ARAB REPUBLIC OF EGYPT

THE INSTITUTE OF NATIONAL PLANNING

Memo No (1650)

Using Intelligent Decision Support Systems in Selected Aspects of Health Care

Prepared by
Basmah El Haddad, Ph.D.
Computer and Systems Analysis

March 2012

CAIRO
SALAH SALEM St-NASR CITY

Using Intelligent Decision Support Systems in Selected Aspects of Health Care

Researcher

Basmah El Haddad, Ph.D.
Computer and Systems Analysis

Human Development Studies Dep.
Institute of National Panning

Cairo
June 2011

Abstract

Research Title

Using Intelligent Decision Support Systems in Selected Aspects of Health Care

Researcher: Basmah El Haddad

Brief Abstract

The research introduces the need of using agent technologies in assisting and aiding the responsible parties and decision makers during the decision-making process in general and in the Human Organ Transplantation Management "HOTMS" domain in specific. The medical scenario is assumed to be a real application of a decision support system. The research proves that integrating agents with their various types, techniques and interaction abilities in decision support systems generally and HOTM systems especially, can provide a great support to decision makers and help them to make right decisions and solve problems in a highly advanced fashion.

The research also introduces and studies precisely the main definitions and background of all the interdisciplinary related fields, like "Artificial Intelligence", "Agent Technology", "Intelligent Decision Support Systems" as well as the Human Organ Transplantation Management System, in order to point to the significance of using the multi-agent technology during the HOTMS.

From one side, the main contribution was represented by introducing the Human Organ Transplantation Management System Structure for the particular case of Egypt. While from the other side it also contributed by introducing, explaining and presenting the proposed Multi-Agent Human Organ Transplantation Management System architecture with its various proposed agent types and roles integrated in the HOTM System. It is assumed that the system will be of great help on the national level as well on the regional level as the HOTMS is considered now one of the most important services to be provided by the government and which has been recently on the spot for development and establishment.

Table of Contents

Chapter Five

Chapter Six

List of Figures

List of Tables

Acknowledgment

I would like to thank very much Prof . Dr. Azza Al Fandary, the head of the Human Development Studies Dep. at the Institute of National Planning for her valuable help and fruitful during discussions.

&

I would also like to thank Mr. Muhammad Afifi the researcher at the Institute of National Planning for his assistance for the data & information gathering and for useful discussions.

Using Intelligent Decision Support Systems in Selected Aspects of Health Care

Chapter One

1. Introduction and Overview

Health care is one of the government's major concerns; it has been on the spot recently for improvement, enhancement and development. The health care domain is facing many problems and complications which require efficient planning, decision making, management and problem solving techniques.

The Intelligent Decision Support Systems IDSS in this domain promise to support decision making in the medical industry as a whole. It assists the different parties, health care professionals and providers during the clinical and medical processes as well as the managerial processes. The IDSS have the ability to add main features and facilities that could assist in countless areas of this domain starting from gathering just-in time information, storing and retrieving it, real time processing, online transaction processing, coordinating and communicating, connectivity and global interaction, continuous examining and monitoring, real-time data analysis and diagnosis and many other areas in this domain.

1.1. The Research Problem and Questions

A lot of studies and reports announce that underdeveloped countries and communities are suffering from high birth rates leading up to overpopulation and all associated needs. These needs result in a variety of challenges and problems on different levels and with respect to various dimensions. In Egypt we are estimated to double by the year 2050, i.e. reach a whopping 160 million. So one of the most pressing issues in the Egyptian healthcare domain is the horribly growing number of liver and kidney patients who are in urgent need of organ transplantation surgeries to save their lives. Recently, and according to the ministry of health and population they estimated the liver patients to be around 10 millions, from which one million at least need a new liver through an organ transplantation surgery. As well as a number not to be underestimated of patients who are in need of other organs such as heart or pancreas.

This, lead the Egyptian government to finally take their decision to allow the organ transplantation surgeries by issuing the **"Human Organ Transplantation Management", HOTM** law after fourteen years of debate, due to the importance of the organ transplantation which stems from the fact that it clearly draws the thin line between life and death. Shortage of such organs raises the mortality and morbidity rates and may as well lead to physical and social complications. They were motivated by the success of organ transplants and the newly developed surgery techniques and medical treatment world wide. One human donor can save one patient, while one human brain-dead donor can save up to eight lives; with his/her eight different organs.

The **HOT** coordination and management is quite a complex process that involves many different organizations, persons, norms and laws. It requires administrative as well as clinical process management. High level of knowledge management, planning/scheduling, coordination and monitoring is also required. The stressing time constraint is a very important aspect due to the nature of the problem. The HOTMS contains two main phases; **Procurement** and **Surgery** phase. Each of them includes many managerial and clinical processes which raise challenges and problems during their execution. In addition, there are many parameters influencing the whole process varying from medical, logistical, managerial ... to ethical. The **Matchmaking** and the **Negotiation** processes during the **Procurement** Phases include some of the main challenges facing the **HOTMS** and the human decision makers and medical experts involved in the system.

In this aspect some **Research Questions** and **Issues** have been raised in an attempt to solve them during the following study as follows:

1- How should the **Human Organ Transplantation Management System's Structure** -in Egypt- look like and why the researcher believes it will be the most fitting for Egypt ?

2- What would be better, an HOTM system relying on centralized or decentralized processes?

3- Is there any chance for negotiations during the procurement phase? And how about using **Intelligent Match Making and Negotiation Techniques !**
4- One of the main questions is the ability to rely on techniques and technologies from the AI domain generally and the agent technology specifically as a main contributor of an **IDSS** during the **Human Organ Transplantation Management Processes.**
5- On which techniques should the decision makers relay in specific when building the proposed **Intelligent HOTM System**. And how should the systems architecture look like?
6- Does the proposed intelligent HOT System assure the fairness, effectiveness and efficiency of the allocation process and the whole HOTM Processes?

All these questions have been analyzed, tackled and answered to some extent during the research and in specific in the second part of it during chapter four and five.

1.2. The Research Objectives

The main objectives of the research are to answer and tackle the research questions and try to solve the main problem through proving what follows:

1- The importance of using intelligent systems and technologies from its broad concept, in assisting and aiding the responsible parties and decision makers during the decision-making process in general and in the Human Organ Transplantation Management System, **HOTMS** in specific.

2- Integrating agents with their various types, techniques and interaction abilities in the HOTM domain provide a great support to decision maker and help them to make right decisions and solve problems in a highly advanced fashion. It also assures an improved degree of autonomy, responsiveness, pro-activeness, mobility, social ability and flexibility.

This will be accomplished through providing and achieving specific objectives like follows:

- **Presenting** and **introducing** the literature review and definitions of "**Intelligence**", "**Artificial Intelligence**" and the "**Intelligent Decision Support Systems**" as well as introducing various "**Intelligent Decision Making**" techniques to encourage decision makers and planners to make use of these different technologies under the umbrella of "Artificial Intelligence" to benefit from its advantages during decision making and planning in the healthcare domain generally and its different topics specifically.
- **Encouraging** researchers from interdisciplinary fields to **apply** and **use** the artificial intelligence technologies and techniques when developing and implementing their intelligent decision support systems
- To **draw** the health care professionals, stockholders, parties and medical specialist's attention to the intelligent systems and techniques used in the health care domain by presenting and defining the intelligent medical and clinical decision making and the classification of the intelligent decision support systems in the health care domain as well as giving some examples and applications in different areas of the domain.
- **Proposing** and **introducing** a **Human Organ Transplantation Management's System Structure** to be considered and adopted while establishing the Egyptian **HOTM** System in the near future.
- As a **proof of concept, proposing and introducing** a **Multi-Agent HOTM System Architecture** to be considered in **Egypt** considering it a real application of decision making systems. Providing it guarantees efficiency, effectiveness and high-quality HOTM services. It also should assure fair and safe resource allocation that saves time, effort and money.

In this Aspect, one will proof that there is an urgent need to develop mechanisms and systems that help to decrease the percentage of losses in each phase and process. Therefore it is worth it to elaborate intelligent systems, efficient information systems and tools to be used as decision supporters during the HOTM. These must have some communicative, informative, cognitive and negotiating functions to guarantee secure distributed communication, maintaining historical information files, and extracting new knowledge from the systems behaviour and from the analysis of the data.

1.3. The Research Importance

Adopting the IDSS and the artificial intelligence techniques in the health care domain promises to improve the domain generally by improving its various medical, clinical and managerial processes, procedures and activities. It has the power to solve some of the common problems and challenges facing the domain.

As mentioned before, the Egyptian government issued the HOTM law to save patients generally and in specific the kidney and liver patients who represent the highest category of people waiting for an organ. Their target is to establish an efficient and effective HOTM system as part of their main plan to improve the whole health care domain.

The research is of great importance at this point in time as it claims that using the multi-agent technology during the Human Organ Transplantation Management will result in effectiveness and efficiency in the whole medical care process. It is a good support and aid for the personnel and decision-makers involved in the system due to the flexible information flows and solutions of the complicated distribution problems. The proposed system could improve some health indicators as follows:

- Reduction of deaths (Mortality Rate) caused by the absence of management of HOT and the scarcity of organs available.
- Increase the number of cured organ failures by increasing the donors organ viability due to effective HOTM
- Decreasing the number of discarded donor organs by facilitating efficient evaluation and negotiation techniques
- Enhancing the effective resource allocation which increases the probability of curing diseases and saving lives
- The importance of the study is also revealed in its relevance to the importance Egypt places on the urgency of establishing and developing the Human Organ Transplantation Management System.

1.4. The Research Approach

The Research will follow a descriptive analytical approach. The problems of the HOTMS will be well studied and tackled to get the best solutions. This will be done by representing a conceptual framework in which the scope is limited due to the scarcity of information and vague vision as it is a very recent issue under development. The main contributing output of the research will be presented by:

- A proposed HOTM system structure for Egypt
- A proposed Multi-Agent HOTM System architecture to be adopted and that can be implemented as a prototype in a following study.

1.5. The Research Outline

The research consists of six chapters divided mainly into two parts. The first part contains chapter one, two and three and represents and introduces the background review of definitions of main topics of "IDSS", "AI and Computational Intelligence", "Intelligent Medical Systems" and the related definitions and aspects. The second part containing chapter four, five and six introduces, represents and explains the proposed Multi-Agent Human Organ Transplantation Management System structure and architecture from all its aspects and concludes with the conclusions, recommendations and contributions. The following is a very brief summary about these chapters:

Chapter **One** consists of the introduction, overview, research problem & questions, objectives, importance and approach.

Chapter **Two**: more or less this chapter is an introductory chapter for non-specialists of Artificial Intelligence. It is mainly addressed to researchers from different disciplines- who read this research- as a compact overview of the AI and DSS fields, techniques, technologies and synergetic systems in an aim to encourage various researchers and experts from other domains to make use of it in order to solve real world problems. Therefore the chapter consists mainly of some related topics with their definitions and background to prove the benefits of using intelligent and agent technology during the health care and medical decision support systems. The topics review the "Intelligence" and "Artificial Intelligence" as a concept as well as the "Intelligent Decision Support Systems". The intelligent decision-making process, phases, techniques, characteristics and properties will also be introduced, ending up with presenting different "Synergistic Approaches".

Chapter **Three**: targets mainly the specialists and researcher in the medical and healthcare domain. It presents the "Artificial Intelligence" and "Computational Systems" in the Clinical and Health care domain by presenting literature review of intelligent medical and clinical decision making, the classification of the intelligent decision support systems in the health care domain giving some examples and applications in different areas of the domain. By that it encourages the decision makers of this domain to try to make use of these intelligent technologies within the healthcare and medical domain believing it could handle many of their problems in an advanced fashion.

Chapter **Four**: starts the core part of the research by stressing and showing the importance of using agent technology in the Human Organ Transplantation System. It starts by presenting the reasons of success of the HOTM System, and then it defines thoroughly the HOTM phases, processes, influencing parameters, nature and characteristics, challenges and problems. After that it introduces and explains the actual state of the HOTMS in Egypt contributing by proposing an HOTMS definite structure with its different levels or layers for the case of Egypt. How it should be structured, organized and managed. Different aspects of match-making and negotiation processes have been discussed and introduced. At the end the chapter claims the benefits, efficiency and effectiveness of using Multi-Agents during the HOTMS.

