by membership function ($\mu_{P(x)}$).

3.2.5. Fuzzy rule and fuzzy inference

Generally an inference is defined as obtaining new information by using current information. In inference there would exist both the representation and notation ways of information. If and therefore rule types are the most common ones among representation methods.

Rule type representation is interpreted as implication (conditional proposition) and it includes antecedent (IF) and consequent (THEN) parts.

Let's have a fuzzy rule of "If x is A, then y is B" type. Fuzzy rule may include fuzzy predicate in both antecedent and consequent, and it is written as follows

"If x is A(x) , then y is B(y) "

Then this rule can be shown as;

R (x,y):If A(x), then B(y) or,
R (x,y):A(x) →B(y)

by intervention of R (x,y) correlation.

If there is a rule or a fact that includes fuzzy sets then we may conduct two types of reasoning; generalized modus ponens and generalized modus tollens.

In Generalized Modus Ponens (GMP);

FACT: x is A (R(x))
RULE: If x is A , then y is B (R(x,y)) (3.3)
CONCLUSION: y is B (R(y)=R(x)°R(x,y))

However in Generalized Modus Ponens (GMT);

FACT: y is B (R(y))
RULE: If x is A, then y is B (R(x,y)) (3.4)
CONCLUSION: x is A (R(x)=R(y)°R(x,y))

We recognize that the facts as above reasoning may be different from antecedent in (A' and B') rules and the results may be different from consequent. Therefore this type of inference is called either fuzzy-approximate- reasoning or fuzzy inference. In order to make fuzzy-approximate- reasoning, compositional rule of inference is conducted. Inference here represents the process, conducted to obtain compositional output. There two main subjects like determining of R (x,y) which is a conditional implication in fuzzy logic and selection of compositional processor in fuzzy reasoning.

3.2.6. Fuzzy systems

Static or dynamic systems, benefiting from fuzzy sets or fuzzy logic and also the mathematical equivalences of this are defined as **fuzzy systems**. These systems, having principles, are based on inference with fuzzy logic and reasoning.

Designing a fuzzy system means developing of a system that provides fuzzy logic inference and reasoning in a digital platform by soft computing methodology. If fuzzy systems are defined in a way "IF-THEN" then they are called rule based fuzzy systems. Fuzzy systems are used for different purposes such as modeling, data analyzing, foresight and controlling.

Some systems contain uncertainty and fuzziness that can not be explained by simple and certain mathematical formulas and equivalences. When an interval mathematics and fuzzy logic are used together then it may provide an alternative mathematical modeling opportunity. In such conditions, confidence interval and fuzzy membership are used for approximate evaluation and so the term of fuzzy system modeling concept appears.

Fuzzy modeling is a new modeling paradigm. The advantage of fuzzy model approach lies along using of both qualitative and quantitative information according to classical black box that is able to use numerical data. The qualitative information which is important and inevitable for applications is the knowledge and the experience of people modeling which is used and obtained as fuzzy logic and fuzzy rules. In fact both the experience and knowledge are the non-linear structures of physical systems and these structures are presented in a linguistic and veiled form rather than a clear and analytical form. As fuzzy stets, fuzzy logic and fuzzy rules are intuitive, fuzzy models are also intuitive. Generally these are black box models and not as simple as the models to be explained by mathematical models. Under certain circumstances it is possible to derive fuzzy models in analytical shape that are not a black box model.

Generally, every system that use fuzzy mathematic in a way might be accepted as fuzzy system. If we examine it in details, fuzzy systems are divided into two groups as complete fuzzy systems and hybrid fuzzy systems. Complete fuzzy systems are the systems, derived from fuzzy mathematical ground fully. Hybrid systems use the mixed ways of fuzzy mathematic with other not fuzzy techniques. Most of the complete fuzzy techniques including fuzzy controller and fuzzy models apply fuzziness, fuzzy reasoning and rinsing processes while they are conducting their duties.

3.2.7. Fuzzy modeling

In modeling context, there are various ways, allowing the use of fuzzy sets. For example fuzzy sets may be used while the system is being defined. A system can be defined as the sum of "if and - then" rules with fuzzy predicate or a fuzzy correlation. Other way in which fuzzy sets are used for establishing a system, is to display system parameters. While the system parameters are being defined, fuzzy numbers are used rather than real numbers and that is defined as algebraic or differential equivalences. Fuzzy numbers allow to definition for the uncertainty at parametrical values.

Other way for using fuzzy sets is the state in which input and output of system and correlation variables may be fuzzy sets. Fuzzy inputs can be the noisy data, obtained from sensors that do not have too much reliability or they can be defined by quantities related to perception of human being such as comfort and beauty. Fuzzy systems apart from classical systems can process such linguistic data. A fuzzy system at the same time can contain more than one design type, mentioned above.

The role of fuzzy mathematic whether complete or hybrid is to allow contribution of non-linear effects as in an intuitive way on to the system. In other words, fuzzy systems are non-linear systems whose co-efficient of variables alters constantly via the alteration of input of the system. If it is designed properly, this co-efficient of variables may increase the performance of fuzzy system.

Classical system theory models by depending upon classical mathematical methods such as algebraic, differential or difference equivalences. Mathematical modeling is provided for some systems like electromechanical systems because physical rules that execute them are well understood. In addition to this for many application fields, gathering of information is very difficult, long, expensive and even impossible as much as what physical modeling requires. In the most part of the system, underlying process is partially understood, classical mathematical models are not derived or they are too complicated. There are many similar examples in the fields such as biotechnology, ecology, finance and sociology in chemistry or food industries. The major part of the information about these systems can be obtained from experts, employees or designers. This information can be fuzzy and uncertain and can not be explained by mathematical functions. In addition to this, it is possible to define these systems via using natural language under the structures of "if- then" rules. Fuzzy rule-based systems may use data-based models. Knowledge-based systems can be formed by utilizing from experts' knowledge of sphere interest. From this point of view, fuzzy systems correspond to expert systems, examined commonly in symbolic artificial intelligence.

Via classical mathematical models, a certain numerical process can be done only when parameters and inputs are known accurately. As it is not a common situation a modeling framework which processes not only data but also related uncertainties for application, is needed. Stochastic approach is a classical method for evaluating uncertainties. In addition to this, all uncertainty types can not be evaluated under the framework of randomness. Fuzzy logic and fuzzy set theory propose an alternative for this issue.

Definition of a dynamic system via input-output measurements is the important subject of the scientific researches related to many practical applications. Many systems are not linear and can not be shown by linear models, used for defining classical systems. Currently, for non-linear systems, methods to be defined by oriented its own data are being tried to develop. The most popular model proposals are artificial neural network, fuzzy logic and other soft computing techniques. From input-output point of view, fuzzy systems are soft mathematical functions that make other functions or measurement results into an approximate state on requested accuracy. This feature is called universal approximation function. Universal approximator can approximate every continuous function in a compact up to certain correctness gradation. Wang, had shown that every fuzzy systems are universal approximator via Universal Approximation Theory that he proved by using Stone-Weierstrass theory. Wang proved this theory also for squared integrallable functions. Thus, all of these theories prove that usage of fuzzy systems almost in every modeling problem. In 1992, also Kosko proved that fuzzy systems were universal approximator. Thus Kosko named this as **Fuzzy *Approximation Theory*** Fuzzy approximation theory argues that a curve can always be covered by limited corresponding ***fuzzy patches*** (fuzzy rules). All these fuzzy systems perform a certain type of fuzzy covering processes. When the sharper cover is required, the more patches are needed. Topology and measurement theory techniques are used in order to prove this principal that seems simple.

Buckley proved universal approximation theory for Sugeno type controllers and Castro and Delgado proved universal approximation theory for fuzzy rule systems. Castro and Delgado also indicated that fuzzy systems are universal approximator that can be categorized by fuzzy correlation and rinsing method which has the constant fuzzy inference and correctness features and also showed that an optimal fuzzy system exist for many problems. Although this result is effective for the concept and the power of fuzzy logic, it does not claim how a fuzzy system to be designed for a certain problem oriented.

3.2.8. Fuzzy model structure

Two basic titles –structure of the system and parameters- can be distinguished in design of fuzzy models. The structure determines the flexibility for approximate state of unknown correlation of the model. Parameters, under these circumstances, are foreseen for modification of the current data. A model having a rich structure can both provide to bring more sophisticated functions into approximate state and also have the features of bad generalization. Good generalization means to provide a model, fits to a data set to work properly in another data set, required from the same process. In the systems, based upon fuzzy logic, generally four categories fuzzifier interface, inference engine, defuzzifier interface, rule base can be mentioned.

Fuzzier interface translates certain data values into fuzzy values. In order to do this, it obtains input values and provides to translate input variable interval into a proper universal set and then it translates input data into proper linguistic values (fuzzy sets).

Fuzzifier interface imitates human being's decision-making process, based upon fuzzy concepts. Also, it applies fuzzy controlling activities that use fuzzy implying and linguistic rules. Inference motor applies reasoning process for obtaining fuzzy outputs.

Rule base application field contains the information of its purposes and defines rule and function membership. Rule base is formed by a data base and a linguistic rule base. Data-base contains controlling rules and the necessary definitions, used in data processing. Linguistic rule base defines the strategy and rules via linguistic terms.

However, ***Defuzzifier interface*** is in charge with translating fuzzy output values into crisp values.

In fuzzy model, there are various parameters for the duties to be conducted by every division. Basically, these parameters can be categorized as logical, structural, correlative and functional. Selection of all these parameters determines the structure of the system to have been put forth.

3.2.9. Fuzzy rule base

Fuzzy rule base is the heart of a fuzzy system. Data transferred to fuzzy system is first of all prepared for processing and then they are processed by inference mechanism according to the rules loaded in fuzzy rule base and defined as "if-then". Actually, in fuzzy rule base a model to be interested in has already been processed according to "if- then (fuzzy sets)" rules by linguistic expressions.

In fact, there are various methods such as rule based, fuzzy linear regression method, cell–oriented fuzzy methods for system modeling via using fuzzy set theory. Rule based systems are explained in this book and also fuzzy logic modeling is said to mean rule based fuzzy modeling.

A linguistic implication-conditional proposition such as "$a \Rightarrow b$" can be expressed as follows;

If "a is true" then "b is true"

Let's $a \in A$ ve $b \in A$ and μ_A is the membership function that defines their accuracy values for fuzzy inference executed in A fuzzy set. Therefore the linguistic expression can be as follows;

If "$a \in A$ is true with $\mu_A(a)$ accuracy value "
Then "$b \in A$ is true with $\mu_A(b)$ accuracy value "

The accuracy value of this expression is as follows;

$$\mu_A(a \Rightarrow b) = \text{MIN}\{1, 1+\mu_A(b) - \mu_A(a)\} \quad (3.5)$$

In this example, both a, and b exist at the same fuzzy sub-set and they have the same membership function. If a, and b were the different sets having different membership functions such as μ_A and μ_B, then we would encounter with a very sophisticated fuzzy correlation. Also in many situation $a \Rightarrow b$ implying correlation is provided in $a \in A$ and $b \in B$ fuzzy sets and this state is expressed linguistically as;

If "$a \in A$ is true with $\mu_A(a)$ accuracy value" then "$b \in B$ is true with $\mu_B(b)$ accuracy value"

The value of this will be as μ_{AxB} $(a \Rightarrow b)$=MIN $\{1,1+\mu_B(b)- \mu_A(a)\}$. As all of these expressions are standard and their meanings are very clear in this context, they could be written in a very simple way as follows;

If "a is A" then "b is B"

This type of fuzzy implication is generally called "if- then" rule.

In general fuzzy "if- then" rule there isn't any "OR" and "NOT" fuzzy logic processor. A fuzzy logic implying expression can be expressed by the general following fuzzy*" IF-THEN"* rules that always contain only fuzzy logic and its processor;

If a_{11} A_{11} and... and a_{1n} A_{1n} , then $b_{1\ is}$ B_1
If a_{21} A_{21} and .... and a_{2n} A_{2n} , then b_2 B_2
.....
If a_{m1} A_{m1} and... and a_{mm} A_{mm} , then b_m B_m

This general fuzzy logic "if- then" rules family is generally named as **fuzzy logic rule base.**

3.2.10. Modeling options in fuzzy rule base

In order to establish a fuzzy model there are two information sources – antecedent information and data (measurements). According to this two approaches can be mentioned for fuzzy modeling. The first one is the linear approach and accordingly it is also called information engineering. Process designers can form fuzzy expert systems via using approximate structure (qualitative and hypothetical) of antecedent information that is obtained from experts like processors. Expert information can be explained by linguistic terms. And this can be faulty and an arrangement should be made in the model. Hence, defining of a process is the more efficient way for using expert information assistance. This process requires the definition of input variables of the model and also determination of the fuzzy model type.

Second approach is data driven modeling. While modeling a system, it is possible to obtain the necessary data via data recording or the custom defined experiments for many processes. An approach based upon establishing of a fuzzy model via data, lies along the ideas oriented neural network, data analyzing and classical system definitions together with focusing on fuzzy logic and approximate reasoning. Establishing or improving of fuzzy model via data is generally explained by fuzzy definition concept.

According to conclusion type, generally fuzzy model depending upon three types of rules is distinguished. These are respectively linguistic fuzzy model, fuzzy relational model and Takagi Sugeno Kang's model. In linguistic fuzzy model is both antecedent and consequent fuzzy hypothesis. Fuzzy correlated model is the generalized form of the terms of linguistic fuzzy model between antecedent and consequent by establishing fuzzy correlation. In Takagi Sugeno Kang's fuzzy model, antecedent is a fuzzy hypothesis and consequent is a certain function.

In this chapter, a linguistic method called ***Mamdani method*** will be explained. This method allows (semi-) qualitative information to be used in "if-then" rules. As long as i=1,2,...,k ;

$$R_i\text{: If } x\ A_i\text{ , then } y\ B_i$$

expression can be given as an example of this rule.

In linguistic fuzzy model, x antecedent input is a linguistic variable and A_i is the term of antecedent and linguistic. In the same way, y output is consequent linguistic variable and B_i is a linguistic term. Via x and y values, linguistic terms of A_i and B_i are fuzzy sets and they can be defined as x and y $x \in X \subset R$ and $y \in Y \subset R$. Term of $\mu(x)$: $X \rightarrow [0,1]$ ve $\mu(y)$:$Y \rightarrow [0,1]$ which is the membership function of antecedent and consequent of fuzzy sets are essentially correlations. A_i fuzzy set in antecedent space, defines the fuzzy areas corresponded to relevant consequent hypothesis.

A_i and B_i linguistic terms are generally selected (like small, medium) among pre-defined term sets. The meaning of linguistic terms is not universal.

3.2.11. Fuzzy inference mechanism

An output is processed via inference mechanism in a fuzzy rule base. In rule base, according to modeling type of information (Mamdani, Takagi Sugeno Kang vs.) output value which corresponds to current input to be determined. This process is an inference and decision-making process. Meanwhile processing of an input with the rules for manipulation is point at issue. Actually the process, done is an inference process and then taking the composition of obtained results. First of all let's handle the evaluation problem of fuzzy "if- then" rules that's to say inference process:

$$\mu_{A\Rightarrow B}(a,b) \equiv \mu_A(a) \Rightarrow \mu_B(b),\ a \in A,\ b \in B \tag{3.6}$$

Evaluation for two-valued classical logic is simple;

$$\mu_B(b) = \begin{cases} 1 & \text{If } \mu_A(a)=1 \\ 0 & \text{If } \mu_A(a)=0 \end{cases} \tag{3.7}$$

That is to say $a \in A \Rightarrow b \in B$;

$$\mu_{\bar{B}}(b) = \begin{cases} 1 & \text{If } \mu_{\bar{A}}(a)=1 \\ 0 & \text{If } \mu_{\bar{A}}(a)=0 \end{cases} \tag{3.8}$$

That is to say $a \notin A \Rightarrow b \notin B$.

For fuzzy logic there are various options according to the selection of certain logic system for "if- then" rules.;

$$\mu_A(a) \Rightarrow \mu_B(b)$$

That is to say;

$$\mu_{A\Rightarrow B}(a,b) = \mathrm{MIN}\{\mu_A(a),\ \mu_B(b)\} \tag{3.9}$$

$$\mu_{A \Rightarrow B}(a,b)=\mu_A(a).\ \mu_B(b) \quad (3.10)$$

$$\mu_{A \Rightarrow B}(a,b)=MIN\{1,1+\mu_A(b)-\mu_B(a)\} \quad (3.11)$$

$$\mu_{A \Rightarrow B}(a,b)=MAX\{MIN\{\mu_A(a),\mu_B(b)\},1-\mu_A(a)\} \quad (3.12)$$

$$\mu_{A \Rightarrow B}(a,b)=MAX\{1-\mu_A(a),\ \mu_B(b)\} \quad (3.13)$$

All of these evaluation formulas are conformable to the purpose of fuzzy logic inference and provide the same formula with inference correlation constantly.