Chapter **Five**: contributes by presenting the proposed Multi-Agent HOTMS processes, architecture, scenarios and integrated agent types and roles. It presents also an overview of a multi-agent system development approach and ends up by introducing general requirements and demands for establishing a reliable, consistent and high-quality multi-agent HOTMS in Egypt.

Chapter **Six** concludes with the research conclusions, contribution and further work.

Chapter Two

2. The 21st Century: Era of Intelligent Decision Making

One of the main aims of decision making is to select the best possible course of actions, scenarios, solutions or decisions from a set of alternatives to support managerial work as well as the decision making processes. Decision-makers are challenged usually with increasingly stressful environments; highly competitive, fast-paced, near real-time, and overloaded with information distributed data sources, which makes the analysis needed to conclude the best decisions more sophisticated and complex [Wren.2005] [Gupt.2006]. Moreover, real-world information and/or data are often incomplete, ambiguous, complex, containing various kinds of noise due to uncertainties of the environments [Jain.2010].

Although, these challenges and difficulties, and according to "Gloria E. and Lakhmi C. in [Wern.2005] they stated, that the infusion of technology and Internet into our communities and environments in the 21st century has its enormous effect on transferring the landscape of decision making in organizations, institutions and even on the personnel level. And for managers, business executives or decision-makers to cope with the challenges of decision making and take fast decisions, almost in real time there is a tremendous need for decision support tools that can effectively lead to intelligent decision at the moment. The combination of the Internet enabling speed and access, and the maturation of artificial intelligence techniques, led to sophisticated aids to support decision making under risky and uncertain conditions that improve the decision making process by suggesting solutions better than those made by human alone [Wern.2005]. Therefore researchers have designed and developed a variety of advanced decision support systems aids assisting human making decision processes. These aids and techniques stem from artificial intelligence, as well as other complementary methodologies, that are useful for the design and development of Intelligent Decision Support Systems "IDSS" that can be utilized to tackle a variety of real-world problems in different domains and fields; e.g. business, management, manufacturing, transportation, engineering, healthcare, biomedicine… etc [Gupt.2006] [Jain.2010].

2.1. Intelligence and Artificial Intelligence as a Concept

A variety of scientists view "**Artificial Intelligence**" from their different perspectives according to their understanding of "**Intelligence**" and "**Intelligent Behavior**". To define "Artificial Intelligence" one must first agree upon the meaning of "Intelligence".

The concept of intelligence has been strongly debated in the psychology and related literature while a standard definition is still elusive, there are some common characteristics of intelligence [Gupt.2006]. Does it describe the properties of a person or group of persons or is it a kind of behavior recognized as intelligent or maybe it's the way of describing how a so-called intelligent behavior has been done. Many researchers and some leading experts in that field argued that various kinds of intelligence occur in people, many animals and some machines [McCa.2007]. Where others assured that intelligence is the province of living creatures and that machines, such as computers, do not and will never display any truly intelligent capabilities or behaviors. To solve this conflict many researchers preferred to distinct between intelligence and human intelligence. While human intelligence is much more related to a certain person with specific capabilities and certain interaction abilities with the surroundings from a very personal point of view, researchers argued that the concept of intelligence by itself includes some capabilities like

- thinking, problem solving, understanding
- learning and using memory to remember followed by the ability to transfer knowledge, store it and use it properly (i.e. increasing conceptual and procedural knowledge)
- communication in natural languages; reading, writing, negotiating (i.e. make sense and generate expected response)
- make decisions and solve problems in a rational way
- perception, creativity and consciousness

which has been also assured by the Webster's Dictionary definition of "**Intelligence**" as "**the capability for learning, reasoning, and understanding**" which proposes that there are component capabilities contributing to the intelligence as a concept [Wren.2005]. These components and capabilities are considered activities of intelligence which are not necessarily equally powerful and which results in various levels of intelligence. Certainly some of these capabilities can be embedded in computer software which leads to the computer intelligence. This agrees with the definition of John McCarthy; that **"Intelligence is the computational part of the ability to achieve goals in the world"**. A valuable benefit will be by applying computer intelligence as a support in parallel with human intelligence. Thus one can conclude that "Intelligence" is multifaceted and not restricted to certain activities. Accordingly it's not easy to define "Artificial Intelligence" and it's rather better to describe it than to define it [Wren.2005] [ElHa.2008].

According to John McCarthy AI is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable [McCa.2007]. Simply saying **AI attempts to understand intelligent entities and tries to build them** and by doing this it comes to a higher level of learning and understanding of ourselves while trying to overcome the challenges of building similar entities. On the one hand, **it's trying to simulate natural human intelligence by studying any living organisms and observing their methods trying to build mechanisms and algorithms that solve problems like they do.** On the other hand, most work in AI involves **studying the problems the world presents to intelligence rather than studying people or animals.** What is important for AI is to have algorithms as capable as people at solving problems[McCa.2007].These machines; computers, programs, tiny brains try to perceive, understand, predict and manipulate the world and the surrounding environment [Russ.2003][ElHa.2008]. AI can also be viewed as a study that addresses new principles by which;

- Knowledge is acquired and used,
- Goals are generated and achieved,
- Information is communicated,
- Collaboration is achieved,
- Concepts are formed, languages are developed

This can be called the **"Science of knowledge"** or the **"Science of Intelligence"** [Slom.2010]. There are various definitions of AI, some of them are gathered by Russel Stuart in [Russ.2003] showing the different point of views of the AI researchers. They defined AI according to two main dimensions:

1- According to **"thought processing and reasoning"** versus **"behaviors and acting"**, the top and the bottom of the following table

2- According to success in terms of **"human performance"** versus the **"ideal concept of rationality"** a synonym to systems doing the right thing, the left and the right column of the following table. Thus there are divided into four groups like follows:

Systems that think like humans:- "The exciting new effort to make computers think ... machines with minds, in the full and literal sense"(Haugeland,1985) "The automation of activities that we associate with human thinking, activities such as decision-making, problem solving, learning..." (Bellman, 1978)	**Systems that think rationally;-** " the study of mental faculties through the use of computational models."(Charniak and McDermott, 1985) "The study of computation that makes it possible to perceive, reason, and act" (Winston, 1992)
Systems that act like humans:- "The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990) " The study of how to make computers do things at which, at the moment people are better." (Reach and Knight, 1991)	**System that act rationally":-** "The branch of computer science that is concerned with the automation of intelligent behavior" (Ludger and Stubbelfield, 1993). "AI ... is concerned with intelligent behaviour in artifacts."(Nilsson, 1998)

Table 2-1 Some definitions of AI, organized into four categories [Russ.2003].

Thus, there is no short definition, defining and capturing the goals covered by AI. It is clear that AI is multidisciplinary; it includes the study of perception, learning, reasoning, remembering, motivation, emotions, self-awareness, communication, etc. which means it overlaps with many other disciplines, especially psychology, philosophy and linguistics. While it also overlaps with computer science and software engineering, because it includes the design of new kinds of information processing systems, either to model those in humans or to solve practical problems (e.g. software controlling a robot or factory, or software helping a child to learn about arithmetic) [Slom.2010].

2.2. Decision Support Systems Historical Overview

Academic researchers from many disciplines have been studying, investigating and building decision support systems for approximately 40 years. They began by building model-driven DSS in the late 1960s, theory development in the 1970s, followed by implementation of financial planning systems, spreadsheet DSS and group DSS in the early 1980s. In the late 1980s and early 1990s, data ware houses, executive information systems, OLAP (Online Analytic Processing) and Business Intelligence have been evolved. Another progression was the knowledge-driven DSS and the implementation of web-based DSS in the mid 1990s [Powe.2008].

Early definitions of decision support systems actually stemmed from two main research areas:

- **Theoretical studies** of organizational decision making at the Carnegie Institute of Technology in the late 1950s- early 1960s
- **Technical development** of interactive computer systems mainly at the Massachusetts institute of Technology in the 1960s [Jain.2010].

Starting from the early period of designing, developing and defining the various DSS, the researcher's main concerns were;

- To deal with unstructured and semi-structured difficult problems that required extensive experience and expert knowledge, which was not dealt with in operations research and management science theory in a more effective and efficient way
- To enable decision-maker to make better and more reasoned decisions without using optimization tools and advanced modeling
- To facilitate decision-maker to make systematic use of their knowledge and experience in an interactive problem solving environment [Carl.2002]

Thus they focused mainly on four aspects;

1. Providing methods and instruments for dealing with unstructured and semi-structured problems to improve management science and operations research methodology
2. Offering interactive computer-based systems more advanced than descriptive theory or traditional decision models.
3. User-oriented systems, which formed a better platform for decision-making than batch-oriented Management Information System MIS application
4. Separation of data and models in computer applications [Wren.2005]

2.2.1. Decision Support System's Definitions over Time

In 1960s, many researchers began studying how to make use of computerized quantitative models to assist in decision making and planning (Raymond 1966, Turban 1967, Urban 1967, Holt and Huber 1969). They were the start of studying, analyzing, designing, implementing, and developing various systems. Simultaneously, DSS researchers started to publish different decision support systems definitions and declarations.

- **Ferguson and Johns, 1969** reported the first experimental study using a computer aided decision system.
- **Little, 1970** identified criteria for designing models and systems to support management-decision making. He relayed on four criteria; robustness, easy of control, simplicity and completeness of relevant details. He designed a model-based set of procedures for processing data and judgments to assist a manager in his decision making.
- **Scott Morton, 1971** was the first researcher using the term decision support system. He argued that Management Information Systems, MIS focused primarily on structured decision and suggested supporting information systems for semi-structured and unstructured decisions which are the DSS. He studied how computers and analytical models could help managers make a recurring key business planning decision. He stated that "DSS are interactive computer-based systems, which help decision makers utilize data and models to solve unstructured problems".

- **Keen and Scott Morton, 1978** provided the first broad behavioral orientation to decision support system analysis, design, implementation, evaluation and development. They argued that "DSS couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions" and assured that a DSS is a computer-based support system for management decision makers who deal with semi-structured problems.

- **Moore and Chang,1980** defined the DSS as "Extendible systems, capable of supporting ad hoc data analysis and decision modeling, oriented toward future planning, used at irregular, unplanned intervals".

- **Alter, 1980** concluded that decision support systems could be categorized in terms of the generic operations that can be performed by such systems, which extends along a single dimension, ranging from extremely data-oriented to extremely model-oriented. The seven types included; data analysis systems, analysis information systems, accounting and financial models, representation models, optimization models and suggestion models.

- **Bonczek et al. ,1981** explained a theoretical framework for understanding the issues associated with designing knowledge-oriented decision support systems. Four essential aspects or components were identified such as follows:

1. A language system **"LS"** specifying all messages a specific DSS can accept.
2. A presentation system **"PS"** for all messages a DSS can emit.
3. A knowledge system **"KS"** for all Knowledge a DSS has
4. A problem-processing system **"PPS"** that is the software engine that tries to recognize and solve problems during the use of a specific DSS

- **Sprague and Carlson, 1982** explained the DSS framework of data base and dialog generation and management software. They defined DSS as a "class of information system that draws on transaction processing systems and interacts with the other parts of the overall information system to support the decision-making activities of managers and other knowledge workers in organizations" [Powe.2008].

- **Turban and Aronson 1898** concluded with a general definition for a DSS as "a system providing support for decision makers by bringing together human judgment and computerized information in an attempt to improve effectiveness of decision-making" [Gupt.2006].

Summarizing; the concept behind all these definition is that a **DSS is a; computer-based system, utilizing data and models, solving semi-structured and unstructured problems, coupling the intellectual resources of individuals with the capabilities of the computer, improving the quality of the decisions and choosing the best amongst alternative courses of action while the purpose is attaining a goal or goals [Turb.1998].**

2.3. Intelligent Decision Support Systems

The advent of digital technologies and information processing techniques to problem solving and decision making resulted in the emergence of the Intelligent Decision Support Systems "**IDSS**". Many new techniques have been incorporated, starting from information technology systems based on spreadsheet software, optimization models from operation research and management science research up to artificial intelligence and statistics techniques that enhanced the design and applicability of DSS [Jain.2010]. Simply saying, integrating and applying AI techniques and technologies within decision making process resulted in the so-called IDSS.

The IDSS differs from the classical DSS in its support of a wide range of decisions including those with uncertainties. They handle domains where the decision process is more complicated and requires expertise as well as assessment of the impact of the proposed solution. The IDSS contains improved user interfaces that can be achieved using some parts of AI, including natural language processing or similar techniques. One of its main advantages is the increased timelines in making decisions, improved consistency in decisions, better explanations and justifications for specific recommendations, improved management of uncertainty, and formalization of organizational knowledge [Turb.1998]. The **second generation** of the **DSS**, which were called the **knowledge-based decision support systems**, was considered as the starting point of developing IDSS. Holsapple and Whinston suggested that these systems should:

- contain various types of knowledge describing selected aspects of the decision-maker's world
- have the ability to acquire and maintain descriptive knowledge
- produce and present knowledge in various ways
- select knowledge to present or derive new knowledge
- interact directly (intelligently) with the decision-maker [Gupt.2006]

According to may researchers the intelligent decision making support system **I-DMSS** extends traditional DSS by incorporating techniques to supply intelligent behaviors and utilizing the power of modern computers to support and enhance decision making [Gupt.2006].

2.3.1. The IDSS Features and Characteristics

- Respond quickly and successfully to new data and information without human intervention
- Process both qualitative and quantitative data (varying levels of precision)
- Deal with perplexing and complex situations (imprecision, uncertainty,...)
- Reasoning to transform data and knowledge to opinion, judgments, evaluations and advice
- Learn from previous experience
- Apply knowledge to understand the environment
- Recognize the relative importance of different elements in the decision
- Incorporate the knowledge of domain experts
- Recommend actions on behalf of the human after being authorized by the decision-maker [Gupt.2006].
- Interacts easily with human users as well as with databases (interactivity)
- Monitors and recognize important changes and events (change detection)
- Represents and communicates information effectively and easily
- Error detection and recovery
- Extract useful information from voluminous data
- Assesses the effect of changes and predicts the impact on the future performance (predictive capabilities) [Jain.2010]

The **modern** support systems **research** is **focused** on the **theory** and **applications** of **intelligent systems** and **soft computing** in management. This includes but is not limited to processes of 1-problem solving, 2- planning, 3-decision-making and ranges from strategic management, business process reengineering, effective collaboration, improved user-computer interfaces and mobile and electronic commerce to production, marketing and financial management. While intelligent and soft computing include research on fuzzy logic, artificial neural networks, genetic algorithms, machine learning, case-based reasoning, intelligent and multi-agents ...

In spite of all these efforts, the new systems have been faced with many social problems related to the peoples view towards these systems; having cognitive constraints adopting intelligent systems, do not understand the support they get, can't handle a huge amount of information and knowledge, they are frustrated and don't trust technology that much.

2.3.2. The Intelligent Decision-Making Process Phases

Several models and paradigms have been reported in the literature describing the decision-making process and how it should be. The most popular ones are based on Simon's original three phase model, first reported in "Administrative Behavior", 1947 [Gupt.2006]. Nobel laureate Herbart A. Simon visualized the decision-making process as the search for feasible paths in a searching space, which suggested that decision making can also be considered as **"a process of choosing among alternative courses of action for the purpose of attaining a certain goal or goals"** [Turb.1998]. Later on, other phases have been added to develop the modern five-phase model of decision making.

1. **"Intelligence"**, the initial phase; in which the decision-maker observes the reality, establishes and understands the problem domain and the associated opportunities and gathers all the necessary data and information concerning the problem. This phase goes through all steps of problem identification, classification, decomposition and ownership.
2. **"Design"**, the second phase; in which the decision criteria, alternatives and course of actions are analyzed and developed by using a certain model, taking the uncontrollable events into account. Different relationships between decisions, alternatives and events should be decided.
3. **"Choice:**, is the most critical phase , in which the alternatives are enabled and logically evaluated. This will be done through the generation, evaluation and selection steps and the best course of action should be

selected and an actual decision be made. The next two phases during the decision making process have been added later and represent the problem solving part of the decision making.

4. **"Implementation"**, during the new expanded fourth phase, the decision maker has to reconsider the decision analysis and evaluation, as well as to weigh the consequences of the recommendations. At the same time, the implementation plan will be developed with the necessary resources secured to be put in action. This will be done through the steps of result presentations, task planning and tracking.
5. **"Learning and Monitoring"**, the last expanded phase; in which the outcome must be continually measured and monitored. And the information about how well the solution is working is fed back to the decision makers. In this way, the identification of the problem can change over time, alternative solutions can be changed, and new choices can be made. This will be done inside the outcome process analysis and outcome process synthesis steps [Jain.2010] [Gupt.2006] [Turb.1998].

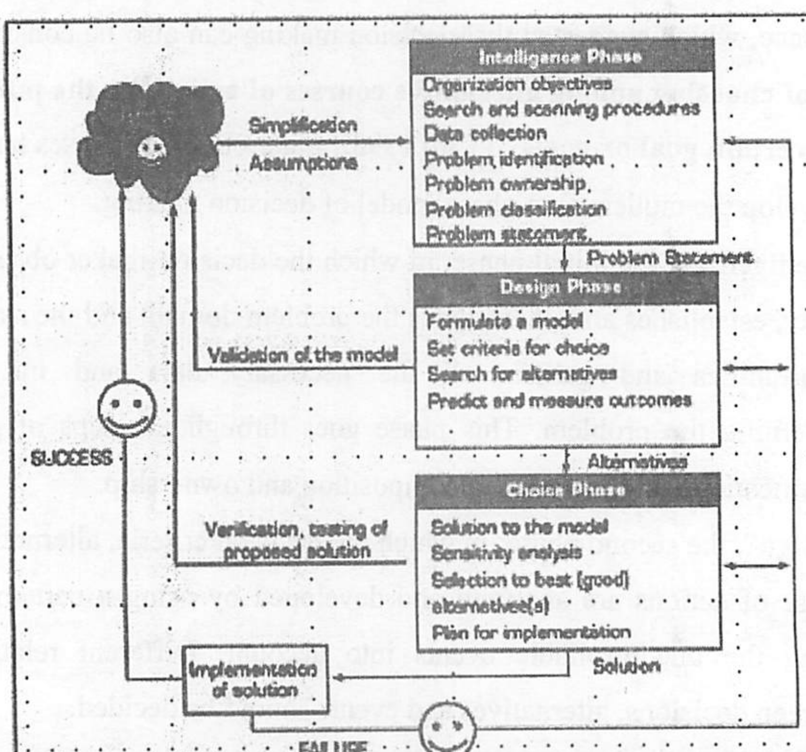

Figure 2-1 The Intelligent Decision Making Modeling Process [Turb.2005]

One should recognize, that the decision making process is a complex task. Its phases are continuous but partially iterative and cyclic so that the phases may overlap. Although the steps are implemented concurrently, decision making is fundamentally a sequential process. "Design" requires "Intelligence", "choice" needs "Design", "Implementation" follows "Choice". The steps are repeated iteratively while the feedback loops allow re-considering and re-evaluating the reality and changes in the problem domain until a final choice has been implemented and lessons learned have been communicated [Gupt.2006].

2.4. Techniques for Intelligent Decision Making

A number of artificial and computational intelligence techniques and technologies have been used to design and develop intelligent decision support systems. These include but are not limited to the following; artificial neural network "ANN", evolutionary computing and genetic algorithms, fuzzy systems, case-based reasoning and agent-based systems. While traditional artificial intelligence focuses mainly on high-cognition formalisms and reasoning about symbolic representations, computational intelligence focuses on low-level cognitive functions such as perception and control. In addition to using these intelligent techniques to solve real-world complex problems, more effective solutions can be obtained by combining two or more of these intelligent techniques in a hybrid paradigms which are more used to solve complex problems. Some of these hybrid paradigms are; fuzzy-neural, genetic-neural, fuzzy-genetic, neural-fuzzy-genetic, fuzzy case-based reasoning, evolutionary case-based reasoning model, agent-based systems, fuzzy agent-based systems and multi-agent case-based reasoning systems and so on. The main advantage of using hybrid system is trying to make use of the features of these combined systems by overcoming the shortcomings of each technique when used individually. Following is a brief overview of the different intelligent techniques.

2.4.1. Artificial Neural Networks

Regardless of considering artificial neural networks a branch of artificial intelligence or one of the main core disciplines of computational intelligence, artificial neural networks, originate from research in modeling the nervous system in a human brain.

Neural networks based on mathematical models are powerful data modeling tools that unlike traditional computing have a structure and operation that resembles that of a mammal brain. They are able to capture and represent complex input/output relationships. The original aim for the development of neural network technology was to understand and shape the functional characteristics and computational properties of the brain when performing cognitive processes such as sensorial perception, concept categorization, concept association and learning. Their main aim was to develop an artificial system that could perform "intelligent" tasks similar to those performed by the human brain and resemble it in following two ways:

1. A neural network acquires knowledge through learning.
2. A neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights.

The neural networks power and advantage lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics. Neural networks are also called connectionist systems, parallel distributed systems or adaptive systems, since they are comprised by a series of interconnected processing elements known as neurons that operate in parallel and are able to adapt themselves to data samples [Jain.2010] [Sord.2008] [44].

The ANN consist of nodes called neurodes or neuron and weighted connections corresponding to nerve synapses that transmit signals between the neurodes in a unidirectional manner. The ANN contains at least three layers, including the input layer (the data receiver), the output layer (communicating the result), and the hidden layer that process the incoming data and determines the results [Bern.2007].

According to [Sord.2008], the interconnected processing elements, called *neurons* process information as a response to external stimuli. The *artificial* neuron imitates the signal integration and threshold firing behavior of biological neurons by means of mathematical equations. The artificial neurons are bound together by connections that determine the flow of information between peer neurons. Stimuli are transmitted from one processing element to another via *synapses* or interconnections [Sord.2008].

"A neural network operates in two different modes: **learning and testing.** The learning stage is the process in which the network modifies the weights of each connection in order to respond to a presented input. At the testing stage, the network processes an input signal and produces an output. If the network has correctly learned , the outputs produced at this stage should be almost as good as the ones produced in the learning stage for similar inputs"[Sord.2008]. There are three main learning modes; **supervised learning, unsupervised learning** and the **reinforcement learning.**

Supervised Networks: receive and use both the input data samples and the target desired output data samples for learning. The target data sample act as supervisory signals to correct the network predictions during the training cycle. After each trial the network compares the actual output with the desired output and corrects any difference by adjusting all the weights until getting almost the desired output or the network cannot improve its performance anymore. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown. Pattern classification is one of the typical tasks of this learning mode. The multi-layer perceptron network and the radial basis function network are of the most popular supervised networks [Jain.2010] [Sord.2008].

Unsupervised Networks: receive and use only the input data samples without any supervisory signals for learning. The network organizes itself internally with each processing element responding to a particular stimulus or a group of similar stimuli. The set of inputs forms clusters in the input space. Each of the clusters represents a set of elements of the real world with some common features. The self-organizing map and adaptive resonance theory models are among some popular unsupervised networks. Clustering, filtering and estimation are common tasks normally carried out by unsupervised learning [Jain.2010] [Sord.2008].

Reinforcement Learning: "At each point in time *t* the network receives an input signal and generates an output. The response produced by the network is evaluated by a cost function *ct*. The aim of this function is to minimize some measure of a long-term cumulative cost. Control problems, games and sequential learning are examples of applications using reinforcement learning. Once the network has reached the desired performance, the learning stage is over and the associated weights are frozen. The final state of the network is preserved and it can be used to classify new, previously unseen inputs" [Sord.2008]. the following figure represents the multilayer perception model (MLP)

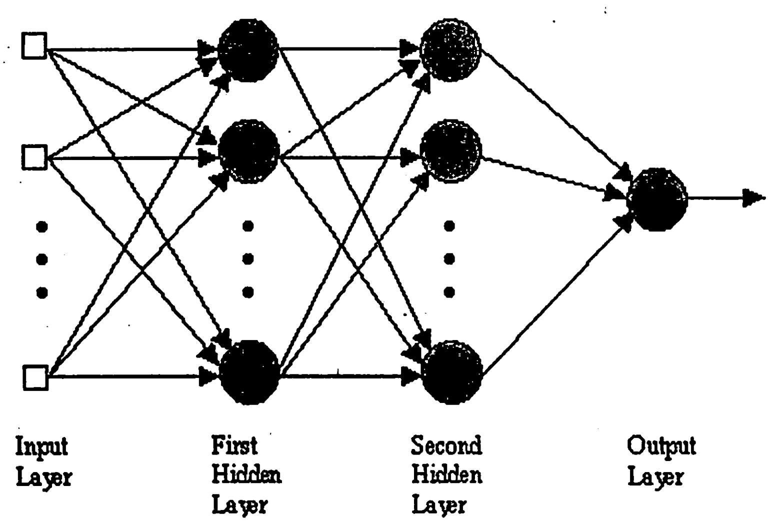

Figure 2-2 Graphical presentation of the MLP

Today, great efforts are focused on the development of neural networks for many applications such as pattern recognition and classification, data compression and optimization.