These formulas can be expanded in a way including much more parts. For instance a general fuzzy "if- then" rule;

If a_1 is A_1 and... and an is A_n , then b is B.

From this making an expansion as the following is possible;

$$\mu_A(a_1,\dots,a_n)= MIN\{\mu_{A1}(a_1),\dots\dots\mu_{An}(a_n)\}$$

$$\mu_A(a_1,\dots,a_n)\Rightarrow \mu_B\equiv\mu_{A\Rightarrow B}(a_1,\dots,a_n,b)=MIN\{1+\mu_B(b)-\ \mu_A(a_1,\dots,a_n)\} \quad (3.14)$$

In order to use a linguistic model, an algorithm which can establish an output value from a given input value is needed. This is called ***fuzzy inference algorithm*** (mechanism). For linguistic model, inference mechanism can be derived via using fuzzy correlation processes.

Every rule can be expressed as fuzzy correlation that is to say a limit where x and y values exist as equivalent: (R_i:XxY→[0,1]) This correlation can be computed according to either Mamdani or Larsen method.

Mamdani's method uses MIN processor as fuzzy inference (condition) processor, and also uses MAX-MIN'i as composition processor. Let's give fuzzy rules in the following way; i=1,2,...,n $x\in U$, $A_i\subset U$; $y\in V$, $B_i\subset V$; $z\in W$, $C_i\subset W$;

R_i: If x is A_i and y is B_i, then z is C.

1. When input data has a singularity like $x=x_0$ and $y=y_0$ then output data is not fuzzified. A_i and B_i equivalence gradation (firing power) is respectively $\mu_{Ai}(x_0)$ and $\mu_{Bi}(y_0)$. Therefore, equivalence gradation of R_i rule;

$$\alpha_i = \mu_{Ai}(x_0) \wedge \mu_{Bi}(y_0) \qquad (3.15)$$

When C'_i, is the result of R_i rule;

$$\mu_{Ci}(z) = \alpha_i \wedge \mu_{Ci}(z) \qquad (3.16)$$

Total result is derived from C individual controlling rules;

$$\mu_{C'}(z) = \bigvee_{i=1}^{n} [\alpha_i \wedge \mu_{Ci}(z)] \qquad (3.17)$$

$$C' = \bigcup_{i=1}^{n} C'_i \qquad (3.18)$$

2. When input data is A' and B' fuzzy sets i=1,2, ..., n ;

$$\alpha_i = \mathrm{MIN}\,[\underset{x}{\mathrm{MAX}}\,(\mu_{A'}(x) \wedge \mu_{A'}(x)),\ \underset{y}{\mathrm{MAX}}\,(\mu_{B'}(y) \wedge \mu_{B}(y))] \qquad (3.19)$$

$$\mu_{C'i}(z) = \alpha_i \wedge \mu_{Ci}(z) \qquad (3.20)$$

Total C' result is determined as (3.15) and (3.16);

$$\mu_{C'}(z) = \bigvee_{i=1}^{n} [\alpha_i \wedge \mu_{Ci}(z)]$$

$$C' = \bigcup_{i=1}^{n} C'_i$$

In Larsen method, multiplication processor (•) for fuzzy inference and MAX-multiplication processor for fuzzy composition is used.

3.3. COMPLEX SYSTEMS AND THE CHAOS THEORY

3.3.1. Dynamic systems theory

Systems can be classified according to the equilibrium state as equilibrium systems, systems which are near-to-equilibrium systems and which are far-from equilibrium systems.

Systems which have no association with the thermal and chemical equilibrium and which are far-from equilibrium seem not to be in a linear manner and they don't go through a phase that can be determined previously. They don't move in the direction of the biggest energy (utilization) and the biggest specific entropy. On the contrary, they invigorate certain rise and falls in order to develop themselves towards the direction of a new dynamic regime which happens to part from a constant state or from a near-to-equilibrium state radically.

Systems of such category are open systems whose imperative entropy alterations cannot be determined through non-recyclable inherent processes all the time. Inherent processes within the systems are particularly loyal to the second principal pf the thermodynamics. Free energy which is consumed for once, are not available for any consequent jobs. Free energy accumulation or the negative entropy which will be necessary for the following jobs can be imported by the open system from the neighborhood. Disequilibrium state related to the systems of such category and the non-linear thermodynamic and the dynamic systems theories which are the classic dynamic of the non-recyclable processes are related to the dynamic systems theory. If one or more directions of the system change within a certain period, this system is called the dynamic system. The feature of the dynamic system is that there is no time-related development which can definitely be identified in the system. Dynamic systems react to the dramatic changes in the neighborhood and they change in an onset manner.

Dynamic system in engineering and mathematics are defined as a deterministic process which change in time due to a rule whose function value is defined on basis of the up-to-date value of the function. Dynamic systems can be continuously dynamic or parted dynamic systems. If the time is measured on parted grades and if they are modeled with repetitive correlations such as those in logistic correlations, the dynamic system is meant to be parted. Indicating the parted grade digits with t; the variable which varies in time with x; the following calculation can be made:

$$x_{t+1} = ax_t (1-x_t) \tag{3.21}$$

If the time is calculated continuously, the result will be continuous dynamic systems which are explained with differential equations. Considering x as the variable which varies within the t time, the following can be explained:

$$\frac{dx}{dt} = ax(1-x) \tag{3.22}$$

Variable x is generally a real number which as well can be a vector.

Dynamic systems can be classified as ***linear*** or ***non-linear*** systems. The right side of the equity in linear systems is directly connected to x. In linear continuous systems, the Leplace cycle method will make sure the differential equities are converted to algebraic equity form. Differential equations show the reality as a process which last continuously without an independent time division and also which is subject to a continuous alteration from time to time. Equations which are used to calculate the variable values try to form the variable world model which we have in the neighborhood.

Non-linear systems cannot be solved or added on to each other acting totally different from the linear systems. Non-linear situations such as friction in mechanic and fluid systems are the ones that people try to rule out from calculation when they need simple results. Variability makes the calculation of the non-linear situation; however it also forms various behaviors which cannot be observed in linear situations. The character of a non-linear equity differentiates right away through a change of both the degree and the order.

3.3.2. Complex adaptive systems and chaos

Non-linear dynamic systems can show completely unpredictable behaviors. Such systems which are also known as complex adaptive systems are those which can affect the behavior of the entire system when the sub units which moves totally unpredictably, influence each other. Such systems are those which are far from equilibrium, non-linear, irreversible, totally uncertain, and which experience evolutionary development in time and have emergent specifications.

This unpredictable behavior which is experienced even though the system is deterministic is defined as chaos. The branch which defines the chaos behavior of dynamic systems is called the chaos theory. This branch of mathematics has been observing the dynamic systems on qualitative aspect. The focus here is not to find definite equities that define dynamic systems (which is generally hopeless) rather to answer questions such as "will the system reach to a stable phase and if yes, what are the possible constant phases?" or "Is the long-term behavior of the system dependent on the initial conditions?"

Chaos is a timely evolution which is sensitive to the initial conditions. The term chaos was used by Jim Yorke from Maryland University as the definition of a paradigm. According to some physicians, the chaos theory which is also know as the (non-linear) science is a branch of science which observes the processes rather than one which observes situations.

Chaos is a concept which you may confront in physics, chemistry, biology, medicine and engineering. Chaos behaviors of lasers, electronic circuits, chemical systems, brains and hearts, in epidemics and outbreaks of diseases, in the motion of the earth, in traffic and many more several systems have been sampled and observed.
Chaos exists everywhere and anytime. It is determined and has a structure. Chaos and instability are two different concepts. A chaotic system can be ultimately stable as long as it can resist against corrosive effects whose personal disorder comes from outside.

Chaotic and complex systems should be distinguished from random systems. Most people think about random systems when it comes to the concept "chaos". In the chaos theory, being different from the random systems, it's considered that chaotic systems have a disordered-order. Once the chaos idea is spoken, ultimately simple systems became to be deemed as extraordinary systems where complexity and order is located all in one and the order is formed per se. People who examine the chaotic dynamics have figured out that irregular behaviors in simple systems are actually creative processes.

A determinist system produces much more than a sole periodic system. A disorder of no rule should be requested and regular structure blocks could be found in the disorder. Simple determinist models may reveal behavior models which might be considered as coincidental. Such behavior actually is entirely nice and fair but it cannot be noticed among all that complexity. If a sudden interference is made tı such system, most probably oscillation begins.

This new science branch has formed a personal language and in that language, terms such as fractal, bifurcation, attractor, phase space and periodicity are used to meet the new phases of motion.

While the linear system is assumed as equal to the sum of parts, it's more than the sum of non-linear system parts. This means, in order to understand a linear system and the principles that lie beneath the behaviors thereof, one should see the system as a whole.

3.3.3. Sensitive dependence on the initial conditions

The mission of the twentieth century scientists was to part their own universe into the most little atoms which will fit to scientific rules. The assumption saying "When approximate information about current conditions which were present as of the initiation of a system, approximate calculations can be made about the system's behavior", constitutes the philosophical basis of today's scientific concept.

However, forecasts which are figured out from minor changes that can be seen in the initial phase may be so different from each other that, after a while all efforts related to this turns out to be meaningless. This idea has been proven by the French mathematician Jacques Hadamard (1865-1963) on latest nineteenth century. French physician Pierre Duhem (1861-1916) is one of the first scientists who notices the concept of Hadamard. The French scientist and famous mathematician Henri Poincare who has provided philosophical works on scientific issues, has explained the term "unpredictable" in a manner which everybody can easily understand in his famous book "Science et Methode" on 1908. One of the most important views of Poincare was that coincidence and determinism have met unknown in the long run. Poincare has understood that definitions based on the classical determinism view related to the world will naturally lead us to possibilities through various ways and explained it as:

> *"A very minor reason that we disregard might cause an effect which we may never disregard and we still believe that effect is coincidental".*

Such as the results that Lorenz achieved on 1961 over weather forecast, "you can interfere to weather issues in order to achieve different results when you never interfere". However, if you do interfere, you will never know what would happen if you never have interfered." Lorenz has ascertained an order which seems to be coincidental and an entire geometric structure through the examinations he made on weather model that he established after stating that minor changes might cause major changes and named this as the butterfly effect. Generally it's knows as follows: "A butterfly's clapping in Southeast Asia, in suitable conditions, might trigger a storm in America" and the technical name of the butterfly effect which is not coincidental but rather imperative is stated as sensitive dependence on the initial conditions.

Some events in science are very critical in magnifying minor changes as in the life itself. However, when it comes to the term chaos, such critical points are meant to be almost everywhere. Sensitive dependence on the initial conditions in systems is an inevitable result of the combination of minor and major scales.

The characteristic of a dynamic system is that there is a definitely-defined-timely evolution in the system. Sensitive dependence on the initial conditions is what we call when a very minor change which occurs in zero point of the system causes a more major change in time. A very minor reason causes a very major effect. Even though it is considered that extraordinary conditions should have necessarily occurred in the zero point for such thing to happen, actually the contrary fact is the truth. The sensitive dependence of several physical systems on the initial conditions is valid in the coincidental initiation case.

In case which there is a sensitive dependence on the initial conditions, the motion is always determined by the initiation case but there is a restricted possibility to see the path we will follow. That means, determinism still exists but now there is an unpredicted concept in the long run. This is simply because, we now have less information as to the initial situation and we can barely tell the difference between the reel initial situation and several initial situations which are very close to that.

3.3.4. Fractal behavior

Fractal geometry concept has been suggested by Benoit Mandelbrot (1924-). Since Mandelbrot was inadequate in understanding the core of Euclidean measures such as length, width and depth, he passed beyond three and more dimensions and reached to a fractal dimension.

Surfaces of the fractal dimension have become to be a method to measure qualities which are not entirely straight and those cannot be identified clearly such as indents, notches and breaks. Fractal approach conceives the entire structure as a whole. The dimension concept is a quality which depends on the point of view. According to the view suggested by the fractal geometry, searching for a characteristic scale which reflects the entire specifications of the item puts the human apart from his purpose. Categories drag people into mistakes. Fluid motion equilibriums are most of the time dimensionless. That means that they can be applied independent with the scale. Blood vessels and circulation system are just like when the Koch curve compresses an infinite line into a limited area, they compress a huge area into a small volume. Lungs are structured in such a manner that, they will have a very broad surface area. However, anatomy specialists are educated in an idea that they will look through a certain scale each time and they classify the circulation system according to the dimensions as big and little arteries. These categories may sometimes be of benefit but most of the time they happen to be misleading. It's often very hard to classify the sub values.

Just after ten years from Mandelbrot, some theoretical biologists began to discover the fractal orders which control the structures within the human body. It turned out to be false that bronchus part regularly based on a specific coefficient. It is understood that urine accumulation system and special net which carries electrical signals to muscles in the heart are actually fractal. A structure in the heart which is known as His-Purkinje led to a serial of research.

Self-similarity which Mandelbrot suggested is symmetry between scales and defines the shapes which went one into another. Mandelbrot suggested through his works that the real power of self similarity is more effective on complex surfaces.
Robert May and James York have found amazing orders in chaotic shapes which can only be defined by comparing big and small scales. Thus, it is figured out that structures which are the key of non-linear dynamic are fractal.

3.3.5. Phase space and attractors

Phase space is an approach which makes it available to convert each type of knowledge gathered from a moving parts system into a view together with all possibilities after abstracting them first. Any phase of any system in any time period may be indicated by a point in the phase space. Coordinates that belong to this point include all information about the position and the speed of that point. When the system changes anyhow, the point takes a new position in the phase space.

Attractor is the group where the point which represents the examined system moves over when temporary formations disappear, which happens in the long run. In order to have this definition made, it's important for outer powers that affect the system to be independent from time. On other outstanding point is that systems which lose energy should be observed and considered. Attractors naturally happen to be very determined. In a real system, moving parts are subject to the threat of outer demolishing effects but those effects are not capable of affecting the general motion of the move.

Point attractor and the periodic attractor which happens to be in the form of a closed ring, represent a repetitive behavior which has reached to a constant level. Apart from all these, an attractor which indicates the final phase of a dynamic system should be in minor dimensions and should not be periodic in a world where many corrosive effects exist. It should be in minor dimensions with an orbit not bigger than a box or a rectangle which has little freedom degree in the phase space. It should never repeat itself as it is and at the end it should not have a rhythm such as a clock or a pendulum. In other words, it shouldn't be periodic. An attractor which meets these requirements is called a strange attractor and ironically it has a strange shape. They are curves or surfaces which are not straight and they have fractal dimensions. They are sensitive dependence on the initial conditions over the motion of strange attractors.

3.3.6. Bifurcation

In certain times, the system may move between various attractor phases. This motion which is between these various attractor phases is called bifurcation. In order to make sure non-linear parameters are indicated at once, bifurcation diagram is used.

Increasing the value of non-linear parameter will mean applying a pushing effect on the system which also will mean increasing the non-linear property. When the parameter value is low, system will reach to a degree. When the value goes considerably high, the value point will divide into two. When physical powers that affect a physical dynamic system are altered, the periodic orbit will be replaced by another orbit which is close to the first orbit but which also makes two tours instead of one before it returns to the initial point. Accordingly, the period of the orbit will be twice as much. This event is called ***period doubling cascade***. As the number of periods increase, intervals get closer to a certain value. As the value increases, bifurcation accelerates. Bifurcation increases initially to four, then eight, then sixteen, then thirty-two and then to sixty-four. After a certain period, periods are superseded by a chaos. However, just in the middle of the chaos, suddenly determined and constant areas appear. Even if the parameter still goes high, a window right in the middle of this chaos will open with a regular period such as three or seven. Later on, bifurcations happen to show up fast again in the form of 3, 6, 12 ... or 7, 14, 28 ... and once again it stops suddenly and a new chaos begins.

One of the best examined examples about this issue is the logistic map. In case true re-scaling of consecutive period cascades which means the fulfillment of necessary changes within the units used in various parameters is done, it's seen that such period cascades are basically the same.

3.3.7. Modeling of the chaotic system

Only three types of attractors should be available in a linear system. These are constant point attractor, periodic attractor and quasi static attractor.