2.4.2. Evolutionary Computing

Evolutionary computing is a collective name for a range of problem solving techniques inspired by biological mechanisms of natural evolution referring to computer models that are useful for tackling optimization-based decision making tasks. Among these techniques, there are **five types of**

evolutionary computing models; evolutionary programming, evolutionary strategies, genetic programming, learning classifier systems, and genetic algorithms. They all share a common conceptual base of simulating the evolution of individual structures via processes of selection, mutation, and reproduction. The processes depend on the perceived performance of the individual structures as defined by an environment.

Evolutionary Programming "EP": introduced by Fogel, Owens and Walsh, simulates intelligent behavior by means of finite-state machines. Candidate solutions to a problem are considered as a population of finite-state machines, its main variation operator is mutation. New solutions (offspring) are generated by mutating the candidate solutions (parents). All candidate solutions are assessed by a fitness function [Jain.2010].

Evolutionary Strategies "ES": optimization technique based on ideas of adaptation and evolution. It was first developed to optimize parameters for aero-technology devices. It is based on the concept of the evolution of evolution. Each candidate solution is formed by genetic building blocks and a set of strategy parameters models the behavior of the candidate solution in its environment. The genetic building blocks and strategy parameters participate in the evolution. The strategy parameters that are adapted from evolution are governing the evolution of the genetic characteristics [Jain.2010].

Both EP and ES use representation to the problem domain and mutation as their main operator [Sord.2008].

Genetic Programming "GP": devised by Koza aims to make computers solve problems without being explicitly programmed to do so and without requiring the user to know or specify the form or structure of the solution in advance. It is a specialization of genetic algorithms (GA) where each individual is a computer program; executable program (i.e. trees). Genetic operators are applied to generate new individuals. It is a machine learning technique used to optimize a population of computer programs according to a fitness landscape determined by a program's ability to perform a given computational task [Jain.2010] [39].

Learning Classifier System "LCS": uses an evolutionary rule discovery module to tackle machine learning tasks. Knowledge is encoded using a collection of production rules. Each production rule is considered as a classifier. The rules are updated according to some specific evolutionary procedure" [Jain.2010].

Genetic Algorithms "GA": developed by John Holland, are the most popular and widely used evolutionary computing models. They are stochastic search methods that operate over a population of possible solutions. They solve problems by selecting the fittest in millions of generations and designed to apply the most fitting process to generate the best solution of a problem. They are mainly used for optimization, machine learning, and intelligent search, in many divert fields as medicine, engineering, economics and business. As an example, it is used by investment brokers to create the best possible combination of investment opportunities for their clients [Jain.2010][Sord.2008][Mone.2005].

The following figure summarizes the steps involved in a typical genetic algorithm, which is a class of population-based search strategies that utilize an iterative approach to perform a global search on the solution space of a given problem [Jain.2010].

1. Let the current generation, k=0.
2. Generate an initial population of individuals.
3. Repeat
    (a) Evaluate the fitness of each individual in the population.
    (b) Select parents from the population according to their fitness values.
    (c) Apply crossover to the selected parents.
    (d) Apply mutation to the new individuals from (c).
    (e) Replace parents by the offspring.
    (f) Increase k by 1.
4. Until the terminating criterion is satisfied.

Figure 2-3 A typical genetic algorithm [Jain.2010]

Note that genetic algorithms use recombination as their primary operator, and mutation as a secondary operator.

2.4.3. Fuzzy Logic

Fuzzy logic was first introduced by Zadeh in 1965. It deals with human reasoning, the process of making inference and deriving decisions based on human linguistic variables in the real world. It is a form of multi-valued logic derived from the fuzzy set theory which works with uncertain and imprecise data and/or information. Fuzzy refers to the fact that the logic involved can deal with fuzzy concepts—concepts that cannot be expressed as "true" or "false" but rather as "partially true". Although genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans. The input variables in a fuzzy control system are in general mapped into by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification". Such "fuzziness" feature occurs in many real-world situations, when it is complicated to decide if something can be categorized exactly into a specific class or not. There are two main useful features contained in fuzzy systems relying on the **fuzzy set theory and fuzzy logic**, i.e. they are used for uncertain or approximate reasoning, for systems for which a mathematical model is difficult to derive; and they also allow decision to be inferred using incomplete or uncertain information with easily comprehensible human linguistic variables. The following figure shows a typical fuzzy inference system containing three procedures, i.e., **fuzzification, reasoning or inference, and defuzzification** [Jain.2010] [38].

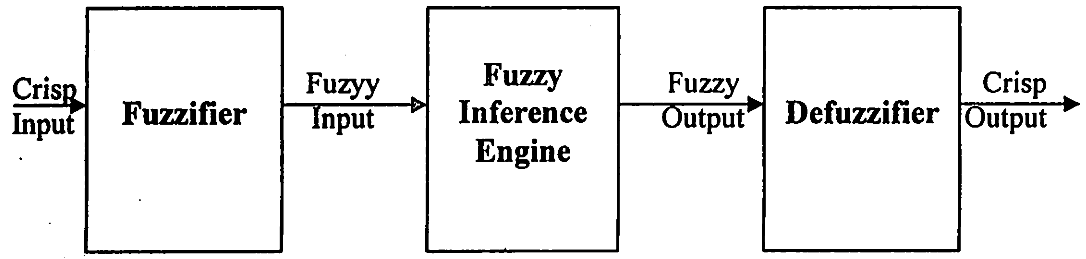

Figure 2-4 Atypical fuzzy inference system [Jain.2010]

2.4.4. Case Based Reasoning

Case based reasoning "CBR" is a branch of artificial intelligence founded on psychological theory of human reasoning where humans often solve a new problem by comparing it with similar ones that they had already resolved in the past [Jain:2010]. It can be utilized as a decision support approach, in which old experience is used to understand and solve new problems. That means adapting old solutions to meet new demands; using old cases to explain new situations or critique new solutions by reasoning from the past to interpret a new situation (like lawyers). The following figure shows a typical CBR cycle including four basic procedures; i.e. **Retrieval, Reuse,** and **Case Revise,** and **Retain** [37].

Retrieve: Given a target problem, retrieve cases from memory that are relevant to solving it. A case consists of a problem, its solution, and, typically, annotations about how the solution was derived.

Reuse: Map the solution from the previous case to the target problem. This may involve adapting the solution as needed to fit the new situation.

Revise: Having mapped the previous solution to the target situation, test the new solution in the real world (or a simulation) and, if necessary, revise.

Retain: After the solution has been successfully adapted to the target problem, store the resulting experience as a new case in memory [37].

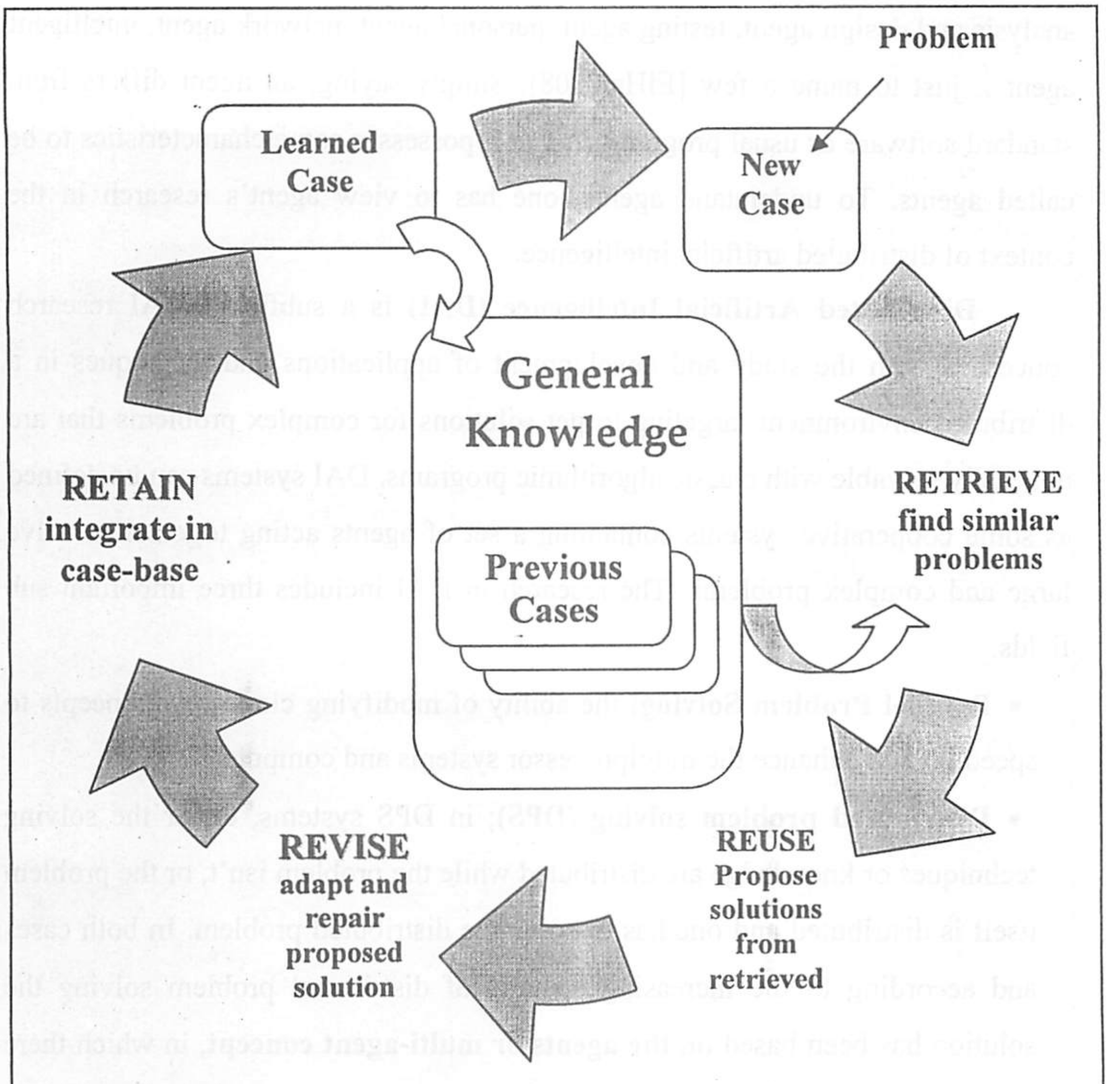

Figure 2-5 A case based reasoning cycle [Jain.2010] [37] [Mone.2005]

2.4.5. Agents, Intelligent Agents & Multi-Agent Systems

It's not easy to define the term "Agent" which ranges from a simple definition to a lengthy and demanding one. The difficulty to define agents, rises as agent researchers doesn't own this term like fuzzy logicians/AI researchers own the term fuzzy. Everyday one hears the word "Agent" as in travel agent, housing agent…etc. From one side agents appear in many aspects; robots are agents that inhabit the physical world, soft-bots are those inhabiting computer networks; task-bots are agents that prefer tasks…etc. From the other side they have plenty of roles they can play, which could be observed by the preceding adjectives to the word agent, like search agent, report agent, navigation agent, management agent, analysis and design agent, testing agent, personal agent, network agent, intelligent agent …just to name a few [ElHa.2008]. Simply saying, an agent differs from standard software or usual programs in that it possesses some characteristics to be called agents. To understand agents, one has to view agent's research in the context of distributed artificial intelligence.