Non-linear dynamic systems might have various behavior templates. Such systems might be continuously constant, continuously enlarging, or might have periodic, quasi-periodic and chaotic motions. The type of the motion depends on the initial phase of the system and the value of the parameters. Meanwhile, non-linear systems are capable of showing chaotic behavior characteristic and they possess strange attractors. Chaos concept based on the attractor behaviors may be defined as the orbit in which a nonlinear system follows in the phase space.

In Hamiltonian (classic) system, phase space volume is secured in the timely evolution. Let's consider a two-dimension (q,p) phase space with q as the position and p as the phase. Hamilton motion equity indicates the initial conditions in the $t=t_0$ time and then makes them evolutionary in a time of $t=t_1$.

By the dissipative system concept, a system with no such characteristic is meant. Area significantly decreases in dissipative systems as the time goes by. Thus the area of the result group might be smaller than the area of the initial group. As a result of this, dissipative systems are characterized in the existence of attractor.

There are various methods to identify and characterize the chaotic systems. Even though the sensitiveness of such systems depends on the initial phases and even though their orbits move rapidly apart from each other in the phase space, some of the measurements are invariable. Such invariables depend on the assumption that the requirements of the ergodic hypothesis are fulfilled. This hypothesis means that orbits' visiting the similar areas time amounts may be comparable. There are three basic invariables. These are Lyapunov exponential, entropy and dimension.

Dimensions of strange attractors are not whole numbers; they are fractal. In Chaotic attractor, and in t=0, the distance of two points (x_1, x_2) which are separated from each other with a minor distance (δ_0) will increase by the increase of time (t). Lyapunov exponential may be defined as follows:

$$\delta_{x(t)} = \delta_{x(0)}\, e\lambda\, t \qquad (3.23)$$

Thus a minor uncertainty in the initial phase makes it impossible to predict the future. Lyapunov exponential constitutes a base for topologic qualities that correspond to concepts such as unpredictability. Lyapunov exponentials within a system make it possible to measure the opposite effects of the tension, contraction and cascade of an attractor within each other in the phase space. For an attractor with a constant point, all Lyapunov exponentials carry a negative value because as it gets closer to the determined phase in the end, attraction direction is inwards. In an attractor with a shape of periodic orbit, the value of an exponential number is zero. The value of all other exponential number is negative. In a strange attractor, there should be at least one positive Lyapunov exponential. Shortly, the Lyapunov exponential of a dynamic system is a measure for the orbits that start from each point in the phase space as to how quick they will part in time. The Lyapunov exponential is equal to the number of dimension in the phase space. But, since it determines the predictability of a dynamic system, it's dedicated to the biggest one. A positive Lyapunov exponential is the operational definition of the chaos and the basic dynamic invariable which is used to characterize the chaotic process.

A chaotic system may be considered as a knowledge source. Sensitive dependence on the initial conditions increases the unpredictability. Uncertainty in our knowledge increases even more as time goes by. Any measurement made in a later time provides extra information regarding the initial phase. Entropy is a thermodynamic quantity which explains the disorder amount in the system. Time which can be assessed as a knowledge source provides an outstanding approach to serial analysis. On microscopic dimension basis, the second law of the thermodynamic tells that the system is in an evolution tendency towards the phase with a condition of the utmost number that is coherent to the macroscopic conditions. In the phase space, with a p_i system and I space, the entropy may be defined as:

$$H=-\sum_{i=1}^{n} \log p_i \tag{3.24}$$

Practically, the area that includes an attractor may be divided to n cells and is calculated by the relevant frequency (or the p possibility) of the number that each system passes each cell.

In dynamic, one important shape of this measurement is the Kolmogorov-Sinai entropy. This is defined as the variance ratio of the entropy during the system evolution. Assuming K_n as the entire evolution of the initial system within a time of n for a time unit of τ, it is calculated as:

$$K_n=\frac{1}{\tau}H_n(1-H_n) \tag{3.25}$$

If the system is periodic, K_n will be equal to zero. The result will increase without any break-off depending on the system's being stochastic or chaotic or will decrease towards a constant value.

The Lyapunov exponential and the entropy are focused on the dynamics of orbits in the phase space. Dimension is the geometric characteristic of the attractors. Fractal geometry is a mathematical tool which is used to evaluate the complex systems. Fractal dimension (d_f), defines the characteristic of an item on space filling basis. In order to quantify self similarity and scaling, d_f is a very important and useful tool. And this dimension will tell how many new parts will be solved as the resolution increases. Self similarity dimension can only be applied to geometric self similar items which are the exact replica of small parts.

3.3.8. Chaos applications

Based on the fact that, nonlinear dynamics have been intensively examined, ideas as to what the practical applications of chaos might be. Auditing, synchronic act, data coding and chaotic behavior in communication can be successfully applied.

Over sensitivity of the chaotic systems on very minor undulations may be used to audit the systems and to make them determined. Making it predictable might be considered as one of the possible areas where the chaotic behaviors can be audited. Today, it's definitely a very attractive idea to audit the chaos.

Having considered today's works, tow major classes could be separated to audit the chaos. Firstly, the up-to-date orbit of the system in the phase space is tracked and a feedback operation can be actualized to make sure an orbit is located to a desired position. The second option which is called methods other than feedback is the usage of characteristic or knowledge that belongs to the system in order to benefit from the chaotic behavior or to change. Feedback methods do not change the audited systems and makes the inconstant periodic orbits or strange chaotic attractors constant.

In the area where chaos is audited by feedback, there are approaches such as the Ott-Grebogi-Yorke method, the Pyraga audit methods and the audit of chaos by chaos. The Ott-Grebogi-Yorke method is the method which the chaos is audited by shadowing one of the instable periodic orbits which exist with a limitless number in the chaotic attractor. Pyraga's audit methods are based on the formation of a special continuous complexity which stabilizes the periodic orbit under particular conditions but which also does not change the shape thereof. Audit of chaos with chaos method is a method where the chaotic behavior of a system is audited by pairing it with another chaotic one.

In the area where chaos is audited by other methods, we can see approaches such as audit over operation conditions, audit through the system design and breakdown of the chaos.

Nearly all natural and engineering systems confront various complexities from outside during the operation. Smart design and audit of these complexities may destroy the chaotic behavior or might move it to the harmless areas of the parameter space. The chaos might be put in order by an appropriate system design or it might be totally destroyed as well. In such audits, a more simple (generally linear) autonomous system (auditor) which is paired by main systems can e used. The concept known as the breakdown of the chaos may be explained as the decrease of weak signals within the dynamic systems or conversance of it to a regular behavior. A periodic complexity might be put in the system as an external force or the equivalent of one of the internal system parameters. Chaotic system is capable of finding an appropriate orbit. Again, the chaotic system might be put in a regular form by the application of random noise.

CHAPTER-4

A NEW PROPOSAL OF FUZZY-CHAOTIC MEDICAL MODEL

In this chapter, a new fuzzy chaotic medical model will be proposed. For this, first of all, a new and different perspective on the concept of human being will be offered and then, the concepts of health and disease/illness will be qualified as the common names of a continual and dynamic phenomenon; the concept of etiology will be discussed and suggestions will be made regarding the fuzziness underlying this concept. Afterwards, clinical table and medical diagnosis process will be redefined as fuzzy categories, processes of treatment and monitoring will be expressed in terms of fuzzy logic.

These questions will be answered via the model to be formed in this chapter:

1. What is human being? In which dimensions should it be studied? The concept of human being can be defined with the integrated relation of the individual and the society. Both the individual and the society are related to each other and include two interrelated perspectives. The perspectives of the individual are biological and psychological; those of the society are environmental and cultural dimensions. The whole of these dimensions have complex adaptive properties.

2. What do the concepts health/disease/illness mean? All these concepts, in fact, are just the identification of the basically one and the same process on different levels and perspectives. There isn't a certain and objective distinction between disease and health. The basic thing is that the body maintains its existence as a whole in an adaptive way.

3. How should be the process of clinical assessment? In order to identify the disease process in the most appropriate way, it is necessary to reveal and evaluate all the causes that affect this process negatively and positively together with the current clinical table (complaint, sign, etc.). In this way, diseases can be expressed as vague-bordered categories defined with three different parameters (causes affecting the adaptive capability positively, those affecting it negatively, and clinical table).

4. How should the treatment be guided? The purpose of the treatment is to restrict the natural adaptive capability to ordinary limits. This, due to the nature of the complex adaptive systems, can sometimes be solved with very simple approaches on other dimensions or can be aggravated. Treatment should handle the system as a whole and help it recover with minimum possible harm and interference.

4.1. HUMAN-INDIVIDUAL-SOCIETY RELATIONS

4.1.1. Dimensions of the concept of human being

The individual and the abstract/concrete categories it forms can not be studied independently from the social structure he is in because the individual, in his personality and psychological state, will necessarily carry the traces of elements from the social and cultural structure where he has grown up even though he may have been isolated from the social life biologically in some period of his life. All these elements will affect the person's capability of perception, understanding and interpreting the reality. Here, a new model will be defined where the individual is defined in interaction with the social environment he is in.

Quants, building stone of the substance according to the quantum theory, have inside both the qualities of particles and wave at the same time. Though one of these qualities can be evaluated independently from the other one, both qualities are "somehow" included in quant. Understanding the behaviors of the quant well can only be possible when these two qualities are accepted to exist at the same time.

In the new model developed, definitions of the individual and the society are also made by the inspiration of the quant concept. Similarly to the wave and particle of the quant, the individual also has psychological and biological perspectives. Both perspectives are in fact not independent and separate from each other, they affect each other and complement. Hence, every instance about the individual should be considered in terms of the relations between these.

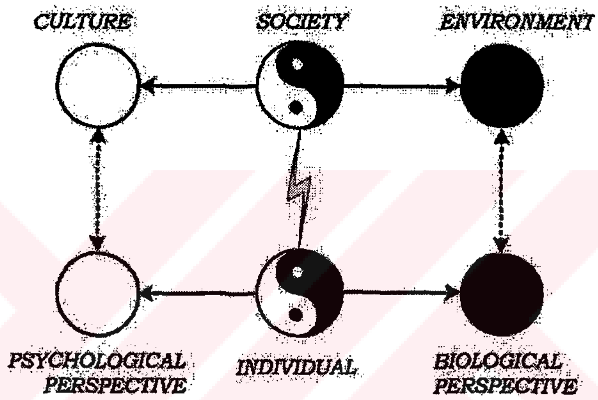


Figure 4.1. *Different levels and perspectives of human being.*

The society has two separate perspectives, too. These can be called as culture and environment. Culture can be defined as a psychological indicator of a society. As for environment, it is the structural and institutional dimension of the society.

The individual and the society perform an integration that is hierarchic and interactive with each other.

In conclusion, the concept of human being is also a two-perspective (biological-psychological, culture-environment), two-level (individual and society), a four dimensional phenomenon in total. Every concept relating to the human being should be defined with all the dimensions included.

4.1.2. Dual structure of the individual

Dual structure of the individual includes psychological and biological perspectives. These structures are interrelated and interactive. It isn't possible they are completely separated from each other.

In ***psychological perspective*** are there the elements of psychological dimension such as cognitive properties, universe of emotion and thought, perception, learning, decision-making. This dimension is mostly formed by interaction types achieved by the structural institutions of the society (family, school, etc.). Advancement of the biological structure and systems (cognitive and motor abilities) of course make contribution to the formation of this perspective.

In ***biological perspective*** are there such elements as molecular structures, cells, tissue, organs, systems that build the biological foundation of the body and the entire organism. When the biological dimension encounters any threat, the body is able to be integrated as a whole and in cooperation thanks to the communication network built by various chemicals or neural stimulations.

Psychological and biological perspectives are continually interacting with each other. Our emotions, thoughts or behaviors or more generally elements such as desire, wish, acknowledgement, perception have a direct impact on the biological structure of the individual. While biological dimension is directly affected by the psychological one, it also can affect the other. As an example, extraordinary increase in several hormones over the limits may cause emotions like anger in the human being. A head trauma or an operation may change the psychological properties of the individual.

4.1.3. Dual structure of the society

Social level has two perspectives, too. These are culture that can be expresses by the psychological perspective of the social level and environment that can be defined as the structural perspective.

The concept of culture can be defined with language, values, acknowledgements and common understanding. The individual performs his interaction with the other individuals and his environment in a common cultural framework (understanding, perception, explanation, thought, assessment, expression).

What meant by the environment is the structural arrangements that cultural perspective has done for the interaction among the individuals. In this sense, all the social bodies such as family, educational system, economic system and health system are the environment. Every kind of social structure and institution is the reflection of a specific culture.

Culture isn't a stable and unchanging phenomenon. Different cultures affect each other at contact points of their individuals. Yet, a wholly cultural exchange isn't possible. Though there may be an import of institutional belief and value, individuals tend to endorse these innovations in accordance with their own cultural tissues.

4.1.4. Individual-society relation

Structural parts (biological structure and environment) of the both individual and society consist of several sub-units inside. Though the difference between individual and the society is basically a qualitative difference, the differences between the structural parts of the individual and the society are not so. For this reason, the hierarchical relation between the categories expressing the qualitative differences such as the individual and society may be defined as ***vertical hierarchy***; interrelation between the sub-elements of the biological and environmental dimensions may be defined as ***horizontal hierarchy***.

As an example, the concept of individual has a different meaning and quality compared to the biological structure that is a group of atoms, molecules and cells. The basic element causing the difference here is the qualitative dimension. Organelles that make the cell, cytoplasm, macromolecules, cell, tissue, organ, system, and the whole organism sequence can be cited as examples for the elements of horizontal hierarchy that is developed by the concepts of quantitative proliferation, differentiation, division of labor and organization. The elements in this sequence define a quantitative increase, not a qualitative one. Similarly, the human being and all the categories like the family, society he is in can be called as the horizontal hierarchic elements.

When the hierarchic difference between these structures is ignored, it will be revealed that the developed model is reduced to the biopsychosocial model of Engel.

While social level is the basis in shaping the psychological properties (emotion, thought, and behavior) of the individual, the individual directly contributes to the shaping of the society as well. Social structures are first formed in their own cultural ground. Institutions such as family, society, education, economy and health are the reflections of the culture. There is also an interaction between the different cultures and social structures. The individuals undertake a both protective and transformative role with their contributions to the cultural and structural perspectives of the social level and their roles in accepting the change.

Different societies show different reactions to the same phenomenon. Societies attach different meanings and values to various definitions regarding the biological and psychological perspectives of the individual even though they use the same concepts. To give an example, while some cases that aren't considered as diseases on individual level (homosexuality, having marginal thoughts, etc.) are accepted in some societies as a preference or personality feature, in other societies it may be considered an abnormal situation.

4.1.5. Complex and adaptive structure of the human being

Human being is a complex and adaptive system both on the individual level and the social level. This system has an unlimited number of parameter interacting with each other; the main goal is protecting this adaptive feature of the human being despite its interaction with every kind of outside factor both on the individual and social level. Complexity theory is defended as a model making all the physical, social, biological systems understood better and giving a better perspective than minimizing and mechanistic models [Holm, 2002]. Complexity is a concept used for the systems characterized by nonlinear interactive units, emergent phenomena, continual or interrupted change, and unforeseeable results. Complex adaptive systems are generally perceived as the opposite of the simple, linear and balance-based systems [Baykal and Beyan, 2004-2].

Complex adaptive systems are interactive, harmonizing and learning structures. Organisms are adaptive within the ecosystems, antibodies in the immune system, people in political system and companies in economic system. While each unit interacts with its own knowledge and experience, these also interact as a whole and adapt to the environment. Change and innovation are the classical features of these systems. The interactions of the units within such structures are not linear and simple. Hence, complex adaptive systems unpredictably can respond to the outside stimulations. Complex systems have vague borders. One element can at the same interact with many systems and the quality of this interaction may be quite different [Plsek and Greenhalgh, 2001].

Many biological systems are governed by nonlinear dynamics and perform chaotic behaviors even under normal conditions. As an example, heart beat intervals in human being are chaotic and being a disease symptom, regular heart beat is a strong indicator for a cardiac arrest. Besides, it's been revealed that many systems do not perform a normally homeostatic balance, that there are chaotic oscillations and a characteristic dynamic state at certain intervals in phase space. This situation is called as ***homeodynamic*** [Skinner, Molnar, Vybiral, Mitra 1992; Holm, 2002; Lipsitz, 2002].