Distributed Artificial Intelligence (DAI) is a subfield of AI research concerned with the study and development of applications and techniques in a distributed environment targeting to get solutions for complex problems that are not easily solvable with classic algorithmic programs. DAI systems can be defined as some cooperative systems containing a set of agents acting together to solve large and complex problems. The research in DAI includes three important sub fields:

- **Parallel Problem Solving**; the ability of modifying classic AI concepts to speed up and enhance the multiprocessor systems and computers.
- **Distributed problem solving (DPS)**; in DPS systems, either the solving techniques or knowledge are distributed while the problem isn't, or the problem itself is distributed and one has to solve the distributed problem. In both cases and according to the increasing demand of distributed problem solving the solution has been based on **the agents or multi-agent concept**, in which there are autonomous entities that communicate and cooperate to solve the complex problems [Mone.2005] [36].
- **Agents and Multi-agent systems**; MAS are formed from a collection of independent software entities (software agents) whose collective skills can be applied in complex and real-time domains. It is much easier to solve and manage a larger problem by getting different solutions provided through separate modules that are able to cooperate and exchange information. The agent-based approach in system development considers the autonomous agents as main components that will be integrated into a coherent and consistent system in which they work together to meet the application needs for a better performance [Luck.2003][36].

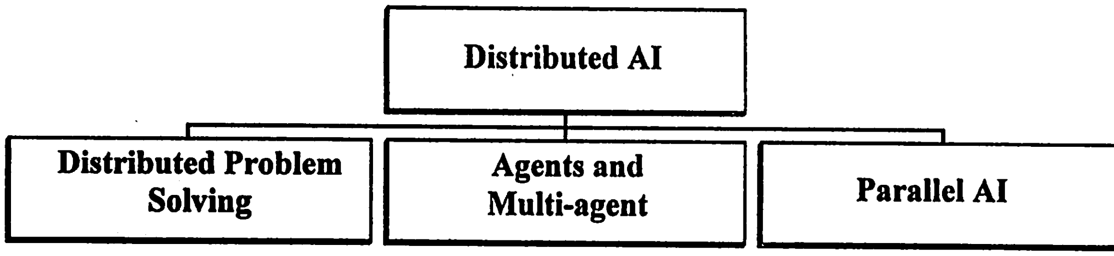

Figure 2-6 context of agent research [Brad.1997]

Thus there are different and various agent types and definitions as follows; The American Heritage Dictionary defines an agent as **"one that act or has the power or authority to act... or represent another"**. Wooldridge and Jennings define an agent as **"a hardware or (more usually) software-based computer system that enjoys some main properties of autonomy, social ability, reactivity and pro-activeness"** [Fran.1996] [Petr.2007].

Similar to the term "Agent", the "Intelligent Agent" assists people and acts on their behalf and works by allowing people to assign their work that they could have done, to the intelligent agent. It uses agent communication protocols to exchange information for automatic problem solving and might have services capabilities, autonomous decisions, and commitments features. Moreover "Intelligent Agents" have some other criteria that makes it more personalizable; cooperation, negotiation and conflict resolution. Hayes-Roth in 1995 defined **"Intelligent Agents"** as follows; **"Intelligent agents continuously perform three functions: perception of dynamic conditions in the environment; action to affect conditions in the environment; and reasoning to interpret perceptions, solve problems, draw inferences, and determine actions"**. She insists that agents reason during the process of action selection and that the agent architecture does allow for reflex actions as well as planned actions [Fran.1996]. While Russell and Norvig assumed that **"an intelligent agent is one that is able of perceiving its environment through sensors and acting upon it through effectors or actuators"**. It's similar to a human agent, which senses its environment through eyes, ears and other organs as sensors and acting upon it through hands, legs, mouth and other body parts as effectors. And also like a robotic agent which substitutes cameras for sensors and motors for effectors or software agents, in which the encoded bits strings are percepts as well as actions [Russ.1995]. Thus intelligent agents are entities that are fixable to changing environments and changing goals. They learn from experience and make appropriate choices given perceptual limitations and finite computation [Jain.2010].Hence it is not an easy task to define what an agent or intelligent agent is, as no universally unique acknowledged definition of an agent is available but an agent can be considered as an umbrella term or meta term for a heterogeneous body of research and development, which covers a range of other more specific and different agent types [Fran.1996] [Weis.1999] [Sugu.2002].

Sycara defined the "**Multi-Agent Systems" (MAS) as "a loosely coupled network of problem solvers that interact to solve problems that are beyond the individual capabilities or knowledge of each problem solver** (Durfee and Lesser 1989). **These problem solvers, often called agents, are autonomous and can be heterogeneous in nature**" [Syca.1998]. Another similar definition is the following; "**A Multi-Agent System (MAS) is a system composed of a population of autonomous agents, which cooperate with each other to reach common objectives, while simultaneously each agent pursues individual objectives**" [Wool.2002].

For MAS to solve common problems coherently, coordination, communication and negotiation are central to them, which help to prevent chaos and allow that, the interdependencies within real problems involving distributed open systems will be properly managed. No agents possesses a global view of the entire agency to which it belongs, they have only their local views, goals and knowledge that may interfere with rather than support other agent actions [ElHa.2008].

2.4.5.1. Agents Characteristics and Properties

Intelligent agents should operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state; this independence from human control can simply be called "**Autonomy**". Franklin and Grasser defined it as follows: ***an autonomous agent is a system situated within and part of an environment that senses that environment, and acts on it, over time, in pursuit over its own agenda and so as to affect what it senses in the future.*** Agents do not have to be intelligent but one of the main characteristics of them is "Autonomy". What really counts is the degree of autonomy that agents have to exhibit, that determine their usefulness to many user. Russell and Norvig argued that, if the agent's actions are based completely on built-in knowledge, such that it need pay no attention to its percepts, then one can say that the agent lacks autonomy. An agent behavior could be based on its own experience and its built-in knowledge used in constructing the agent for a particular environment. Hence, one can say that, ***an agent is autonomous to the extent that its behavior is determined by its own experience*** [Russ.1995]. Like mentioned before, an autonomous agent acts in a flexible way perceived by the degree of Reactivity, Pro-activeness and Social Ability [Fran.1996] [Sugu.2002].

Reactivity and Responsiveness: intelligent agents are able to perceive their environment, and respond in a timely fashion manner to changes that occur in it, in order to satisfy their design objectives. The agents perceive the environment - which could be the physical world, a user via a user graphical interface, a collection of other agents, the Internet, or perhaps all of these combined- in different ways. At the same time agents take in consideration the varying environment and the changeable user needs [Weis.1999] [Sugu.2002].

Pro-activeness: intelligent agents do not simply act in response to their environment, but they can take a proactive role and are able to exhibit goal-directed behavior by taking the initiative and making suggestions in order to satisfy their design objectives [Weis.1999] [Wool.2002] [Sugu.2002].

Social Ability: intelligent agents interact with other agents (and possibly humans) via some defined protocols and a kind of agent-communication language to obtain their goals, satisfy their design objectives and solve problems. A very important aspect of social ability is the negotiation and communication between the different parties whatever they are. This kind of social ability is much more complex and less well understood than exchanging binary information [Weis.1999] [Wool.2002] [Sugu.2002].

Concluding, agents, muti-agents or intelligent agents, they all possess a variety of features and properties including autonomy, goal orientation, reactivity, interactivity, mobility and social ability. Agent-based systems are empowered by their intelligence and ability to communicate and negotiate. These features shouldn't all gather in one agent at the time but they are acquired by various agents according to various problem solving demands. Following table shows some of the agent's characteristics.

Agent-Hood Attributes or Features	**Description**
Autonomy	Capability of an agent to follow its goals autonomously without interaction or commands from outside. It encapsulates some state and makes decision about what to do. It has control over its internal state and behaviour.
Reactivity(Responsive; sensing &acting)	Agents are able to respond in a timely fashion to changes that occur in their environment
Pro-activeness (Goal-oriented)	Agents are able to act in anticipation of future goals by taking the initiative. They should have a well-defined goal or even a complex goal system
Adaptability	The ability to successfully adapt to the environment makes an agent be adaptive to uncertainty and changes.
Learning	The ability to learn from previous and own experience makes an agent improve itself.
Mobility	Being able to migrate in a self-directed way from one host platform to another.
Interaction	Agents are situated in a particular dynamic environment; they receive inputs related to the state of their environment and they modify the environment through effectors.
Social ability	Agents are able to interoperate with humans, other agents, legacy systems, and information sources.
Co-operation	Agents cooperate together for the realization of common tasks. Co-operation indicates the summary of collaboration, coordination and negotiation
Collaboration	An agent relating to another agent, which participates at the same task.
Coordination	Coordination between agents in order to work on a common task. The indicator gives the average time effort for the coordination
Negotiation	Preparation and coordination of task solution between software agents.
Communication	An agent can use the communication capability to make contact with its environment and other agents. Agents are able to send and receive messages to each other in a MAS.
Mental Notations	Agents have to keep information about the environment, the internal state and the actions to perform (Beliefs). They can adopt a set of (Goals) and may employ plans to achieve their goals (Intentions).

Table 2-2 Agent properties [ElHa.2011]

When dealing with agents, many other areas can be investigated including agent classifications, types, architectures, environments, infrastructure, communication protocols, programming...etc.

2.4.5.2. Multi-Agent Systems Strength

Within a multi-agents system computation is asynchronous, data is decentralized, there is no system control and each separate agent has incomplete information or capabilities to solving the whole problem and therefore limited viewpoint. Actually this is the multi-agent strength which is presented by some abilities like to:

1. Solve problems that are to large or complex for a centralized agent.
2. Give a chance for the interconnection and interoperation of various legacy systems for example by building an agent wrapper around the software to enable it to interoperate with other systems.
3. Provide solutions to problems that are regarded as a society of autonomous interacting components-agents, in a way that each agent can be defined as a reflection of its user preferences and constraints.
4. Provide solutions for problems that make use of various different information sources that are spatially distributed; eg. Use it in sensor networks, information gathering, internet application ...
5. Provide solutions for problems that need exchange for distributed expertise, like concurrent engineering, healthcare, and manufacturing.
6. Enhancement of some factors and dimensions like:
    - Computational efficiency; using concurrency of computation by transmitting high level information rather than low level data through minimal communications.
    - Reliability; recovery of component failures through easy dynamically finding of agents with redundant capabilities.
    - Extensibility; no of capabilities and agents working on a problem can be easily extended or altered
    - Robustness; systems ability to tolerate uncertainty through exchanging information between agents.
    - Maintainability; multi-agent systems can be easier maintained because its modularity.

- Flexibility; the different agent abilities are organized adaptively to solve problems
- Reuse; in the sense that specific agents could be reused in different agent teams and application areas according to their functionality [Syca.1998] [Elha.2008].

2.5. Synergistic Approach

As mentioned before, each of the preceding technologies has advantages and disadvantages. For example, neural network is a robust approach for classification; however, its disadvantage lies in its need for large training dataset which is not always the case. The advantage of fuzzy logic is its usefulness for approximate reasoning; till now the membership function supporting fuzzy logic reasoning under uncertainty sometimes can produce inaccurate results. Although the strength of genetic algorithms is their robust performance in problems with complex fitness landscape in which genetic algorithms rely strongly on the fitness function as searching mechanism for optimal solution, it will be a problem, if it has a deceptive; ill-defined fitness function that misleads the whole search process away from finding the true optimum [Sord.2008].

Hence, integrating or coupling between these approaches will be a step towards more powerful and flexible tools relying on synergetic approaches, embracing the advantages and minimizes the limitations of each methodology alone. Theses synergism can be either loose or tight. Interaction in loosely coupled synergism is well-defined in time and space. Each tool works independently with minimum communications and preserves their own structure and modular identity. While, in tightly coupled synergism there is more interaction between modules, communication is through common internal structure and information is not exchanged but shared. Following are some examples of such synergism as presented in [Sord.2008].

Fuzzy Neural Networks "FNN": combine the learning and connectionist structure of Neural Networks with the human-like reasoning of Fuzzy Logic into a hybrid intelligent system. Its main advantage is the ability to accurately learn from noisy datasets with interpretable outputs [Sord.2008].