The individual may have a critical disease that may result in death or disability. In this case, the units of biological system act to protect the complex adaptive structure. These structures are always interacting with each other; critical diseases may harm this relation. Healthy people have diversity and flexibility. Orderness or strictness in this sense may be the indicator of a disease or pathology. Less complex systems mean that liveliness will be lost so that the disease becomes known. In complex human being system, injury or loss of the diversity on any connective level causes organ isolation and following that, decrease in the ability of the organs to stabilize themselves [Plsek and Greenhalgh, 2001].

In studies done about the psychological perspective of the individual, nonlinear, adaptive structures maintained their dominance in the areas of cognitive sciences, social and organizational psychology, personality and clinical psychology [Guastello, 2000].

Social systems are complex adaptive as well. Individuals and their social relations produce completely new results by interacting with wider social, political, economic and cultural structures in an unforeseeable way [Wilson and Holt, 2001].

For this reason, it is now said that health care and education systems which are social structures should be restructured according to the principles of the complex system [Plsek and Wilson, 2001; Fraser and Greenhalgh, 2001; Petros, 2003].

4.2. CONCEPTS OF HEALTH-DISEASE, ILLNESS AND SICKNESS

4.2.1. Different perspectives of the concepts of health and disease

Individual's processes of health and disease should be defined on both perspectives of the individual and social level as is the case in all the human-related processes. According to this approach, there are four different definitions of the concepts of health/illness as being social-cultural, social-environmental, individual-psychological and individual-biological. It is only possible to mention a full sense of health when health exists regarding all these four perspectives.

Cultural structure attaches a meaning to the concept of health/disease and accordingly, configures the environment in order to ensure healthy life. Disease-related definition of the cultural dimension can be expressed as ***Illness.*** Health can be defined as lack of illness in cultural dimension. Yet, the relation between these two is a fuzzy one. That is, health and illness do not exclude each other. A person can be both ill and healthy at the same time. One person can be included in two categories at the same time because these are fuzzy categories. As an example, it may be said about a person in society (family, business circle, close friends)
"He is a bit ill "

"You are leading a very unhealthy life"
using such linguistic fuzzy expressions.

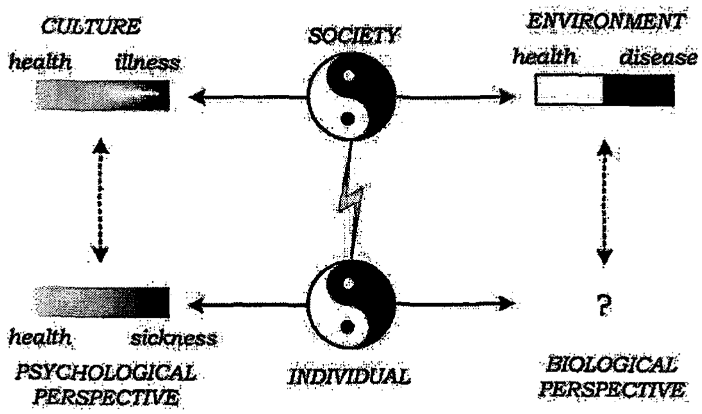


Figure 4.2. *Different levels of disease, illness and sickness.*

Environmental dimension of the society reveals the concept of disease via structured, formal institutions of education and health. Today, due to the dominance of the scientific methods, almost universal **disease** definitions have been endorsed in modern societies. These concepts reflect the values, acknowledgements and determinations of the scientific community rather than being completely objective expressions. Conceptual and categorical grounds of the diseases can change from time to time due to the structure and characteristics of the scientific methodology. The concept of health in terms of environmental dimension can be defined as lack of the categories in individual that are considered by the social medical environment (circles of health and education service) as diseases. Though the concept of being healthy seems to be the opposite of having disease because of the Aristotelian background of the current social structure, compliance percentage of disease identification and criteria (written in books) to the realities in daily life is quite small. After all, disease/illness concepts correspond to a variable and dynamic process on biological level.

Even if an individual is included in a category that isn't considered as disease (homosexuality, a chronic disease that has passed or a psychiatric disorder, personality disorders), he may be called as "ill" by the other individuals of the society because of the social culture. This situation may affect the life quality and standards of the individual. The opposite may also happen. That is, the individual's condition that isn't considered illness or paid attention by the society may be included in disease categories in medical terms (baldness, various skin lesions, not advanced audio and visual disorders).

Individual's expression of his perceptions about his own health on psychological level can be defined with the concept of ***sickness.*** Here, healthy/sick perception of the society the person has grown up is closely related to the person's acceptance. One of the most obvious examples is that certain complaints are perceived in certain societies as disease, in others it is not paid attention to. As an example, most frequent reason for application to doctor in the USA is coughing. However, in Turkish society, coughing can be considered as a natural reaction, as long as no additional findings exist. Also, in several cases where the individual is complaining, it may be defined as a psychiatric problem when it can't be included in any disease category. Health on psychological level can be accepted as lack of sickness. Yet, the relation between these two is also vague. That is same person may somewhat healthy and somewhat sick at the same time. The person can explain this situation when asked how he is with these expressions:
"I'm a bit sick."
"I'm fine"

Can disease be defined as of the biological perspective of the individual? Objectively, making a disease definition is "impossible" in this sense. It isn't possible to claim a precise diagnostic method determining the direct pathological process. For all the time, it is possible to develop a "pre-determining diagnostic method." Physiopathological mechanisms of many diseases haven't been explained. As an example, in many cases of coronary artery disease, disease table can be undergone without noticing (silent ischemic cases). In some cases of vein occlusion that is accepted as the basic pathological process, the person may lead his life comfortably without any harm or damage though the disease is on its highest level. In some cases of bone fracture, the person can spontaneously recover and lead his life without being aware of the situation. It is possible to co-live with many pathogenic microbes but these can cause "disease table" from time to time. Cancer cases can remain silent for years, and sometimes can regress spontaneously and end.

After all, the individual is a complex adaptive system and the process of disease/health is a process where it is always possible that it changes into unforeseeable courses (spontaneous recovery included).

Hence, on the biological level of the individual, another approach is needed, which will ensure the appropriate operations and treatments by assessing the concept of disease/health as a process rather than an objective category.

4.2.2. Concept of health/disease on biological level

On biological level, concepts of disease and health are not separate; they are different expressions of the situation where the body is in an ongoing interaction. Human existence can be defined with three terms biologically: perfect health condition, health/disease condition and death phenomenon.

Actually, as the all other human-related terms have, these terms, too, have different definitions with respect to the four dimensions of the human being.

Perfect health condition is the level where the person can be expressed as completely healthy. Perfect health in psychological terms is a state of well-being where the individual has no problem perception defines himself as completely satisfied and contented. Perfect health, culturally, is related with the acceptability of the individual within society and his endorsement degree. Perfect health regarding the environment that is social structure, is the state where it is included in no current disease category and every kind of biological parameter is at normal limits. On biological level is it a fictional-hypothetic level that does not exist objectively. Human being, since its creation, is exposed to detrimentals every time being in interaction with his environment and tries to protect his own functional and structural integrity against them. So, there is not even "a moment" when this struggle stops.

The second level, ***health/disease level*** is quite dynamic, changing, and continual, a reflection of the detrimental-individual interaction. Its different perspectives are detaily explained in 4.2.1.

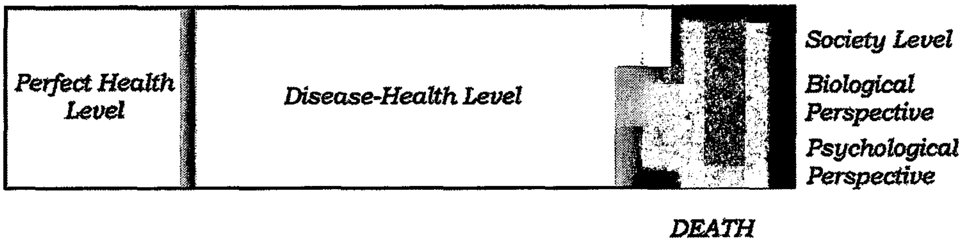


Figure 4.3. *Definitions of disease/health process in different levels.*

The second level of existence, ***death process*** can be defined in four different perspectives as the all other human-related terms. In death, loss of the psychological level, loss of the social level (social environment and cultural structure) and then loss of the biological level are the relevant issues.

Loss of the psychological level is individual's failure to realize the features of the psychological dimension. Despite the loss of the biological level, some functions still continue to operate in several parts of the biological level (cell, tissue, and organ) for some time. Vegetative state or coma cases are the conditions where such functions of the psychological level as perception, judgment are lost while biological level is still active. These situations aren't perceived as death by current medical understanding (circle), either.

The institutions (environment) built by the social structure can claim the several criteria of the death. Yet, death on biological dimension, isn't a phenomenon that can be defined with an objective criterion as is the case for disease. Death can biologically be defined as a process of heterogeneous degeneration from integrity to molecular level and a process of dissolution. As an example, a person's certain organs, who has lost his integrity, can be transplanted in certain period of time and can go on living.

On biological level, health or normal conditions aren't characterized by orderness, stability or balance but by chaos and complexity [Holm, 2002]. The phenomena of disease and health aren't objective, precise bordered categories that can be defined as a single but *symptom-sign (clinical) tables* emerging as a result of the relations between *harmful (destroying the adaptive capability of the person) factors* and *internal resistance mechanisms (supporting the adaptive capability of the person).* The phenomena of health/disease, in this sense, represent the response of a complex and adaptive system to the environment.

The approach that makes health staff unsuccessful is the insistent search for standards in medical education and approaches and this being a part of the current cultures despite this vague limitedness and dynamism in disease tables. Today, all of the medical practices of artificial intelligence try to adapt these categories that have been set up by the social environment to the dynamic biological states of the individual only with data on hand and without considering the distorted understanding and categorization in current structure. However, the categories are static and precise limited while available states are chaotic and vague limited.

Modern society perceives the phenomenon of disease as precise limited and as a case and puts the responsibility on health professions.

For this reason, first, medical model and education system should be structured as to express this dynamic interaction between the individual as a complex and adaptive system and factors affecting his adaptive capability.

4.2.3. Health phenomenon-society with disease on sociocultural level

The concept of health can be defined in an eclectic perspective as the individual's regaining of his health in terms of all the perspectives. This type of statement can be claimed to be not objective though it can be considered comprehensive and acceptable by most people. Yet, it gives an indirect statement of evaluations affecting the complex and adaptive response of the individual.

Change in any of these dimensions can negatively affect the objective health condition in biological terms. In this case, the concept of detrimental can be mentioned on psychological, cultural or environmental level.

Health-detrimental elements on psychological level can be personality features of the individual, his preferences and life-related habits. The individual may have preferences different from the present cultural structure.

Detrimental elements on social level is the dimension related with the formation of both social level and environmental structures and life style the person is lead to. If a society has a negative effect with its products on human health, it can be said that that social structure is "unhealthy". Especially the selfish societies emerged after the rise of the modernity, by ignoring the integrated interaction of the individual and the rights of the "other", have caused many interactions (environmental disasters, destruction of the ozone layer, increase in cancer cases, hygienic conditions and infectious diseases, nuclear tests, destroy of the natural flora, production of the biological and chemical war agents, industrial waste and pollution, etc.).

At this point, we can put forward the concept of healthy society" by making a comparison with the impact on the ***health profile*** of the individual. The features of the healthy society may be:
-ability to co-live with other societies,
-ability to evolutionize without losing the adaptive capability,
-producing structures protecting the health of the individuals inside

Of course, it should be kept in mind that there are destructive external and internal interactions in every healthy social structure and that the society tries to tolerate them in a complex and adaptive way. Handling the phenomenon of healthy society on the levels of social structure and institutions is correct but not enough. Environmental sensitivity, environmental movements can be targeting the healthy society but it will be possible for a cultural perspective to correct itself by rejecting its main action point and its own cultural structure.

When the institutions set up by the social level acquire the "diseased" quality, this is directly shown in the individual structure. Pollution, wastages, ozone hole are the institutional diseases of the social structure. All these come clear with the negative aspects of the social level.

4.3. CLINICAL ASSESSMENT AND CATEGORIZATION

4.3.1. Causes of diseases (Etiology)

The individual is always in an uninterrupted process of health/disease. As emphasized before, this process is a complex and adaptive process between detrimentals and individual. It's been observed in the studies that maladaptive reactions are shown against the loss of complexity and perturbation in cases of aging and disease, in resting dynamics.

The individual is exposed to two-level interactions regarding the health/disease process. These are biological and psychological levels. Interaction on psychological level can cause biological-level diseases in time. Yet, medical education and service system, as of current social environment, is more focused on diseases related with biological-level interactions. In health and disease process, no matter what interaction it's been exposed to, change in another dimension after a certain degree will happen as long as the individual can not protect its complex structure with a suitable response.

There are two factors determining the disease/health process of the individual: individual's adaptive response capability and the combination of risk factors/preventive factors. Every person has an adaptive response capacity because of his social or individual dimensions. This response changes negatively or positively according to the combination of preventive and risk factors from outside. Protective factors are factors that change the adaptive response of the individual other than normal responses in a positive way. Risk factors reduce this respond.

4.3.2. Adaptive response of the body

The elements affecting the adaptive response are bound to the individual or social factors. Individual factors can be genetic features, age, race, parental features, general health condition, and psychological features. Social factors can be family structure, social or geographical conditions, environmental institutions, social interaction, economic conditions, cultural activation, work conditions, housing. These factors are that elements that happen in daily life chronically, that can't be changed or whose medical affect can't be evaluated.

A combination of these factors affecting the adaptive response of the body is expressed as ***individual well-being***. A clear gauge or standardization that can objectively determine the biological adaptive response of the individual isn't currently available. So, evaluation of the well-being can be considered as an approach. The value and importance of these parameters on individual health differs from society to society. Hence, when evaluating the individual well-being, social level-specific criteria should be used. Besides, most of these factors are vague-limited categories. Using fuzzy logic in computing their combined value may give more effective results [Lelli, 2001].

There aren't, for now, precise parameters that will determine the well-being of the body on biological level. Though there are some studies about this issue, these aren't considered as new and pervasive. As an example, in one study, it has been claimed that heart rhythms have an effect in relation with the whole body. Similarly, monitoring various hormonal and neural discharges in brain can help determine the general biological well-being [McCraty, 2004-1, 2004-2].

4.3.3. Risk factors and protective factors

In biomedical approach, biological, chemical or physical etiological cause or causes that generally cause the disease are searched. Yet, the studies have shown that many causes other than basic etiological agents affect the disease table or treatment process negatively or positively, either. These factors can affect the disease/health process positively or negatively with their effect on the individual's adaptive response. Those affecting negatively are called ***risk factors*** and those affecting positively are called ***preventive factors.***

In general, any positive/negative factor person has on psychological and biological levels can be risk/preventive factor for the individual. For evaluating this property of any factor, the duration and quality of its affect are important.

Classical epidemiological studies have shown that there is a relation between smoking and lung cancer and heart diseases and cholesterol. Yet, risk factors are not enough to explain by themselves that why these diseases perform such different courses in the society. Besides, some factors can only be effective when exposure to them is long. It's been determined that there is a relation between the adult-age diseases and early conditions in early childhood. It may not be known beforehand what kind of interaction will happen when different factors exist at the same time in the same environment [Nolte and McKee, 2004].

There are studies especially recent years that are supported by the success of *human genome project*, focused on studying the genetic reasons of the disease etiologies [Kaprio, 2000].

However, in various studies, it is emphasized that environmental factors can be critical to the course of the disease even for the single-gene inherited diseases. Other than socioeconomic conditions, access to health care, nutrition, susceptibility to infection, even climate can cause obvious differences. In time, it's understood that there are differences among the races regarding acceptance and endorsement of chronic diseases. Differences among religious beliefs are one of the most significant reasons that affect not only the reaction of the patient but also health care pattern. There are complex interactions between social and cultural causes. There can be clinical difference among people with the same genetic defect [Weatherall, 2000].

There have been intense studies on diseases with complex genetic components especially after the genes of the single-gene inherited diseases have been learned. While it's been revealed that genes causing very different intermediate phenotypes that will increase the risk of the disease, it's also been learned that they may cause other diseases. Environmental factors can have affect intermediate phenotypes while they also affect disease risks independently. Some is known about the genetics of intermediate phenotypes such as blood fats, homeostatic factors and blood pressure for the diseases like coronary heart disease. Findings regarding hypertension, breast cancer and colorectal cancer make us think that known genes are just a part of the estimated gene component. Moreover, risk factors (smoking, alcohol consumption, obesity, physical inactivity) [Kaprio, 2000; Day and Wilson, 2001].