Genetic Evolving Neural Networks: "Neuro-GA synergism employs a GA for the optimization of the most important parameters of a Neural Network, namely, the internal structure and initial weights. By optimizing the configuration of nodes in a NN and its weights, training time is reduced while reducing the risk of getting trapped at local minima" [Sord.2008].

Fuzzy-GAs: Fuzzy Logic and GAs may synergistically interact in two ways: Fuzzy Logic can be used to improve the GA behavior by modeling the GA fitness function or reproduction operators; and GAs can be used for optimization of membership functions in Fuzzy classifiers [Sord.2008].

Neuro-Fuzzy-GAs : "Optimized learning of imprecise data: this summarizes a common synergy of GAs, NN and Fuzzy Logic. Its advantageous is that GA can be used for the optimization of the most important parameters of a Neural Network. After that the Neural Network is then trained with fuzzy membership distributions defined with Fuzzy Logic [Sord.2008].

Chapter Three

3. Artificial Intelligence and Computational Systems in the Clinical and Health Care Domain

Health care organizations are known and will for ever be one of many organizations that operate under pressure and resource constraints that seem to get tighter every year. The organizations in the health care environment are characterized by dealing with invaluable human lives where risks are extremely high, demanding constant need to continually improve their operational efficiency and at the same time decrease the overall operating cost without degradation of the delivered quality of health care [Meil.2010]. Moreover, by entering the second decade of the 21st century, the clinical and health care domain became more complex and sophisticated. It is driven by a flood of overwhelming medical data and information contained in the domain. More players inside and outside the healthcare domain are involved in every aspect of medical care [Jain.2010]. Advanced decision support systems are required to successfully navigate this turbulent environment. Healthcare is becoming worldwide, increasingly digital, and globalized, massive stockpiles of medical information are being collected. Technologies, such as cell phones, are making unexpected advances into disease control and prevention, telemedicine is increasingly becoming a reality and it is usual now for medical diagnosis and healthcare to acquire coordinated efforts of multiple units and team of experts. As a result, recent advances in artificial and computational intelligence have branched out promising to face and fulfill the escalating challenges and demands of the domain to obtain patients information, and assist physicians in making difficult clinical decisions. They are no longer concerned just with medical diagnosis, symbolic models of disease or clinical encounters, they now embrace medical education, telemedicine, data mining and a bunch of intelligent systems allover the domain. Intelligent systems are actually reshaping medicine, medical practice and computers are doing more than storing, retrieving, organizing and analyzing information [Brah.2010]. They process such vast data to extract and produce new meaningful knowledge, implementing robust computer applications to foster healthcare safety, quality and efficiency, bringing top medical care into regions formerly lacking any care, enabling medical practitioners visualizing, inventing, and performing new procedures [Bahr.2010]. Simply saying they are making "Intelligence". The chapter presents and reviews some examples and applications of intelligent systems and technologies used in specific areas of clinical and healthcare domain [Jain.2010] [Brah.2010] [Sord.2008].

3.1. Intelligent Medical and Clinical Decision Making

As mentioned before, advances in artificial and computational intelligence have improved the medical decision process by providing presentation of the uncertain and imprecise knowledge contained by the domain.

- **Artificial Neural Network** imitates the biological information processing mechanism on a certain level and integrates the learning ability during decision making.
- **Fuzzy Systems** enable computer programming to achieve the human reasoning system in a certain way.
- **Evolutionary Computing** is based on a collection of algorithms inspired by the evolution of population towards a solution of a certain problem. Where the genetic algorithms, are a main part of evolutionary computing used in tasks of optimization, automatic generation of artificial neural networks, pattern recognition and classification.
- **Multi-Agent Systems** designed and developed to act autonomously on behalf of the user in a social, proactive and collaborative way [Ande.2009]

3.1.1. Types of Intelligent Clinical Decision Support Systems

Usually clinical decision support systems are assumed to be computer systems designed to support clinicians during making decisions and by that improving the patient outcome as well as the cost of care. There are many categorization schemes, of the clinician decision support system; one of them is to categorize the CDSS to knowledge-based systems, or non-knowledge-based systems [Bern.2007].

3.1.1.1. Knowledge-Based Clinician Decision Support Systems

More than 50 years ago, clinician decision support systems arose with the early expert systems research. Its main objective was to build a computer program simulating the human's ability of thinking, reasoning, solving problems and making decisions. Medicine and diagnostic was the main domain of applications. They concentrated mainly on the logical rather than the computational part of the DSS functions. One of the best-known early expert systems was Mycin, which was developed to help doctors in antimicrobial drugs to prescribe such drugs for blood infections; it was a program advising physicians on treating bacterial infections of the blood and meningitis. In fact, Medical expert systems have been developed to motive and reason with patient's data to come up with reasonable conclusions. They were applied in various areas of medical domains like diagnosis assistance, agents for information retrieval, expert laboratory information systems and generating alerts and reminders…etc. [Qays.2010].

As the demands of the domain became grown, the target wasn't just to simulate the expert's decision making and giving final answers any more. The researchers and developers started to adapt early DSS to support real-life patient problems by providing information to the user, who filter, discard or use the information in the best context. The user transferred from a passive to an active recipient during decision making process and systems became more explanatory and interactive. These improved systems were developed to assist in a variety of decisions like; supporting laboratory test ordering, providing a suggested list of potential diagnosis, providing support of medication orders. The systems output usually came in a form of alerts, recommendations, e-mails or wireless notifications.

The knowledge-based decision support systems contains of three main parts;

- **Knowledge Base**: consisting compiled information usually in the form of if-then rules, while other knowledge bases might include probabilistic associations of signs and symptoms with diagnosis, or known drug-drug or drug-food interactions.

- **Inference Engine**: also called the reasoning mechanism contains the formulas for combining the rules or associations in the knowledge base with actual patient data.
- **Communication Techniques**: allowing the data exchange from and into the system and providing the interaction with the user to make the final decision.

Electronic medical records "EMR" support very much the clinician diagnostic decision support system as they provide the system with the electronic patient record. The system start with the patient's signs, symptoms or even blood test results entered directly or by the EMR, which will be mapped by the inference engine with the knowledge contained in the knowledge base to result in a list of suggested diagnosis and treatment options handed to the clinicians to reconsider [Bern.2007].

3.1.1.2. Non-Knowledge-Based Clinician Decision Support Systems

Unlike classical knowledge-based decision support systems, some of the non-knowledge-based systems in the clinical domain allow computers to learn from past experience, recognize patterns and present uncertain knowledge.

One example of these systems is the **artificial neural network** and the **fuzzy systems**. Although the structure of the ANN is to some extend similar to that of the knowledge-based DSS but it varies in the contents. While the knowledge-based DSS contain a knowledge base filled with medical literature and expert's knowledge, the ANN analyzes the patterns in the patient data, to derive the associations between the patient's signs and symptoms and a diagnosis. As mentioned before, these systems could learn from examples when supplied with known results for a large amount of data. The system analyzes the information, make guesses for the output, compare it to the given result, find patterns matching the input to the correct output, and adjust the weights of the connections between the neurodes accordingly to produce the correct result. The whole process is called training the artificial network. From one side, the main advantage of using the ANN stems from eliminating the classical if-then rules entered by the expert. ANN can process incomplete data by inferring what the data should be and improving it every time due to its dynamic nature. It also doesn't need a large database but instead it needs more training. On the other side its main disadvantage is that the training process could be time consuming and it follows a statistical pattern of recognition to derive formulas for weighting and combining data which are usually not easily interpretable resulting in a non-reliable unjustified output. Despite all the concerns, ANN have been applied many times in the healthcare domain like will be presented.

Another example of the non-knowledge-based CDSS is the **genetic algorithm**, which were based on the evolutionary theories by Darwin that dealt with natural selection and survival of the fittest. Without any domain-specific knowledge, components of random sets of solutions to a problem are evaluated, the best one are kept and recombined and mutated to form the next possible solutions to be evaluated, and continue until the proper solution is discovered. The fitness function is used to determine which solutions are the best and which should be eliminated. ANN like GA works in that they derive their knowledge from patient data rather than rules. In the next section there are some examples of intelligent medical and clinical application in healthcare that proved to be a helpful aid in clinical decision making [Bern.2007].

3.1.2. Intelligent Medical and Clinical Diagnosis Decision Support Systems

One of the most important issues nowadays is the medical and clinical diagnosis, which is the core of medical problems recently. This diagnostic approach is defined as a process of identifying a medical state or disease by its symptoms, signs, and from the results of different diagnostic procedures. Despite this definition, the diagnostic practitioners are challenged with several difficulties during this approach. Uncertainty is often an important factor in medical diagnosis. Sometimes patients gets symptoms that indicate a number of illnesses because the overlap among diverse areas of disease. Other times there is no illness at all or maybe the patient has a mixture of diseases. Uncertainty is a core element of modern medicine where diagnosis is the classification of medical knowledge in disease categories. Therefore many computerized medical diagnosis decision systems are proposed in the medical domain. Various techniques in different applications have been used like; Bayes probability expected risk, optimal decision with the total risk, decision theory, swarm technologies, multi-agent systems and others. All these improve the accessibility of knowledge of patient symptoms resulting in quality improvement of the diagnosis process, increase of efficiency and the cost reduction [Qays.2010]. Clinical decision support systems are based mainly on expert systems as a decision support tool. They can be used in many forms; electronically medical textbook, expert consultant program, intermediate level spreadsheets for combination and exploration of simple diagnostic concepts, while they can also be available as an application in the world wide web [Qays.2010]. Many clinical decision support systems like Mycin, PUFF, DXplain have suffered some problems related to expert systems regarding the difficulties to solve complexities of the medical decisions as medical diagnosis needs more requirements like; increased autonomy, pro-activity, capability of communication and cooperation with other systems. Afterwards, expert system agents arise to cover the diagnosis needs by integrating agents in these systems to make use of their properties and characteristics of autonomy, social-ability, reactivity, learning, pro-activity and adaptability [Qays.2010]. Many multi-agent systems and agent-based systems have been used as a helping tool in the medical and diagnosis decision support systems. Not only expert systems and agents have been used for diagnosis and prognosis but also neural networks, fuzzy logic, evolutionary computing like mentioned before [Qays.2010]. According to [Sord.2008], many neural networks have been developed for clinical diagnosis. Neural networks have been used for assisted screening of Pap (cervical) smears, prediction of metastases in breast cancer patients, breast cancer diagnosis. Similarly, neural networks have been used for prognosis and assessment of the extent of hepatectomy of patients with hepatocellular carcinoma and prognosis of coronary artery disease [Sord.2008].

3.2. Classification of Intelligent and Computational Decision Support Systems in the Health Care Domain

One can perceive and categorize IDSS in the health care domain according to many aspects, e.g. intelligent techniques used, intelligent features and characteristics utilized, complexity degree or even the application level; personal, organizational or national. The following table will highlight some examples of intelligent decision support systems categorized according to the application levels and areas.

Personal (individual) level; patient, doctor, nurse...	Organizational level; hospital, medical centers, medical providers, pharmacy...	National level; governmental, institutional
Intelligent Diagnosis Systems; expert systems, expert system agents, multi-agents, Neural networks, fuzzy logic...	**Intelligent Hospital;** resource management (nurses, doctors, rooms, beds, drugs...), intelligent operation theaters...	Intelligent Tissue and Organ Transplantation Management
Intelligent Monitoring Systems; patient monitoring, emergency medical services, surgical intensive care units...	**Intelligent Pharmaceutical Systems;** drugs development, drugs mixture, drugs management	Intelligent National Electronic Patient Record
Intelligent Tele-care; community care, home care; elder care...	**Intelligent Medical Educational Systems;** telemedicine, electronic libraries, electronic databases (for doctors, patients, students...)	Intelligent Tracing Systems for Chronic Diseases
Intelligent Image Interpretation; medical image interpretation (x-rays, MRI, mammograms)...	**Intelligent Clinical Decision Support Systems;** workflows, time management and scheduling...	Intelligent Resource Management; vaccination, drugs, medical equipments(incubators, ...)