Today, we have a long way to proceed to know the genes affecting such diseases as migraine, depression, asthma, schizophrenia, coronary heart disease. Genes and environmental factors should be taken into account together in complex diseases [Kaprio, 2000].

4.3.4. Clinical process and its phases

Health/disease process is generally a gradually progressing process. Any etiological agent can lead the disease/health process to a negative point by affecting on biological level beyond the adaptive response of the body. This process, at the beginning is mostly outside the perceptible level and limits of the individual or his outside surrounding. If the problem remains unsolved, the process moves to perceptible level. In this case, destruction and change caused by the disease/health process are now noticeable and perceptible in forms of objective and subjective symptoms and signs. This perception can be either a complaint voiced by the individual himself or a phenomenon/change that he can notice with the warning of his surrounding. This level can be defined as ***normal perceptible level***. Moreover, there is also a ***professional perceptible level*** where the health staff and doctors specialized in this area notice some symptoms and signs by using sense organs such as inspection, palpation, percussion, auscultation (by increasing their effectiveness or not) or several other methods.

Psychological perception system is also formed by interacting with the social system the individual is in. So, the degree of perception is different and elective from society to society.

In general, before an objective health/disease condition becomes a complaint on psychological level, it hints some parameters on biological level via signals. That is, health/disease process is generally a phenomenon moving from biological level to perceptible level. The course of this process can be very fast or it remains on biological level for years without being noticed by the patient, without moving on to perceptible (psychological) level. Some cancer cases and autoimmune diseases can continue their course for years without revealing any symptoms after they have started on molecular/genetic cell level.

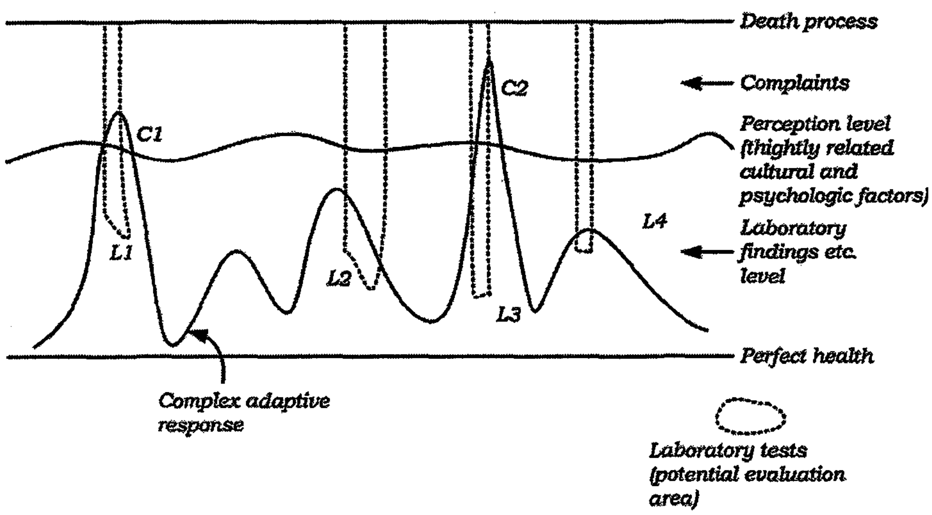


Figure 4.4. Clinical processes and its phases. C:Complaints, L: Laboratory etc. findings.

On the one hand the effect of detrimental, on the other hand the adaptive response of the individual to them combines and so, the disease can reach the perceptible level. If it can not, diagnosing the process is only possible with advanced diagnostic methods. However, the fact that it's not been diagnosed, it's not reached the perceptible level or even though it has reached, that it's been left outside the assessment do not mean that it is not a disease.

4.3.5. Complaints, symptoms and signs

The complaining of the individual expressed by himself are complaints. More comprehensive symptoms can be reached by health professional's questioning. They can also detect the symptoms the individual is unaware by the examination to be done.

All the complaints that can be expressed by the patients are basically divided into three groups: subjective ones, objective ones and subjective/objective ones according to their degrees.

Subjective complaints are perceived and expressed by the person himself. Any kind of pain, fatigue, exhaustion, weakness, nervousness, forgetfulness, fear, inattentiveness and lack of concentration can be included in this group.

Objective symptoms are complaints observed and perceived by a second person (ordinary man or health professional) other than the person himself. These can be categorized further according to how the second person perceives. As an example, second person may notice the symptoms such as vomiting, formal disorders, swelling, color changes, wounds, and changes in hair and trembling with his eyes, burps, coughs, snoring with his ears, and bad mouth smell with his nose. With the advanced medical methods, tasting is now not used in diagnostic process. Bleeding, excretion and efflux and related symptoms are also checked by a second person.

Subjective/objective complaints are symptoms that can only be noticed by the individual depending on its affect and degree, but by a second person when it gets worse. These are mostly physiological functional disorders (sense organs, movement, balance, sexual, intestinal movements, digestion, metabolism, heart rhythm, menstruation/ovary functions). Subconscious changes are included in this group, too. Functional problems can be sense functional problems, motor functional problems and physiological (autonomous) problems.

After these complaints and symptoms coming from the patients or noticed by other individuals via sense organs, health professionals can reach more detailed signs by directly using their senses with simple devices whose sensitivity has been increased.

Examination or questioning process is a process where linguistic expressions are used in general. Occupational professional (doctor) communicates with the patient orally. Even numerical or measurable expressions (a little big, very big) are linguistic qualifiers. In very rare cases (number of respiration, pulse, heart beat), directly precise numerical expressions are used. Since the signs used here are linguistic, fuzzy logic modeling is more suitable in decision support systems that are to assess this.

4.3.6. Advanced techniques and methods

Today, for the purpose of determining and monitoring the patient tables without becoming complaints or mixing with other patient tables, advance techniques and methods have been developed. These are microbiological, pathological, radiological and genetic methods and techniques. They have been developed for determining the functional and structural conditions of the individual level without reaching the complaint level. But these methods and techniques have also limits. The findings obtained by them are vague. It is questionable how important the values at limits are. Mostly, these kinds of examination methods aren't specific to a single disease. Due to the vague characteristics of measurement-based techniques, it will give advantage to evaluate them with fuzzy logic method for determining the general disease table.

In order to overcome these limitations and check its features regarding the complex adaptive structure of the body, being based on General Systems Theory, computer-aided pattern recognition system called Balascopy and related Relonics technology have been developed. The basic intention of these approaches is to have information in early stages of disease/health process by analyzing the complex multiple relations among person-specific immunological, hematological, physiological and behavioral parameters. Yet, these approaches haven't been wide spreadly studied within modern medicine yet [Mahler, Schmidt, Kvitash 1993; Kvitash 2002-1, 2002-2, 2002-3].

4.3.7. Diagnostic categories

Current medical system (environment) has set up several categories under the name of disease. These categories are formed in relation with etiological agents that are assumed to cause the disease in general, physiopathological process and clinical table (complaint, symptom and finding, advanced study and method results). When a clinician putting his diagnosis, by acting according to the findings he has obtained from the patient, examination and advanced methods, tries to find the most appropriate among the present categories. After this, diagnostic procedure isn't an objective operation but a professional process of categorization conducted from outside.

Several classification methods are used for the diagnostic categorization of the diseases. One of the most comprehensive and widely used of them is ICD-10 classification. The Ministry of Health has accepted ICD-10 as standard in Turkey. When this standard is examined, it is observed that some diseases are categorized according to the cell, some are categorized as to the tissue/organ/system and some are in line with the perceptibility level. Hence, this structure, very diverse in its own level, is more complicated since it is also categorized by using different layers' criteria. This increases the uncertainty.

While we are in fact in a continual process of disease/health, diagnostic process is activated sometimes after the table reaches complaint level, after a measurement by using advance measuring methods showing values outside the normally accepted ones. In fact, all these are different-level parts of the process of disease/health. It is always possible to return in disease/health process from any level. A disease table on the complaint level can completely be eliminated. Main reason for this is that organism always tries to protect in a dynamic way the functional and structural integrity.

It is possible that individual who interacts continually with an unlimited number of factors during this effort produce a unlimited number of responses depending on many variables. It isn't possible to restrict this struggle to a limited number of precise categories.

4.3.8. Setting up new fuzzy categories

Disease tables are based on the categorization of similar symptoms, signs and complaints. Since there are many probable sub-groups here, it isn't possible to define precise-limited groups.

General disease definitions that have been proposed are quite rough prototypes. For this reason, Lakoff's prototype can be used in modeling these tables. George

Lakoff said he had expressed a concept with vague limits with his concept of prototype that was the basics of his theory. Since this isn't easily explained by the Aristotle's logic predominant in the West, Zadeh's fuzzy logic and daCosta's paraconsistent logic are suggested for explaining the prototypes.

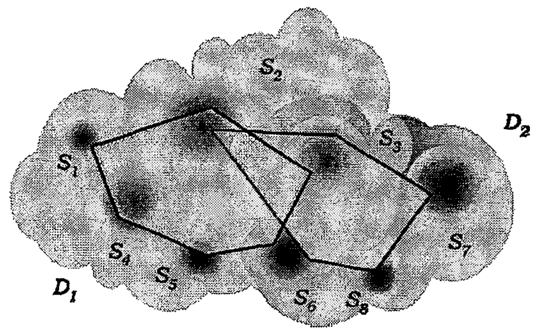


Figure 4.6. *Fuzzy characteristics of disease categories. S;Symptoms, signs or complaints, D; Diseases.*

First of all, broadest prototype for diseases should be determined. All the processes that a category defined as disease according to the current medical structure undergo during its whole course can be considered as subgroup. The combination of these subgroups that can be accepted as α-cut sets in fuzzy group theory will form the fuzzy prototype.

Yet, structuring of medical knowledge and education do not approach the process in this way so developing a system that will give the most probable disease table from the data at hand is explained in chapter 5.

4.4. CONCEPT OF TREATMENT

Human being is a multidimensional phenomenon. Every process related to the human being includes the same dimensions as well. The concept of treatment of the human being that is a whole of complex and adaptive systems will require that these four dimensions be interrelated. That is, treatment process includes not only the methods of the scientific community but also treatment dimensions of the sickness and illness. Only in this case can it be considered that a treatment in objective sense can be achieved.

There can be tree potential interferences at least that will ensure healthy dynamics in biological systems with respect to the medical community: single interferences affecting the multiple systems such as exercise, drug and hormone use, defining and treating the specific contributions of the different systems helping disease or disability, affecting the system dynamics directly via external control devices and operations. The researches are continuing to be done in this issue [Lipsitz, 2002].

Interference, necessary for all the time in order that the body keeps its dynamic balance within life limits by ensuring that it is withdrawn to normal limits, can sometimes be enough with a supporting treatment and sometimes means eliminating chemical physical detrimental effects. Treatment means, in an integrated perspective, supporting the protective mechanisms of the body and eliminating other things consuming them. Basic aim should be focused on achieving the optimum level of body balance (both qualitatively and quantitatively) via acceptable risk management.

4.5. MODEL IN SHORT

General structure and features of the proposed model can be summarized as follows:

-What are the reasons for diseases? Disease is a continual process originated from the interaction between the detrimental factors and individual's own adaptive system. Disease causes are any factor that decreases the complexity and response of the complex adaptive system.

-Who is responsible for the illness? Illness is perception by the individual of this dual contradiction-interaction within his structure on a psychological level.

-How should treat? Treatment should be done by giving the individual the complex adaptive response back and make him give ordinary rich responses.

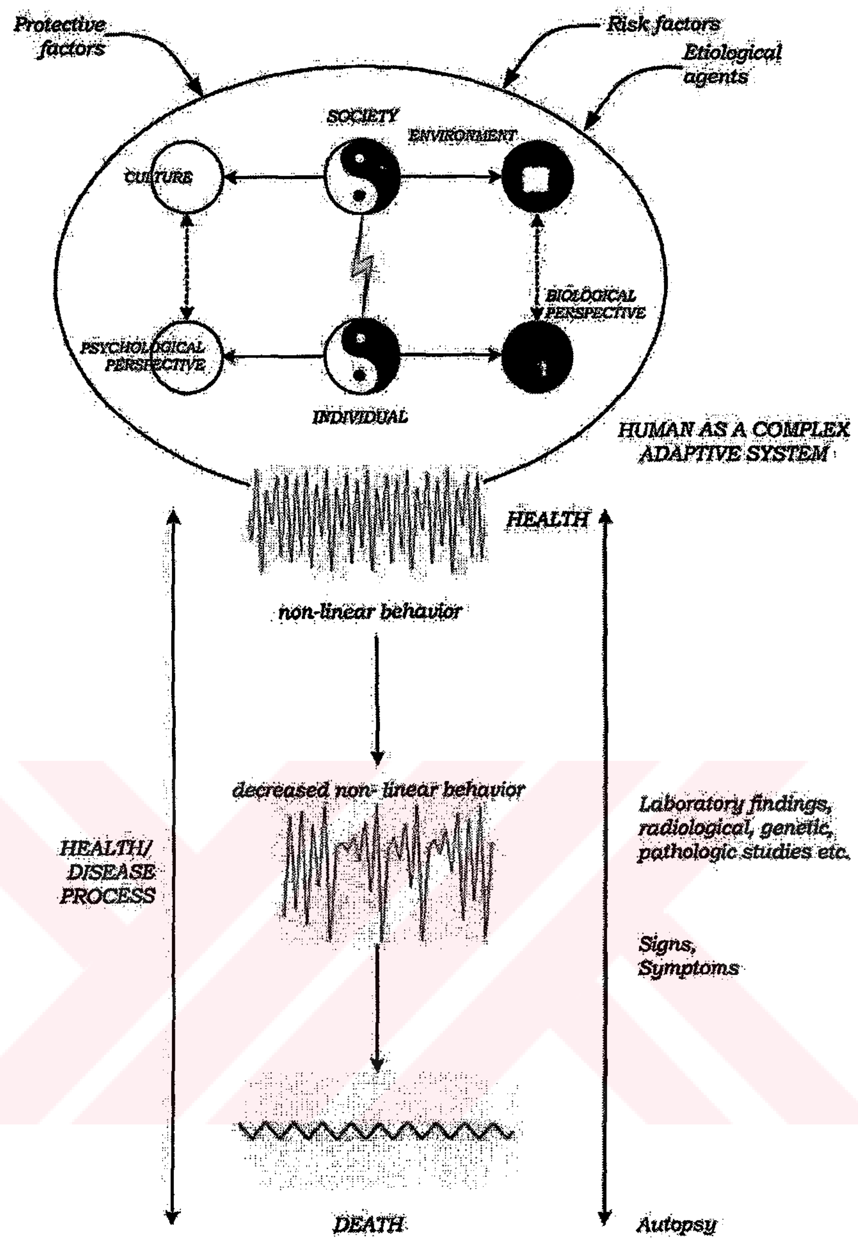


Figure 4.7. *General overview of the proposal mode*

-Who is responsible for the treatment? Treatment is the responsibility of not only the individual or doctor but also the institutions and other individuals on all the cultural and social dimensions.

-What is the correlation between health and sickness? Health and sickness are the reflection of the single and same process in different perspectives.

-What is the correlation between the mind and the body? Mind (psychological structure) and the biological structure are just two different perspectives of the single and same thing as it is the case in the same quant particle.

-What is the role of the psychology in the phenomena of health and sickness? Psychological structure of the individual affects this process and is affected by it.

CHAPTER -5

AN EXAMPLE OF FUZZY LOGIC DECISION SUPPORT SYSTEM: "FROM COMPLAINTS TO DIAGNOSIS"

The purpose of this approach is to determine what kind of diseases individual would have via evaluating subjective complaints of individuals and their individual features (age, position, various risk factors) and provide to develop a system to be able to reach a decision about dispatching priority and period via making evaluation of their risk/possibilities.

5.1. MAIN STEPS OF APPROACH

This approach includes two basic steps; determining of possible diseases and the maximum period for interfere them.

5.1.1. Determining of possible disease

The person, complaining (patient) informs the system about his/her complaints.

Example:
Let's assume that basic complaint of the person is a long lasting cough.

At this point, system finds out the possible diseases and complaints exist in this domain via using complaints-disease pattern tables (Table 5.1).

Table 5.1. Reasons for chronic cough and other possible complaints		
1	Sinusitis Allergic Rhinitis	Facial pain
		nasal discharge
2	Lung Abscess Bronchiectasis Lung cancer	shortness of breath
		weight loss
3	Gastroesophageal Reflux Diseases Esophageal stricture	chronic heartburn
		Regurgitation
		sour taste in mouth
4	Asthma Bronchitis Pneumonia	wheezing
		shortness of breath
		rapid or irregular heartbeat
5	Congestive Heart Failure Pulmonary Embolism	need to sleep on several pillows
		shortness of breath
		rapid or irregular heart beat
		Swollen leg
6	Chronic Obstructive Pulmonary Disease Bronchiectasis	sputum
		wheezing
7	Drug Side Effect	ACE inhibitory, NSAID or beta blocker drug
8	Tuberculosis Sarcoidosis	night sweats
		weight loss
		fatigue
		sputum
		shortness of breath
		Fever
9	Pulmonary Embolism Asthma Bronchiectasis	shortness of breath
		chest pain
		swollen leg

Patient is again questioned about these possible complaints. If any complaint to be expressed is present, then disease categories where complaints combinations exist are obtained by them. The obtained list is about the possible diseases, determined by subjective complaints of patients.

Example:

Other complaints to be questioned for chronic cough (from relevant table) can be determined as follows;

Sour flavour in mouth	*Fever*
Legs become distended	*Expectoration*
Night sweats	*Chest pain*
Heart arrhythmia	*Deficiency of weight*
Stinking Sniffling	*Chronic heartburn*
Breathing Difficulty (Dyspne)	*Regurgitation*
Fatigue	*Pain on face*

Please mark the following symptoms that you have related to your disease.

(Let's assume that the patient mark breathing difficulty in addition to the following symptoms.)

(Breathing Difficulty +Long lasting cough) combination exists in the following diseases according to the table.

Lung abscess	*Congestive Heart Failure*
Lung cancer	*Pneumonia*
Asthma	*Pulmonary embolism*
Bronchiectasis	*Sarcoidosis*
Bronchitis	*Tuberculosis*

Possible diseases are divided into five fuzzy categories (VERY HIGH, HIGH, MAYBE, LOW, VERY LOW) according to total value of complaints as similarity degree.

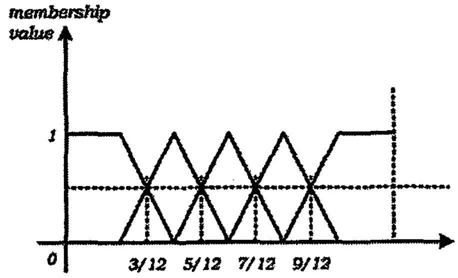
For this purpose, three kinds of values (measurement parameters) are used; i.e. total score, disease score and weighted score (Table 5.2). Disease score means the total number of complaints for each disease in disease/complaint table. Total score means current value of disease score with respect to evaluated patient. Weighted score is the ratio of total score and disease score.

Table 5.2. Diseases, complaints and several measurement parameters

COMPLAINTS/ SYMPTOMS	Asthma	Bronchitis	Bronchiectasis	Congestive Heart Failure	Lung Abscess	Lung Cancer	Pharyngitis	Pleural Effusion	Pleuritis	Pneumothorax	Pneumonia	Pulmonary Embolism	Tuberculosis
Chest pain					+	+		+	+	+	+	+	+
Difficulty breathing		+						+			+	+	
Fever							+						
Fever and chills		+	+		+						+		
Foul smelling breath			+		+						+		
Loss of appetite					+	+							+
Need to sleep on several pillows				+							+	+	
Rapid or irregular heart beat	+	+		+						+	+	+	
Runny nose							+						
Shortness of breath	+	+		+	+	+		+	+	+	+	+	+
Sore throat							+						
Sputum		+									+		
Sputum, bloody			+		+						+		
Swollen leg				+				+			+	+	
Weight loss					+	+							+
Wheezing	+	+								+	+		
DISEASE S.	3	6	3	4	7	4	3	4	2	4	11	6	4
TOTAL SCORE													
WEIGHTED S.													
LINGUISTIC CATEGORY													

After calculating weighted score, linguistic categories are determined. For this purpose, the membership function, which illustrated in figure 5.1, is used.

The ratio of the possibility can be used by fuzzified. Although some statistical data exists on social frequencies of diseases, they are not enough. For many diseases, relying on the branch knowledge of expert doctors is a must. Therefore occurrence possibility of the disease can be evaluated into five groups: VERY OFTEN, OFTEN, NORMAL, RARELY, TOO RARELY.



$$\text{weighted score} = \frac{\text{total score}}{\text{disease score}}$$

Linguistic Category →

WS <= 3/12	→ *very low*
3/12 <WS <= 5/12	→ *low*
5/12 <WS <= 7/12	→ *maybe*
7/12 <WS <= 9/12	→ *high*
9/12 <WS	→ *very high*

WS= Weighted Score

Figure 5.1. *Membership function of linguistic category*

Here, the advantages of fuzzy logic modeling are utilized. Particularly, in countries like Turkey, it is not possible to say that epidemiological information is too correct. Therefore determining of occurrence frequencies of the diseases is only possible by approximately. Via using the approximate values obtained by branch experts, determining of linguistic categories for every disease is possible.

Then, possibility of diseases and linguistic category can be combined. For this purpose a revision table is used. This table gives us revised linguistic category (Fig 5.2).

Afterwards, the symptoms that stand in the foreground in certain diseases are questioned and then they are added to the possibility (if any) as a positive value. The main purpose of this process is to evaluate the contribution of the information that accompanies with possibility of the disease. Factors evaluated here are the factors whose effect for the table is not well-known but expressed approximately.

For accompanying situations, via giving 1 point for every parameter, the possibility categories of the diseases, having risk factor that exists in the exponential number, obtained via dividing total point by the contribution possibility of the disease (total point number/ current disease number) are increased up to one gradation.

Revision Table	very low	low	maybe	high	very high
very often	maybe	high	very high	very high	very high
often	low	maybe	high	very high	very high
normal	low	low	maybe	maybe	high
rarely	very low	very low	low	low	maybe
too rarely	very low	very low	very low	low	low

Figure 5.2. *Revision table to calculate revised linguistic category.*

Example

As an example risk factors in various diseases are as follows;

DISEASE	***RISK FACTOR***
Lung abscess	*Lung diseases, having been infected before such as pneumonia and tuberculosis*
Lung cancer	*Smoking cigarette, pipe, exct.* *Being exposed to air pollution* *Being exposed to radon, asbest* *Diseases, having been infected before such as tuberculosis, lung cancer*
Asthma	*Low socioeconomical condition* *Allergy*
Bronchiectasis	*A kind disease; having been infected before such as tuberculosis, lung cancer , asthma*
Chronic Bronchitis	*Smoking cigarette, pipe, etc.* *Being exposed to air pollution* *Fatness* *Living in a cold and humid atmosphere* *Often infected by respiratory infection.*
Congestive H. F.	*Hypertension* *Hearth Attack having been had before*
Pneumonia	*Pressure in immune system, AIDS, alcoholism* *Upper respiratory infection or lower respiratory infections such as asthma, flu, lung cancer*
Pulmonary embolism	*Trauma, hybrid* *Fatness* *Cancer, heart disease* *Surgical Intervention* *Long lasting bedrest* *Pregnancy or taking (OKS)*
Tuberculosis	*AIDS, diabetes,nutrition disorder, KKS treatment, alcoholism;*

usage of injected pharmaceuticals
Living in bad conditions

Let's assume that a person;

Infected by tuberculosis before

Smokes cigarettes

Being exposed to air pollution

Often infected by respiratory infections

The diseases with these symptoms are;

RISK FACTORS	Lung abscess	Lung cancer	Bronchiectasis	Pneumonia	Chronic Bronchitis
Infected tuberculosis before	+	+	+	+	
Smoking cigarrette		+			+
Being exposed to air pollution		+			+
Often infected by respiratory infection					+
Total Risk Factor=9	+	+++	+	+	+++

Weighted Risk Factor = Total Risk Factor/Disease Number = 9/5=1.8
Risk categories of lung cancer and chronic bronchitis whose risk factor is bigger than 1.8 to be increased by one gradation. Thus, "maybe" this exists in "low" category to be passed over "high" possibility category which exists in "maybe" category. According to all these, pre-diagnosis is respectively evaluated by their possibility gradations.

5.1.2. Evaluation of emergency degree

Second step is to evaluate of intervention emergency of the disease. In order to do this, diseases are classified (disease intervention emergency table) by pre-determined five basic principles (URGENT and IMPORTANT, NOT URGENT but IMPORTANT, NORMAL, BETTER FOR INTERVENTION, INTERVENTION WHENEVER POSSIBLE). This classification should be done by branch experts. An example of general classification type is given as follows:

CATEGORY I: URGENT and IMPORTANT: should be transmitted immediately.

CATEGORY II: NOT URGENT but IMPORTANT: *should* be transmitted within 3 days.

CATEGORY III: NORMAL: should be transmitted within 5 days.

CATEGORY IV: BETTER FOR INTERVENTION: should be transmitted in 1 month.
CATEGORY V: INTERVENTION WHENEVER POSSIBLE: No time limiting is determined. (Elective cases. Time is determined by taking into consideration of intensity of the division to where it is to be transmitted.

However, approximate categorization of the disease might not be satisfactory. Because some individual factors which can alter the course of diseases, exist. (Table 5.3). These individual factors are the features that affect the immune system of a person and its respond.

Table 5.3. General risk factors

Lifestyle	inactivity stress diet aging	Infection	animals birds insects water travel
Behaviors	sex smoking alcohol drugs	Exposures	environment occupation sunlight radiation chemicals
Fatal four	obesity cholesterol diabetes hypertension	Medications	medications contraceptives steroids
Diseases	HIV heart diseases cancer autoimmune diseases immunocompromise individuals	For women	pregnancy childbirth menopause

Also the individual risk factors should be combined to the general attitude. Several approaches were developed to assess personal well- being. Personal well-being affects the progress of disease and the personal response to the etiological agents and risk factors. For example, a person's disease process who is exhausted, alcoholic, and smoker, will be more serious than others'.

After a person was evaluated with respect to personal risk factors, personal risk value can be categorize as VERY HIGH, HIGH, and NORMAL. With these information, previous emergency degree can be modified (revised emergency degree).

Revision rules (example);

	VERY HIGH	HIGH	NORMAL
CATEGORY I	CATEGORY I	CATEGORY I	CATEGORY II
CATEGORY II	CATEGORY II	CATEGORY II	CATEGORY III
CATEGORY III	CATEGORY IV	CATEGORY IV	CATEGORY III
CATEGORY IV	CATEGORY V	CATEGORY IV	CATEGORY IV
CATEGORY V	CATEGORY IV	CATEGORY V	CATEGORY V

After that, all possible conditions rank order to degree of their risk values and the priority of the personal referral is determined according to most possible disease.

5.2. ASSESSMENT OF THE APPROACH

To asses the model explained above, a research technique was developed. The technique only prepared to evaluate first step of the model, because there is no reliable and sufficient information to assess second step in Turkish health services and no electronic communication that perform to transfer electronic patient records between primary and secondary care units.

To compare with diagnostic results of "from complaint to diagnose" application that one of the possible practical application of fuzzy chaotic diagnostic modeling proposal and general practitioners' diagnostic decision is the universal set of this research technique.

Proposed model, applied in two different primary care units and by four different general practitioners to the 77 different patients.

As a data acquisition tool, a evaluation form that based on "from complaints to disease" application was developed and used (Appendix).
Because of health statistics lack of sufficient and reliable in Turkey, there is no information about most appeared complaints. For this reason, using heuristic information and health statistics of some other states (USA, Australia), possible complaints universe was reduced to 5 possible complaints (Table 5.1,5.4-5.7).

To determine fuzzy diagnostic categories and fuzzy complaints categories, other possible complaints were evaluated. Then, with assessment of risk factors, orders of possibility were reevaluated and reordered.

All of patients, whose model was applied, were men and young (under middle age) persons.

This model proposes a new model with respect to contents and systematization. The first goal of this system is to refer patients without any primary care provider's directions.

Because the lack of developed central database system in Turkish Health Services, it is not possible to compare the current data with actual facts. For this reason, satisfying quantitative results were not carried out.

Table 5.4. Reasons for acute cough and other possible complaints		
1	Pharyngitis	Sore throat
		Runny nose
		Fever
2	Pneumonia Bronchitis	Sputum
		Fever and chills
		Shortness of breath
		Difficulty breathing
3	Pulmonary Embolism Pneumonia Pleural Effusion	Shortness of breath
		Difficulty breathing
		Swollen leg
		Chest pain
4	Lung Abscess Pneumonia Bronchiectasis	Fever and chills
		Foul smelling breath
		Bloody sputum
5	Pneumothorax Pneumonia Pleuritis	Chest pain
		Shortness of breath
6	Lung Abscess Tuberculosis Lung cancer	Shortness of breath
		Chest pain
		Loss of appetite
		Weight loss
7	Congestive Heart Failure Pulmonary Embolism Pneumonia	Shortness of breath
		Swollen leg
		Need to sleep on several pillows
		Rapid or irregular heart beat
8	Asthma Pneumonia Bronchitis Pneumothorax	Wheezing
		Shortness of breath
		Rapid or irregular heart beats

<table>
<tr><th colspan="3">Table 5.5. Reasons for vertigo and other possible complaints</th></tr>
<tr><td rowspan="5">1</td><td rowspan="5">Migraine Headache
Hypoglycemia</td><td>weakness</td></tr>
<tr><td>numbness</td></tr>
<tr><td>speech problems</td></tr>
<tr><td>Headache</td></tr>
<tr><td>visual disturbances</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Migraine Headache
Seizures</td><td>Aura</td></tr>
<tr><td>Headache</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Labyrinthitis
Meningitis
Otitis Media
Mastoiditis
Acoustic Neuroma</td><td>hearing loss</td></tr>
<tr><td>ringing in the ear (tinnitus)</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">Anxiety Disorder
Depression</td><td>feeling of apprehension, fear and irritability</td></tr>
<tr><td>difficulty sleeping</td></tr>
<tr><td>Fatigue</td></tr>
<tr><td>6</td><td>Drug Reaction</td><td>medication use: diuretics, anticonvulsants or antibiotics</td></tr>
<tr><td>7</td><td>Benign Paroxysmal Positional Vertigo
Otitis Media
Brain Abscess</td><td>nausea and vomiting</td></tr>
<tr><td rowspan="4">8</td><td rowspan="4">Anemia
Hypoglycemia</td><td>Pallor</td></tr>
<tr><td>rapid or irregular heart beat (arrhythmia)</td></tr>
<tr><td>Weakness</td></tr>
<tr><td>tarry stools, hemorrhoids or heavy menstrual bleeding (bleeding symptoms)</td></tr>
<tr><td rowspan="3">9</td><td rowspan="3">Meniere's Disease
Labyrinthitis
Benign Paroxysmal Positional Vertigo</td><td>hearing loss</td></tr>
<tr><td>nausea and vomiting</td></tr>
<tr><td>Sweating</td></tr>
<tr><td rowspan="3">10</td><td rowspan="3">Cervical Spondylosis
Whiplash</td><td>neck pain</td></tr>
<tr><td>weakness</td></tr>
<tr><td>numbness</td></tr>
<tr><td rowspan="2">11</td><td rowspan="2">Otitis Media
Impacted Cerumen
Mastoiditis</td><td>earache</td></tr>
<tr><td>hearing loss</td></tr>
</table>

	Otitis Externa	discharge from ear
		Fever
		swollen lymph nodes in neck
12	Brain Tumor	Headache
		forgetfulness
		weakness
		Numbness
		difficulty with speech
		nausea and vomiting
		Head injury
13	Benign paroxysmal positional vertigo migraine headache	nausea and vomiting
		Headache
		Balance problems
14	Acoustic Neuroma Cholesteatoma	hearing loss
		facial weakness
		balance problems
		Headache

Table 5.6. Reasons for nasal discharge and other possible complaints		
1	Sinusitis Osteomyelitis	Facial pain
		fever
		headache
2	Allergic Rhinitis	watery nasal discharge
		itchy eyes
		sore throat
		sneezing
3	Lupus Vulgaris Sarcoidosis Midline Granuloma	reddish lump of nasal septum
		weight loss
		night sweats
4	Wegener's Granulomatosis Nasopharyngeal Carcinoma	dead mushy tissue in nasal cavity
		nasal discharge, at times bloody
		nasal obstruction
		earache
		chronic cough, may cough up blood
5	Diphtheria Peritonsillar Abscess Tonsillitis Pharyngitis	sore throat
		hoarseness
		difficulty or painful swallowing
		difficulty breathing

Table 5.7. Reasons for neck pain and other possible complaints		
1	Whiplash Injury Herniated Disc Fracture Of The Cervical Spine Metastatic Cancer Cervical Spondylosis	Head or neck injury
		Shoulder pain
		Headache
		Muscle spasms
		Numbness, arms
		Weakness, arms
2	Subarachnoid Hemorrhage Meningitis Migraine Headache	Sudden severe headache
		Neck stiffness
		Nausea and vomiting
		Sensitivity to light
3	Discitis	Muscle spasms
		Fever and chills
4	Rheumatoid Arthritis Herniated Disc Cervical Spondylosis	Weakness, arms
		Numbness, arms
		Pain and swelling of joint
		Stiffness of joints
5	Brain Tumor Hydrocephalus	Headache
		Nausea and vomiting
		Visual difficulties
6	Tuberculosis Metastatic Cancer	Chronic cough
		Weight loss
		Night sweats
		Muscle spasms
7	Peritonsillar Abscess Meningitis	Fever and chills
		Neck stiffness
		Sore throat
8	Ankylosing Spondylitis Cervical Spondylosis	Back and neck stiffness
		Fatigue
		Weight loss
		Back and hip pain

CHAPTER -6

CONCLUSION, DISCUSSION AND FUTURE WORKS

This study mainly evaluates the validation of a possible approach based on fuzzy-chaotic diagnostic model, and focuses to a number complaints and diseases category.