Table 3-1 Intelligent DSS Application Levels and Areas

3.3. Examples of Intelligent Systems in Various Areas and Applications of the Healthcare Domain

Artificial and computational intelligence and computers have been seamlessly integrated in all realms of our daily lives and rose to the essential challenges of the healthcare domain. While computational intelligence comprises computational models and theories inspired from neuro-cognitive and biological functions focusing on low-level cognitive processes such as perception and control, traditional artificial intelligence focuses mainly on high-cognition formalisms and reasoning about symbolic representation [Sord.2008]. Following are some application areas and examples of intelligent decision support system in the healthcare domain.

3.3.1. Signal and Image Analysis and Interpretation

Identifying specific characteristics in medical imagery is a type of image processing problem. Artificial Neural Networks are useful for pattern recognition and also popular as classification mechanisms in medical decision support systems, they can be used to solve image processing problems and can apply what they have learned to new cases. Examples of image processing in medicine include the detection of characteristics in ultrasound and x-ray features. For example, image data from studies of mammograms can be used for the detection of breast cancer. One of the many studies found that neural networks provide a useful tool to aid radiologists in the mammography decision making task. In clinical cases, the performance of a neural network in features extracted of lesions from mammograms by radiologist was found to be higher in distinguishing between benign and malignant lesions than average performance of radiologist alone, without the aid of a neural network [43]. Following are some examples of the various intelligent techniques used in different signal and image analysis like presented by M. Sordo et al in [Sord.2008]:

- A back propagation neural network performing image processing operations; filtering and segmentation of brain magnetic resonance image(MRIs)
- A cellular neural network to improve resolution in brain tomography and in global frequency correction for detecting calcifications in mammograms
- A self-organizing network multilayer adaptive resonance architecture for the segmentation of CT images of the heart and another two layer NN for segmentation of the abdomen
- Development of neural network-based method for the classification of heart sound and a hybrid network trained by genetic algorithms for the classification of electrocardiogram "ECG" beats

- NN were successfully applied to enhance low-level segmentation of eye images diagnosing Grave's ophthalmopathy as well as segmentation of ultrasound images
- ...etc [Sord.2008].

Fuzzy logic applications have been used also in signal processing ranging monitoring and control of electrical and chemical responses of nerve fibers, analysis of eye movements to clinical monitoring of disease progression and radiation therapy.

- Fuzzy image enhancing techniques used to improve the radiographic images
- A fuzzy two-dimensional image restoration tool developed for diagnostic and treatment planning

A combination of neural network and adaptive fuzzy logic has been used for image restoration for quantitative imaging for planar and tomographic imaging [Sord.2008].

Multi-agent systems could also be used for image interpretation like the medical image interpreter of medical images (x-rays or MRI) that is used in behalf of the user to ask and integrate opinions from different radiologist agents about certain images [ElHa.2008].

3.3.2. Drug Development

Drug, one should understand the drugs mechanism of action from its pattern activity against a disease. Some researchers developed a Neural Network to predict the mechanism of action of an anti cancer drug while others used genetic programming, decision trees and neural networks to predict behavior of virtual chemicals for the inhibition of a P450 enzyme. M. Sordo et al reported another study developing a knowledge-oriented approach to deploy biochemical information for drug discovery [Sord.2008].

3.3.3. Disease Treatment

According to [Sord.2008], disease treatment is mainly a two-fold task; Treatment is targeted at the offending agent, and at the same time directed at restoring the normal physiological state of an individual affected by a disease. Some researchers applied evolutionary approaches to chemotherapy scheduling and cancer treatment, and in the emergency rooms. While others developed fuzzy rule systems for validation and interpretation of genotypic HIV-1 drug resistance based on virological outcomes. Sordo et al developed a state-based model for management of type II diabetes. Additional fuzzy finite state machine model have been developed for treatment regimens, where genetic-algorithm-based optimizer regimen selection were used for HIV/AIDS treatment [Sord.2008].

3.3.4. Community Care and Patient Monitoring

Community care includes coordinating all the activities that have to be performed to provide an efficient health care to the citizens of a community (like older, diabetics or disabled citizens). The agents will be able to provide information and care monitoring to these citizens similarly as in the care management system for elder people, in which each person has its agent, which is responsible for receiving medical data, giving reminders to the person, and alerting the medical center if needed [More.2003].

Another example of patient monitoring is extracted from [Sord.2008] including several fuzzy logic application in the field of anesthesia in which the patient vital signs are monitored controlling the drug infusion to maintain the anesthetic level constant. Such applications include but are not limited to depth of anesthesia, muscle relaxation, hypertension during anesthesia, arterial pressure control, mechanical ventilation during anesthesia and post-operative control of blood pressure. [Sord.2008].

3.3.5. Telemedicine

The researchers of telemedicine developed application of clinical medicine where medical information is transferred via telephone, the Internet or other networks for the purpose of consulting, and sometimes remote medical procedures or examinations. Telemedicine ranges from simple applications as discussing a case over telephone to very complex ones like using satellite technology and video-conferencing equipment to conduct a real-time consultation between medical specialists in two different countries. Telemedicine makes use of modern communication tools and information technologies for the delivery of clinical care and to enable a physician to collect and analyze information obtained from experts worldwide with the help of a decision support medical system communications and information technologies.

Chapter Four

4. Intelligent Human Organ Transplantation Management System: The case of "Egypt"

Every minute people are born and others die. Life and death are the most natural phenomena in our lives. The problem arises when the society or the responsible organizations feel they could have done better or they didn't do their best to save a person's life.

A lot of studies and reports announce that underdeveloped countries and communities are suffering from high birth rates leading up to overpopulation and all associated needs. These needs result in a variety of challenges and problems on different levels and with respect to various dimensions. In Egypt we are estimated to double by the year 2050, i.e. reach a whopping 160 million. Health care is one of the government's major concerns; it has been on the spot recently for improvement, enhancement and development. The health care domain is facing many problems and challenges which require efficient planning, intelligent decision making, management and problem solving techniques.

One of the most pressing issues in the Egyptian healthcare domain is the horribly growing number of liver and kidney patients who are in urgent need of organ transplantation surgeries to save their lives. Recently, and according to the minister of health and population they estimated the liver patients to be around 10 millions, from which one million at least need a new liver through an organ transplantation surgery. As well as a number not to be underestimated of patients who are in need of other organs such as heart or pancreas.

This, lead the Egyptian government to finally take their decision to allow the organ transplantation surgeries by issuing the "Human Organ Transplantation", HOT, Management law after fourteen years of debate, due to the importance of the organ transplantation which stems from the fact that it clearly draws the thin line between life and death. Shortage of such organs raises the mortality and morbidity rates and may as well lead to physical and social complications. They were motivated by the success of organ transplants and the newly developed surgery techniques and medical treatment world wide. One human donor can save one patient, while one human brain-dead donor can save up to eight lives. Moreover this issue has been discussed and argued thoroughly from the religious aspect and been provided by the verse of the Holy Quran "And whoever saves one- it is as if he saved mankind entirely" Holy Quran – 5: 32. [1]

Therefore the Egyptian government has assigned a higher committee of human organ transplantation, which will be in charge for management of the whole human organ transplantation processes all over Egypt. This committee will have a certain organizational structure and certain authorities during the various processes. Before presenting the committee's roles, structure relations within the Human Organ Transplantation Management System "HOTMS", the next section will present briefly the organ transplantation definitions, processes and challenges.

4.1. General Reasons for the Success of the Human Organ Transplantation Management System

Worldwide, many countries allowed the Human Organ Transplantation processes believing of its importance in saving human lives. They were motivated by two main reasons of success as follows:

1. The success of organ transplants in itself by the newly and most advanced developed surgery techniques and medical treatment
2. The establishment of many organizational and managerial frameworks, structures and laws on different levels- local, regional, national or international - that manage and regulate the human organ transplantation phases and processes in a highly advanced fashion to enable an effective and efficient HOTM system.

4.2. Human Organ Transplantation Management "HOTM"

According to[42], one can generally define **Organ Transplant** as **"a surgical operation in which a failing or damaged organ in the human body**

[1] و"ومن أحياها فكأنما أحيا الناس جميعا". سورة المائدة: أية 32

(Recipient) is removed and replaced with a functioning one. The donated organ may be from a deceased donor/ human dead-brain donor, a living donor or an animal. In some cases an artificial organ is used". Whereas the word human before organ transplantation denotes that the process is just from and to human beings. Organs that can be transplanted are the heart, kidneys, liver, lungs, pancreas, intestine, and thymus. Tissues include bones, tendons (both referred to as musculoskeletal grafts), cornea, skin, heart valves, and veins. Worldwide, the kidneys are the most commonly transplanted organs, followed closely by the liver and then the heart. The cornea and musculoskeletal grafts are the most commonly transplanted tissues [40]. The first human organ transplants were performed in the early 1960s, when it became possible to use special tissue-matching techniques and immunosuppressive drugs that reduced the chance that a transplanted organ would be rejected by the host body. By the early 1980s, the new immunosuppressive drug cyclosporine led to great advances in the success rate of organ transplants [41].

While organ donation, is defined as "the process of removal and transplantation of viable organs from donor to recipient". Recipients have to be matched with the donor organ in order to reduce the recipient's rejection of the new organ. For more definitions of the World Health Organization, see Appendix

4.2.1. HOTM Phases and Processes

Recently organ transplantation has risen to a great importance, as it is now seen as a valid way to treat disease and no longer the last option therapy [Fuzz.2005].The human organ transplant coordination and management is quite a complex process that involves many different organizations, persons, norms and laws. It requires administrative as well as clinical process management. High level of knowledge management, planning/scheduling, coordination and monitoring is also required. The stressing time constraint is a very important aspect due to the nature of the problem. Distinction has to be done between transplants of tissues and transplants of organs. The main difference is that the tissue could be frozen and stored in tissue banks while the donated organs degrade very quickly (heart stays useable for no more than four hours outside the body, six hours for lungs, sixteen-twenty four for liver, kidney lasts up to 36)[Fuzz.2005].

Generally, one can count some of the administrative and medical main organ transplantation processes as follows:

- Detection of potential organ donor
- Clinical examination of the organ donor
- Brain-death confirmation
- Maintenance and handling of the organ donor
- Legal brain-death confirmation
- Arrangement of organizational factors
- Securing legal authorization
- Organization of the organ extraction and transplant
- Clinical examination of the evolution of the receiver [More.2003]

The organ transplantation contains two main phases like shown in the next figure;

1. **The Procurement Phase**: which is more administrative, managerial and more about finding the most appropriate recipient and organizing logistic solutions.
2. **The Surgery Phase**: comes later including pure medical issues; surgical operations, anti-rejection treatments, medicine and drugs…

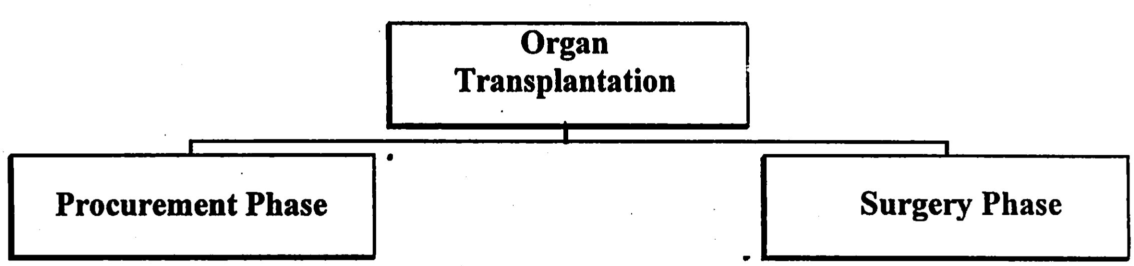

Figure 4-1 Main organ transplantation phases

In the research, the researcher will mainly concentrate on the administrative and managerial procurement phase. From the WHO's definition of the **Procurement Phase,** it is the process that includes donor identification, evaluation, obtaining consent for donation, donor maintenance and retrieval of cells, tissues or organs. This phase includes mainly three sub-processes containing different activities like follows;

- **Matchmaking Process**: the patients distributed all over the country should be registered in the waiting list and their key information should be revealed at the organ transplant hospitals. At the presence of an organ, the human medical experts analyze the potential recipients and the most appropriate patient will be decided according to all the affecting factors and parameters; medical, logistic and ethical.