6.1. CONSTRAINTS

In several textbooks or references, there are more then 150 basic complaints and symptoms. In this study, five complaints evaluated; acute cough, chronic cough, vertigo (dizziness), neck pain, and nasal discharge.

There is no enough information about incidences of these complaints in Turkish Health service systems. There are some information why the patients refer or visit physician in USA and other developed countries. But these values do not wholly overlap with Turkish health system and socio-cultural characteristics of Turkish people. For these reasons, complaints evaluated in this study were determined based on heuristic information of domain experts.

Disease categories that may cause these complaints and related information about epidemiological, demographical and risk factor aspects of them were acquired from classical textbooks and medical references. There is not sufficient statistical data about accuracy and validity of this information in Turkey. For this reason, to express of these values, fuzzy linguistic categorization of these values was preferred and accepted as an advantage.

This research evaluated only first step of proposed model. Firstly, in medical references, there is not adequately sophisticated information in order to use in this research. In addition, this kind of research can be carried out only under coordination of primary and secondary health services. This is not possible for Turkey. There is not sufficient cooperation and coordination between hospitals' (paper or electronic) documentation systems.

Research was performed in two different care units by four general practitioners. Due to lack of structured studies that could be compared with current results, prepared forms and physicians' decisions were compared.

Target population was consisting of young and male people. In future, researches, aim to evaluate this model need to perform in more crowded and heterogeneous samples (containing different gender and age categories).

6.2. RESEARCH RESULTS

Diagnostic process starts with five primary complaints, i.e. acute cough, chronic cough, nasal discharge, neck pain and vertigo.

In model system, there are several kinds of diseases (totally 58) that cause these complaints (Table 6.1).

Table 6.1. Possible conditions cause five major complaints.

Acoustic Neuroma	Drug Side Effect (ACE inhibitory, NSAID or beta blocker)	Osteomyelitis
Allergic Rhinitis	Esophageal stricture	Otitis Externa
Anemia	Fracture of The Cervical Spine	Otitis Media
Ankylosing Spondylitis	Gastroesophageal Reflux Diseases	Peritonsillar Abscess
Anxiety Disorder	Herniated Disc	Pharyngitis
Asthma	Hydrocephalus	Pleural Effusion
Benign paroxismal positional vertigo	Hypoglycemia	Pleuritis
Brain Abscess	Impacted Cerumen	Pneumonia
Brain Tumor	Labyrinthitis	Pneumothorax
Bronchiectasis	Lung Abscess	Pulmonary Embolism
Bronchitis	Lung Cancer	Rheumatoid Arthritis
Cervical Spondylosis	Lupus Vulgaris	Sarcoidosis
Cholesteatoma	Mastoiditis	Seizures
Congestive Heart Failure	Meniere's Disease	Sinusitis
Chronic obstructive pulmonary disease	Meningitis	Subarachnoid Hemorrhage
Depression	Metastatic Cancer	Tonsillitis
Diphtheria	Midline Granuloma	Tuberculosis
Discitis	Migraine Headache	Wegener's Granulomatosis
Drug Reaction (Diuretics, Anticonvulsants or Antibiotics)	Nasopharyngeal Carcinoma	Whiplash Injury
Muscle spasm (miyalgia)		

In these conditions, with primary complaints, several other symptoms may be appeared (Table 6.2).

Table 6.2. Possible symptoms maybe appeared with primary complaints in diseases.

Arythmia	Aura	Back and hip pain
Back and neck stiffness	Balance problems	Bleeding symptoms
Chest pain	Chronic cough	Chronic cough, may cough up blood
Chronic heartburn	Dead mushy tissue in nasal cavity	Difficult sleeping
Difficulty breathing	Difficulty or painful swallowing	Difficulty speech
Discharge, ear	Drug use (ACE inhibitory, NSAID or beta blocker)	Drug use (Diuretics, Anticonvulsants or Antibiotics)
Earache	Facial pain	Facial weakness
Fatigue	Feeling of apprehension, fear and irritability	Fever
Fever and chills	Forgetfulness	Foul smelling breath
Head injury	Head or neck injury	Headache
Hearing loss	Hoarseness	Itchy eyes
Loss of appetite	Muscle spasms	Nasal discharge
Nasal discharge, at times bloody	Nasal obstruction	Nausea and vomiting
Neck pain	Neck stiffness	Need to sleep on several pillows
Night sweats	Numbness	Numbness, arms
Pain and swelling of joint	Pallor	Rapid or irregular heart beat
Reddish lump of nasal septum	Regurgitation	Runny nose
Sensitivity to light	Shortness of breath	Shoulder pain
Sneezing	Sore throat	Sour taste in mouth
Speech problems	Sputum	Sputum, bloody
Stiffness of joints	Sudden severe headache	Sweating
Swollen leg	Swollen lymph nodes in neck	Tinnitus
Visual Difficulties	Visual Disturbances	Nasal discharge, watery
Weakness	Weakness, arms	Weight loss
Wheezing		

In research period, determined primary complaints and their percents are in Table 6.3. Most frequent primary complaints were acute cough and nasal discharge (seasonal dependency).

Table 6.3. First complaints and its numbers	
First complaint	**Number**
Acute cough	34
Nasal discharge	27
Neck pain	2
Vertigo	1
Chronic cough	13

Distribution of diseases (according to physicians) is in Table 6.4.

Table 6.4. Diseases caused primary complaints		
First complaint	**Diseases**	**Number**
Acute cough	Pharyngitis	23
	Bronchitis	8
	Asthma	3
Nasal discharge	Pharyngitis	16
	Sinusitis	6
	Tonsillitis	4
	Allergic rhinitis	1
Neck pain	Muscle spasm	2
Vertigo	BPPV	1
Chronic cough	GERH	3
	Sinusitis	5
	Bronchitis	3
	Asthma	2

Evaluated models' results are in Table 6.5.

Table 6.5. Diagnostic results of the model		
First complaint	**Diseases**	**Number**
Acute cough	Pharyngitis	21
	Bronchitis	11
	Asthma	2
Nasal discharge	Pharyngitis	12
	Sinusitis	8
	Tonsillitis	6
	Allergic rhinitis	1
Neck pain	Muscle spasm	2
Vertigo	BPPV	1
Chronic cough	GERH	2
	Sinusitis	7
	Bronchitis	3
	Asthma	1

Appropriateness ratio of model's decision to the fuzzy categories and physicians' diagnostic decision is in Table 6.6. The success percent of model is %84.6 to compare with physician.

Table 6.6. Appropriateness ratio of model's decision to the fuzzy categories and physicians' diagnostic decision

First complaint	**Appropriateness to fuzzy disease category**	**Appropriateness to physicians' diagnose**
Acute cough	34/34	31/34 (%91.1)
Nasal discharge	27/27	23/27 (%85.1)
Neck pain	2/2	2/2 (%100)
Vertigo	1/1	1/1 (%100)
Chronic cough	13/13	11/13 (%84.6)
TOTAL	**77/77**	**68/77 (%88.3)**

6.3. ASSESMENT OF RESEARCH RESULTS

These results can be criticized with several respects. Firstly, the population quantity is not adequate to reach satisfying results. Some kinds of diseases, listed in table 6.1. only appeared with a very little probability.

The other factor is the homogeneity of population with respect to gender and ages. Some kinds of diseases only appeared in old ages or childhood period. And some diseases are frequently appeared in female more than male.

System does not include biochemical or other laboratory studies. But today, in health services, laboratory studies seem as an important and valuable part of diagnostic process.

Model's results only compared with practitioners' decisions due to lack of enough epidemiological information in Turkey and un-coordination between different health units. But it can not be guaranteed that physicians' decisions are more reliable or accurate from models' decision.

Another problem domain is the lack of standard coding. Every practitioner can define same conditions from different perspectives. There is no objective criteria (or forcing to physicians) to use a standard coding methodology. This factor affects the statistical results of researches.

Finally, this research is an example of models usability assessment. This kind of systems can be used to self-refer to secondary health units without primary care providers. But to tune of systems parameters, more and longer time researches are required.

6.4. FUTURE WORKS

The research, which evaluated above, is an example of fuzzy modeling techniques. But the philosophical or epistemological level of this thesis includes more than simple application. But this approach needs a new and comprehensive model in medical domain (both services and education). In this section firstly, the applicability of fuzzy chaotic model will discuss and then several ideas and suggestions are proposed.

In the scientific aspect, the "proof" of an invention is not enough for application and acceptance. Sector, should be accepted by formal institutions (university, society, political institutions, bureaucracy etc.), adopted and most of all should be supported. Today, there are two important forces regarding this issue. One of which is the industry enterprises in economy and the government. Generally, if a financial satisfaction can be told, even firms with a competition among each other tend not to change the background and the scientific substructure. This is a fact which can only be overcome by economic forces that can –by an effective observation- see that such change will be appropriate or inevitable.

Science also bears the complex adaptive system characteristics. There are always alternative or evolutionary theorems. However they are always forgotten or disregarded since they have not been converted into practice. A scientific education merely accomplishes its target as to develop a model different from the current scientific model within the countries whose scientific philosophy has not been improved as an approach.

Science does not deal with truth or reality; it rather deals with the truth or reality which can be applicable, acceptable, and also is manipulative. The concept applicability has various directions on psychological, social, economical, technological, ethical and political aspects. When talking about the applicability on psychological aspect, we can talk about the people's not having paradox with the reality, thinking, emotion and practice levels of itself or of the people in the cultural environment. On the social aspect, the person may prefer not to be in contradiction with the social structures. If a paradox exists, then many de-motivating rituals might be confronted. A complete appropriate model might be deleted simply because it did not get support from the academy. Technologically, applicability of knowledge is very important. It also should be available for conversion to an economic power. An economical dimension covers the cost of model's conversion to economic perspective and the costs emerging during the process. An ethical dimension covers the contradiction of a suggested scientific knowledge with the religious, cultural or implemented acceptances. Political dimension can be evaluated through various perspectives such as ideology, companies, international dimension and academic politics.

Therefore applicable knowledge is a phenomenon which was "allowed" by ethics, acceptances, approaches, religion, economy, politics and science societies. However as mentioned before, science is also subject to chaos laws of complex adaptive systems just like the human affection is. Despite of all these restrictions, it's potentially possible that opportunities that scientific frame may change are still available.

When applying the artificial intelligence on a medical model, the priority should be providing a connection between medicine model and reality. When evaluated on the above aspects, only such model would make the effort of "artificial intelligence" meaningful. Aforementioned model or a similar process should support approaches which have basis, which extends logical principles and which seek different epistemological basis on an academic level.

The health psychology seeking for a ground for itself in Australia and in some other countries is an example of medical model shifting. However achieving such target will not be so easy in countries in which normal science conditions are almost impossible (economically and culturally).

The following can be suggested having considered that it's supported;

- Doctor Service should be seen as an interactive service with the individual and its close environment rather that a stand-alone service away from the individual. In order to put this in practice;
    - Family doctor concept should be developed in order to assess the sick person and his family and his close environment,
    - All data as to the sick person should be kept in a database which responsible doctors can access,

- Within the medical training process, doctors should be provided with characteristics which enable them to scan facts as a whole,

- Model structuring of the medical science should be altered. And for this;
    - General measures that will change the complex adaptive capabilities and the overall well-being of facts should be searched. Researches as to the complex adaptive systems in medicine should be processed.
    - New tools, methods and approaches that will be capable of evaluating this should be developed.
- In the education field, medical science should be an interactive field with all other fields rather than being an isolated study.
    - Sub-science disciplines should be established for that
    - The science philosophy should be taught together with practical sciences rather than as a theory field.

Only by achieving all these, it may be possible to understand the line between health and disease is not definite or bold. Artificial intelligence studies might be a great support for this.

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APPENDICES

APPENDİX A

EVALUATION FORM 1-A:

IF THE FIRST COMPLAINT IS ACUTE COUGH:

COMPLAINTS/ SYMPTOMS	Asthma	Bronchitis	Bronchiectasis	Congestive Heart Failure	Lung Abscess	Lung Cancer	Pharyngitis	Pleural Effusion	Pleuritis	Pneumothorax	Pneumonia	Pulmonary Embolism	Tuberculosis
Chest pain					+	+		+	+	+	+	+	+
Difficulty breathing		+						+			+	+	
Fever							+						
Fever and chills		+	+		+						+		
Foul smelling breath			+		+						+		
Loss of appetite					+	+							+
Need to sleep on several pillows				+							+	+	
Rapid or irregular heart beat	+	+		+						+	+	+	
Runny nose							+						
Shortness of breath	+	+		+	+	+		+	+	+	+	+	+
Sore throat							+						
Sputum		+									+		
Sputum, bloody			+		+						+		
Swollen leg				+				+			+	+	
Weight loss					+	+							+
Wheezing	+	+								+	+		
DISEASE S.	3	6	3	4	7	4	3	4	2	4	11	6	4
TOTAL SCORE													
WEIGHTED S.													
LINGUISTIC CATEGORY													

EVALUATION FORM 1-B:

DISEASE	LINGUISTIC CATEGORY (VERY HIGH, HIGH, MAYBE, LOW, VERY LOW)	FREQUENCY (VERY OFTEN, OFTEN, NORMAL, RARELY, TOO RARELY)	REVISED LINGUISTIC CATEGORY (VERY HIGH, HIGH, MAYBE, LOW, VERY LOW)
Asthma		NORMAL	
Bronchitis		NORMAL	
Bronchiectasis		RARELY	
Congestive Heart Failure		OFTEN	
Lung Abscess		RARELY	
Lung Cancer		RARELY	
Pharyngitis		VERY OFTEN	
Pleural Effusion		RARELY	
Pleuritis		RARELY	
Pneumothorax		RARELY	
Pneumonia		NORMAL	
Pulmonary Embolism		RARELY	
Tuberculosis		NORMAL	

EVALUATION FORM 1-C:

DISEASE	RISK FACTORS	TOTAL SCORE
Asthma	Low socioeconomic status Poverty Substandard housing Indoor allergens Lack of education Inadequate access to health care Respiratory infections (colds, flu, etc.)	
Bronchitis	NOT DETERMINED	
Bronchiectasis	NOT DETERMINED	
Congestive Heart Failure	Aging Hypertension Previous heart attack Heart failure	
Lung Abscess	NOT DETERMINED	
Lung cancer	Smoking Starting smoking at early age Smoking many packs a day Passive smoking Air pollutants Radon Asbestos Pollution Lung Diseases Tuberculosis Personal history of lung cancer	
Pharyngitis	NOT DETERMINED	
Pleural Effusion	NOT DETERMINED	
Pleuritis	NOT DETERMINED	
Pneumothorax	NOT DETERMINED	
Pneumonia	Elderly Young children Immunocompromised Alcoholism Asthma Smoking Lung scarring Lung fibrosis Lun cancer HIV	
Pulmonary Embolism	Smoking Overweight Elderly Childbirth Oral contraceptives International travel Heart disorders Circulatory disorders Polycythemia Surgery Bedrest	

Tuberculosis	Elderly Young children HIV Diabetes mellitus Malnutrition Corticosteroid therapy Alcoholism Exposure to someone with TB Certain countries (low socioeconomical areas) Injection drug use Overcrowding Homeless shelters Migrant farm camps Prisons Some nursing homes Contaminated beef Contaminated milk Latent TB	
	TOTAL VALUE	

APPENDIX B:

EVALUATION FORM 2-A:
IF THE FIRST COMPLAINT IS CHRONIC COUGH:

COMPLAINTS/ SYMPTOMS	**Asthma**	**Allergic Rhinitis**	**Bronchiectasis**	**Bronchitis**	**COPDisease**	**Congestive HF**	**Drug Side Effect**	**Esophageal Str.**	**GER Disease**	**Lung Abscess**	**Lung Cancer**	**Pneumonia**	**Pulm. Embolism**	**Sarcoidosis**	**Sinusitis**	**Tuberculosis**
Chest pain	+		+										+			
Chronic heartburn		+	+		+			+	+	+	+				+	
Facial pain		+													+	
Fatigue														+		+
Fever														+		+
ACE inh., NSAID or beta blocker							+									
Nasal discharge		+													+	
Need to sleep on several pillows						+							+			
Night sweats														+		+
rapid or irregular heart beat	+			+		+						+	+			
Regurgitation								+	+							
Shortness of breath	+	+	+	+		+				+	+	+	+	+		+
Sour taste in mouth								+	+							
Sputum			+		+									+		+
Swollen leg	+	+				+							+			
Weight loss			+							+	+					
Wheezing	+		+	+	+							+		+		+
DISEASE S.	5	5	6	3	3	4	1	3	3	3	3	3	5	6	3	6
TOTAL SCORE																
WEIGHTED S.																
LINGUISTIC CATEGORY																

EVALUATION FORM 2-B:

DISEASE	LINGUISTIC CATEGORY (VERY HIGH, HİGH, MAYBE, LOW, VERY LOW)	FREQUENCY (VERY OFTEN, OFTEN, NORMAL, RARELY, TOO RARELY)	REVISED LINGUISTIC CATEGORY (VERY HİGH, HIGH, MAYBE, LOW, VERY LOW)
Asthma		NORMAL	
Allergic Rhinitis		OFTEN	
Bronchiectasis		RARELY	
Bronchitis		NORMAL	
COPD		NORMAL	
Congestive Heart Failure		OFTEN	
Drug Side Effect		TOO RARELY	
Esophageal stricture		TOO RARELY	
Gastroesophageal Reflux Diseases		NORMAL	
Lung Abscess		RARELY	
Lung Cancer		RARELY	
Pneumonia		NORMAL	
Pulmonary Embolism		RARELY	
Sarcoidosis		TOO RARELY	
Sinusitis		VERY OFTEN	
Tuberculosis		NORMAL	

EVALUATION FORM 2-C:

DISEASE	RISK FACTORS	TOTAL SCORE
Asthma	Low socioeconomic status Poverty Substandard housing Indoor allergens Lack of education Inadequate access to health care Respiratory infections (colds, flu, etc.)	
Allergic Rhinitis	NOT DETERMINED	
Bronchiectasis	NOT DETERMINED	
Bronchitis	NOT DETERMINED	
Chronic Obstructive Pulmonary Disease	Cigarette smoking Aging Heredity Occupation pollution exposure Environmental air pollution History of childhood respiratory infections Low socioeconomic status	
Congestive Heart Failure	Aging Hypertension Previous heart attack Heart failure	
Drug Side Effect	Use of ACE inhibitory Use of Beta blocker Use of NSAID	
Esophageal stricture	NOT DETERMINED	
Gastroesophageal Reflux Disease	Alcohol Overweight Pregnancy Smoking	
Lung Abscess	NOT DETERMINED	
Lung Cancer	Smoking Starting smoking at early age Smoking many packs a day Passive smoking Air pollutants Radon Asbestos Pollution Lung diseases Tuberculosis Personal history of lung cancer	
Pneumonia	Elderly Young children Immunocompromised Alcoholism Asthma Smoking Lung scarring Lung fibrosis Lun cancer HIV	
Pulmonary	Smoking	

Embolism	Overweight Elderly Childbirth Oral contraceptives International travel Heart disorders Circulatory disorders Polycythemia Surgery Bedrest	
Sarcoidosis	NOT DETERMINED	
Sinusitis	NOT DETERMINED	
Tuberculosis	Elderly Young children HIV Diabetes mellitus Malnutrition Corticosteroid therapy Alcoholism Exposure to someone with TB Certain countries (low socioeconomical areas) Injection drug use Overcrowding Homeless shelters Migrant farm camps Prisons Some nursing homes Contaminated beef Contaminated milk Latent TB	
	TOTAL VALUE	

APPENDIX C

EVALUATION FORM 3-A:
IF THE FIRST COMPLAINT IS VERTIGO:

COMPLAINTS/ SYMPTOMS	Acoustic Neu.	Anemia	Anxiety Dis.	BPPV	Brain Absc.	Brain Tumor	Cerv. Spondy.	Cholesteatom	Depression	Drug React.	Hypoglycemia	Imp. Cerumen	Labyrinthitis	Mastoiditis	Meniere's Dis.	Meningitis	Migraine H.	Otitis Externa	Otitis Media	Seizures	Whiplash
Aura																	+			+	
Balance problems	+			+				+									+				
Difficult sleeping			+						+												
Difficulty speech						+															
Discharge, ear												+						+	+		
Earache												+						+	+		
Facial weakness	+							+													
Fatigue			+						+												
Feeling of appreh., fear and irritability			+						+												
Fever												+					+		+		
Forgetfulness						+															
Head injury						+															
Headache	+			+		+		+			+						+			+	
Hearing loss	+							+				+	+	+	+	+		+	+		
Medication use: diuretics, anticonv. or antibiotics										+											
Nausea and vom.				+	+	+							+		+		+		+		
Neck pain							+														+
Pallor		+									+										
Arythmia		+									+										
Tinnitus	+												+	+		+			+		
Speech problems											+						+				

Sweating													+		+						
Swollen lymph nodes in neck												+						+	+		
Bleeding symptoms		+									+										
Visual Disturbances											+						+				
Weakness		+				+	+				+						+				+
Numbness						+	+				+						+				+
DISEASE S.	5	4	3	3	1	7	3	4	3	1	8	5	4	2	3	2	9	4	7	2	3
TOTAL SCORE																					
WEIGHTED S.																					
LINGUISTIC CATEGORY																					

EVALUATION FORM 3-B:

DISEASE	LINGUISTIC CATEGORY (VERY HIGH, HİGH, MAYBE, LOW, VERY LOW)	FREQUENCY (VERY OFTEN, OFTEN, NORMAL, RARELY, TOO RARELY)	REVISED LINGUISTIC CATEGORY (VERY HİGH, HIGH, MAYBE, LOW, VERY LOW)
Acoustic Neuroma		TOO RARELY	
Anemia		OFTEN	
Anxiety Disorder		NORMAL	
BPPV		RARELY	
Brain Abscess		RARELY	
Brain Tumor		RARELY	
Cervical Spondylosis		RARELY	
Cholesteatoma		TOO RARELY	
Depression		RARELY	
Drug Reaction		TOO RARELY	
Hypoglycemia		RARELY	
Impacted Cerumen		TOO RARELY	
Labyrinthitis		RARELY	
Mastoiditis		TOO RARELY	
Meniere's Disease		RARELY	
Meningitis		TOO RARELY	
Migraine H.		VERY OFTEN	
Otitis Externa		NORMAL	
Otitis Media		NORMAL	
Seizures		RARELY	
Whiplash		RARELY	

EVALUATION FORM 3-C:

DISEASE	RISK FACTORS	SCORE
Acoustic Neuroma	NOT DETERMINED	
Anemia	Menstruating women Dieting (Vegetarians, Not eating red meat) Pregnant women Childbirth	
Anxiety Disorder	NOT DETERMINED	
BPPV	NOT DETERMINED	
Brain Abscess	NOT DETERMINED	
Brain Tumor	Certain occupations; Oil refining Rubber manufacturing Drug manufacturing Chemists Embalmers	
Cervical Spondylosis	NOT DETERMINED	
Cholesteatom	NOT DETERMINED	
Depression	Stress and emotional trauma (e.g. Family member death) Family history of mood disorders Family history of depression Family history of bipolar disorder Cancer patients Stroke patients Diabetes Heart disease *Low self-esteem* Tobacco use Alcohol misuse Excess weight Smokers	
Drug Reaction	NOT DETERMINED	
Hypoglycemia	NOT DETERMINED	
Impacted Cerumen	NOT DETERMINED	
Labyrinthitis	NOT DETERMINED	
Mastoiditis	NOT DETERMINED	
Meniere's Disease	NOT DETERMINED	
Meningitis	Age under 5 years Age group 15-24 Contacts of confirmed meningococcal cases Immune compromise Travel to Africa or parts of far Asia where meningococcus is more common. Institutions (Schools, College, University, Dormitories) Child care Low humidity	

	Dust storms Cigarrette smoke Skull fracture	
Migraine H.	Puberty Gender (women are 75%) Family history of migraine	
Otitis Externa	Swimming Ear injury	
Otitis Media	Colds Jumping into water Diving into water	
Seizures	NOT DETERMINED	
Whiplash	NOT DETERMINED	
	TOTAL VALUE	

APPENDIX D

EVALUATION FORM 4-A:

IF THE FIRST COMPLAINT IS NASAL DISCHARGE:

COMPLAINTS/ SYMPTOMS	Allergic Rhinitis	Diphtheria	Lupus Vulgaris	Midline Granuloma	Nasopharyngeal Carcinoma	Osteomyelitis	Peritonsillar Abscess	Pharyngitis	Sarcoidosis	Sinusitis	Tonsillitis	Wegener's Granulomatos
dead mushy tissue in nasal cavity					+							+
earache					+							+
Facial pain						+				+		
fever						+				+		
headache						+				+		
itchy eyes	+											
nasal discharge, at times bloody			+									
nasal obstruction					+							+
night sweats			+	+					+			
reddish lump of nasal septum			+	+					+			
sneezing	+											
sore throat	+											
watery nasal discharge	+											
weight loss			+	+					+			
chronic cough, may cough up blood					+							+
sore throat		+					+	+			+	
hoarseness		+					+	+			+	
difficulty or painful swallowing		+					+	+			+	
difficulty breathing		+					+	+			+	
DISEASE S.	4	4	4	3	4	3	4	4	3	3	4	4
TOTAL SCORE												
WEIGHTED S.												
LINGUISTIC CATEGORY												

EVALUATION FORM 4-B:

DISEASE	LINGUISTIC CATEGORY (VERY HIGH, HIGH, MAYBE, LOW, VERY LOW)	FREQUENCY (VERY OFTEN, OFTEN, NORMAL, RARELY, TOO RARELY)	REVISED LINGUISTIC CATEGORY (VERY HIGH, HIGH, MAYBE, LOW, VERY LOW)
Allergic Rhinitis		OFTEN	
Diphtheria		TOO RARELY	
Lupus Vulgaris		TOO RARELY	
Midline Granuloma		TOO RARELY	
Nasopharyngeal Carcinoma		TOO RARELY	
Osteomyelitis		RARELY	
Peritonsillar Abscess		TOO RARELY	
Pharyngitis		VERY OFTEN	
Sarcoidosis		TOO RARELY	
Sinusitis		VERY OFTEN	
Tonsillitis		VERY OFTEN	
Wegener's Granulomatosis		TOO RARELY	

EVALUATION FORM 4-C:

DISEASE	RISK FACTORS	SCORE
Allergic Rhinitis	NOT DETERMINED	
Diphtheria	NOT DETERMINED	
Lupus Vulgaris	Race (African Americans, Hispanic Americans, Latino Americans, Native Americans) Women between the ages of 15 and 44 Mother-infant transmission Mother-to-fetus contagion	
Midline Granuloma	NOT DETERMINED	
Nasopharyn. Carcinoma	NOT DETERMINED	
Osteomyelitis	Wounds Injury Surgery	
Peritonsillar Abscess	NOT DETERMINED	
Pharyngitis	NOT DETERMINED	
Sarcoidosis	NOT DETERMINED	
Sinusitis	NOT DETERMINED	
Tonsillitis	NOT DETERMINED	
Wegener's Granulomatos	NOT DETERMINED	
	TOTAL VALUE	

APPENDIX E

EVALUATION FORM 5-A:

IF THE FIRST COMMPLAINT IS NECK PAIN

COMPLAINTS/ SYMPTOMS	Anky.Spondylitis	Brain Tumor	Cerv. Spondyl.	Discitis	Fract.Cerv.Sp.	Herniated Disc	Hydrocephalus	Meningitis	Met. Cancer	Migraine	Periton. Abs.	Rheumatoid A.	Subarach. Hem.	Tuberculosis	Whiplash Injury	Miyalgia
Back and hip pain	+		+													
Back and neck stiffness	+		+													
Chronic cough									+					+		
Fatigue	+		+													
Fever and chills				+				+			+					
Head or neck injury			+		+	+			+						+	
Headache		+	+		+	+	+		+						+	
Muscle spasms			+	+	+	+			+					+	+	+
Nausea and vomiting		+					+	+		+			+			
Neck stiffness								+		+	+		+			+
Night sweats									+					+		
Numbness, arms			+		+	+			+			+			+	
Pain and swelling of joint			+			+						+				
Sensitivity to light								+		+			+			
Shoulder pain			+		+	+			+						+	
Sore throat								+			+					
Stiffness of joints			+			+						+				
Sudden severe headache								+		+			+			
Visual difficulties		+					+									
Weakness, arms			+		+	+			+			+			+	

Weight loss	+		+					+						+		
DISEASE S.	4	3	12	2	6	8	3	7	8	4	3	4	4	4	6	2
TOTAL SCORE																
WEIGHTED S.																
LINGUISTIC CATEGORY																

EVALUATION FORM 5-B:

DISEASE	LINGUISTIC CATEGORY (VERY HIGH, HİGH, MAYBE, LOW, VERY LOW)	FREQUENCY (VERY OFTEN, OFTEN, NORMAL, RARELY, TOO RARELY)	REVISED LINGUISTIC CATEGORY (VERY HİGH, HIGH, MAYBE, LOW, VERY LOW)
Ankylosing Spondylitis		RARELY	
Brain Tumor		TOO RARELY	
Cervical Spondylosis		TOO RARELY	
Discitis		TOO RARELY	
Fracture Of The Cervical Spine		TOO RARELY	
Herniated Disc		RARELY	
Hydrocephalus		TOO RARELY	
Meningitis		RARELY	
Metastatic Cancer		RARELY	
Miyalgia		VERY OFTEN	
Migraine Headache		VERY OFTEN	
Peritonsillar Abscess		RARELY	
Rheumatoid Arthritis		RARELY	
Subarachnoid Hemorrhage		RARELY	
Tuberculosis		NORMAL	
Whiplash Injury		TOO RARELY	

EVALUATION FORM 5-C:

DISEASE	RISK FACTORS	TOTAL SCORE
Ankylosing Spondylitis	Family history of disease	
Brain Tumor	Certain occupations; Oil refining Rubber manufacturing Drug manufacturing Chemists Embalmers	
Cervical Spondylosis	NOT DETERMINED	
Discitis	NOT DETERMINED	
Fracture Of The Cervical Spine	NOT DETERMINED	
Herniated Disc	Age Twisting Bending Lifting	
Hydrocephalus	NOT DETERMINED	
Meningitis	Age under 5 years Age group 15-24 Contacts of confirmed meningococcal cases Immune compromise Travel to Africa or parts of far Asia where meningococcus is more common. Institutions (Schools, College, University, Dormitories) Child care Low humidity Dust storms Cigarrette smoke Skull fracture	
Metastatic Cancer	NOT DETERMINED	
Migraine Headache	Puberty Gender (women are 75%) Family history of migraine	
Peritonsillar Abscess	NOT DETERMINED	
Rheumatoid Arthritis	Family history Autoimmune diseases	
Subarachnoid Hemorrhage	NOT DETERMINED	
Tuberculosis	Elderly Young children HIV Diabetes mellitus Malnutrition Corticosteroid therapy Alcoholism Exposure to someone with TB Certain countries (low socioeconomical areas) Injection drug use	

	Overcrowding Homeless shelters Migrant farm camps Prisons Some nursing homes Contaminated beef Contaminated milk Latent TB	
Whiplash Injury	NOT DETERMINED	
	TOTAL VALUE	