- **Transport Routes Planning Process**: once the most suitable recipient has been chosen, the organ should be transported from the donor's hospital to the recipient's hospital. It's necessary to arrange the transportation facility; certain emergency vehicle, train, airplane...and it's important to decide the shortest and easiest route and estimate the time of transportation. According to different laws there could be more regulations like the case of Switzerland, in which a team from the recipient's hospital should attend the explanting operation of the organ before implanting it at the recipient's hospital, which needs arrangement for transporting the medical team too.
- **Medical Team Scheduling Process**: after deciding the most suitable recipient, the organ must be explanted from the donor and implanted in the recipient. All the necessary elements for performing the operations must be ready when the organ arrives so that the operation can be done as soon as possible. The operation theatres should be reserved and prepared, medical personnel should be recalled and all the medical drugs or equipments should be at the theatre.

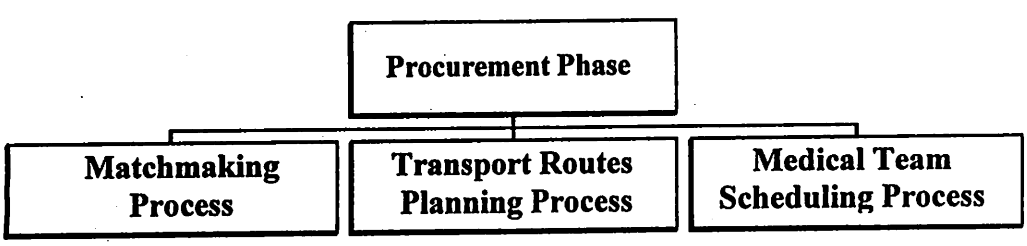

Figure 4-2The Procurement Phase main Processes

4.2.2. HOTM main Affecting Parameters

In the presence of a donor, a group of compatible potential recipients should be found. Among the whole group of compatible recipients the best fitting recipient with the donor should be decided [Fuzz.2005].

Gathering and managing mandatory set of personal and medical information about each recipient and each donor is one of the main activities affecting the whole process. Reliability, correctness and completeness of information and data is of huge importance for making right decisions. Many parameters influence the different phases and process varying from medical, logistical to ethical.

4.2.2.1. Medical Parameters affecting the HOTM

Medical information gathered and examined about each recipient and each donor verify the first operations of recipient choice compatibility like;

- Blood group: determines a definite incompatibility
- Tissue characteristics (human leukocyte antigen HLA groups): the more the tissues characteristic match in both persons, the less the chance of a rejection reaction will occur. " The recipient immune system recognizes the donor organ as an alien"
- Weight
- Height
- Age

all of these three factors show how much the donor matches with the recipient.

- ...

4.2.2.2. Logistical Parameters affecting the HOTM

Not only medical parameters influence the decision making process but there are some logistical considerations during the "Transport Rout Planning" process and "Medical Teams Scheduling" process like;

- Transport method of the organ from the donor's to the recipient's hospital
- Transportation route
- Transport team
- Available operation theatre
- Available surgical team (surgeons, specialized doctors)
- Available medical team (nurses, anesthetists ...)
- Available drugs and compatible blood reservoir

- Available required equipments
- ...

4.2.2.3. Managerial and Ethical Parameters affecting the HOTM

Out of a fairness point of view, there are other important Parameters affecting the final assignation of an organ. Information of key importance for the definition of the best fitting recipient are;

- The relative recipients position in the waiting list
- The presence of compatible recipients in the emergency cases waiting list
- Ethical rules and regulations (according to each countries law)

Sometimes a doctor assigns an organ to a patient who has a worst compatibility but is in the emergency cases waiting list to save his life rather then to assign it to the best fitting recipient leaving no chance for the emergency list patient to survive. Therefore it's of great importance to declare and report the real conditions of the potential recipient in order to verify the decision made [Fuzz.2005].

These parameters are just samples of the affecting parameters. On top of them, a very strict time constraint affects the whole process. It's extremely difficult to maintain acceptable vital parameters of donors involved in accidents for a long time, any variation in them can lead to the loss of the organ. Moreover the organs that have been taken from the body can be stored for very few hours and the transplant must take place in the shortest period possible [Fuzz.2005].

4.2.3. People Involved in the HOTM Phases and Processes

The patient receiving the organ is not the only person involved in the process, in addition there is the physician, the donor or deceased patient, the family, the transplant coordinators, the nurses and the clinical staff, the extraction surgery team, the implantation surgery team, the staff of the laboratories, the legal advisors and the authorities, the logistic team, etc.

All these people should organize administration tasks and activities with clinical or medical tasks and activities that follow the norms and legislation established by various countries heath authorities and organizations, which make the whole process very complex and complicated.

4.2.4. Nature and Characteristics of the Human Organ Transplantation Management System "HOTMS"

The human organ transplantation management processes like the whole health care domain share some characteristics and properties as follows:

- ***Distributed***: required data and information are spread among different requesters and units, distributed across various kinds of media (fax, data sheets, data bases, electronic patient records etc.) and introduced in different ontologies. During the human organ transplantation processes, data and information will be accessed from; accident scene, donors hospital, recipients hospital, ministry of health and population, higher committee for human organ transplantation waiting lists, human organ transplantation centers waiting lists and various authorities and legislative organizations. The donors and patients history and electronic records should be exchanged and transferred if available. For example at the matchmaking process there are data about the donor's organ from the donor's hospital, the recipient medical history from the health insurance files and maybe the recipients and donors electronically record from the different hospitals that treated this patient before, which should be all transferred and exchanged.

- ***Parallel***: many of the tasks contained at the human organ transplantation processes run parallel. The matchmaking process includes parallel tasks and activities; gathering the required information and data for both sides, checking the compatibility at different places like; higher committee for HOT and the various HOT Centres. The transport rout planning process and the medical team scheduling process also run in parallel.

- ***Decentralized control***: the higher committee for HOT in the capital, involved HOT centers in different region, specialized surgeons and doctors all over the hospitals, donor and recipients and families themselves and others affect the workflow of processes and information during the different phases of matchmaking, transport route planning and medical team scheduling. Therefore the best coordination of activities is required, where all these participants negotiate, manage and coordinate their actions to provide the best result for the recipient and the living donor.

- ***Communicative***: all the data, information, schedules, request etc. have to be communicated and exchanged easily during the procurement phase and the surgery phase processes. This communication prevent allot of management and coordination problems (e.g. One can avoid assigning an organ to a non-compatible recipient or transporting the organ to a wrong hospital (not equipped or ready) through a wrong route (crowded or closed) from the beginning due to right communication and negotiation processes.

- ***Self-organizing***: the problem solutions, tasks and activities are flexible according to the varying situation as well as the negotiation during the processes [Knub.2000] [Elha.2008].

4.2.5. The HOTM Challenges and Problems

Many problems and challenges face the HOTM phases and processes; some are generally common in the health care domain, while others are more related to the HOTM. Healthcare domain problems can be summarized in the following points generally.

- Unreliable, uncertain and un-actual data and information
- Incorrect and incomplete information and data
- Lack of smooth, easy and fast information exchange and flow between various organizations and parties
- Lack of data sharing between the personnel
- Lack of information integrityDistributed information and data sources and resources (various data sources; patient history, patient file at hospital, laboratory test...)Complex Problems and shortage of distributed problem solving techniques

- Deficiency of communication and negotiation processes
- Absence of good coordination and management.

There are specific problems threatening the well being of the patients, diminishing and weaken the functionality of the HOTM at its different phases. These happen almost because of the overload and stress of the human actors during this process, communicational deficiencies in addition to the absence of highly advanced technologies. Therefore, the researcher assumes that these problems could be reduced and dealt with due to the right use of information, communication and advanced intelligent technologies. Following are some obstacles and challenges facing the HOTM decision makers during the different processes in particular.

- Misleading or absence of a donors organ detection
- Misleading or absence of deciding the best fitting recipients
- Complications and problems due to family negatives and barriers
- Complications and problems due to judicial and legislative negative regulations
- Occurrence of some medical contradiction according to the various opinions of specialized surgeons and different argumentations. As well as failure of different compatibility tests and examinations.
- Medical experts overload during the matchmaking process, as they have to evaluate and consider all the possible receivers one by one with weak supports to process large amount of data
- Information of different format is usually not stored in a compact, re-usable way resulting in delayed coordination and communication between medical experts, surgeons and decision makers. So they have to pass them through telephones and facsimile…
- Failure to decide the best route, best transporting time and most appropriate transporting method

- Complexity of medical scheduling and failing coordination between the medical team, theatre and the recipients themselves. Unavailable medical personnel or operating theatres

- Unexpected maintenance losses

- Complications and failures during the surgical operation

- If the case happened that after going through all these procedures the best fitting recipient is not available (has fever, not at the country, the specified theatre is not available), the whole processes has to start from scratch again leading to undesired delays and the worst case losing the organ.

- Usually when the donor is a deceased donor there is more than one organ which means that we have to proceed through all the phases many times in parallel and we need an efficient system of resource allocation.

Sometimes when all or some of these problems or challenges faces the decision makers and staff, they prefer to stop the matchmaking process when they reach the first fit rather than wait for the best fit or they prefer to send all the organs to one HOT center instead of allocating each organ to the best fit, most appropriate rout planning, most appropriate theatre [Alde.2001].

From all the previous difficulties and challenges facing human decision makers and medical experts during their work in HOT management, one concludes that there is an urgent need to develop mechanisms and systems that help to decrease the percentage of losses in each phase and process. One has to elaborate intelligent systems and efficient information systems to be used as decision support aids in the coordination and management of transplants. These intelligent decision making systems must have some communicative, informative, cognitive and negotiating functions to guarantee secure distributed communication, maintaining historical information files, and extracting new knowledge from the systems behaviour and from the analysis of the data.

4.3. The Human Organ Transplantation Management System in Egypt

As mentioned before, Egypt's government and decision maker seek to provide the Egyptian citizens, a top quality treatment and services in the healthcare domain. The plan of the ministry of heath and population aims to assure the performance quality in all the constituents of the healthcare domain in general. In specific, one of their main targets was using advanced technologies of organ transplantation surgeries to save Egyptian patient's lives. Therefore they issued finally the "Human Organ Transplantation Management" law after fourteen years of debate. This will help to solve the ever-growing no. of kidney and liver patient's problems, which are in urgent need of a human organ transplantation operation.

Until this moment, there isn't a detailed description of the Egyptian Human Organ Transplant Management System "HOTMS", as far as we know. Since the HOTM law has been purchased recently, the Egyptian government and the domain specialists are working hard to establish the system; set the organizational and administrative structure of the HOTM system, define its components, approve law through various regulations and rules, describe the working guidelines, determine different authorities and roles ... to assure fairness, safety, efficiency and effectiveness of the system, but they are still at the designing and establishment phase.

Thus the researcher thought it a great chance as a member of the "Institute of National Planning", to contribute by proposing the following initial structure and model as an aid or a modest guideline for decision makers, while they are tackling this issue thoroughly.

Starting up the researcher tried to get a preliminary vision of the HOTMS structure and working guidelines. Unfortunately it was hard to get specific answers, as the whole subject is still vague and unclear to lot of people, decision maker and specialists. As a result of some interviews and semi-official sources, the researcher got to know the broad lines of this HOTMS's structure as follows:

A Higher Committee of HOTM has been established, which is the official organization responsible of the whole management of the HOTM processes all over Egypt. Its main role is to guarantee the fairness, security and safety of the processes as well as assuring the best resource allocation of donor organs, recipients selection, medical players and theatres. This committee will monitor all the parties and collaborators, their behaviour and commitment to the rules. It also has the authority to give the HOT centers the license to make such surgeries after they fulfill all the requirements. They should be aware of all the pieces available and have the right to allocate them and plan for the organ transplant considering the waiting list fairly and transparently. The Higher Committee of HOTM contains five other committees, each has a certain role; financial committee, scientific committee, ethical committee, HOTM monitoring and licensing committee and the waiting list management committee.

Actually, this information weren't enough to define and describe how the structure or work should actually look like. Many of the researchers questions at the questionnaire didn't get an answer, which was the basic reason not to include the questionnaire in this particular preliminary research.

Therefore and in order to answer the first two research questions of the main research problem mentioned in chapter one;

- How should the **Human Organ Transplantation Management System's Structure** -in Egypt- look like and why the researcher believes it will be the most fitting for Egypt ?
- What would be better, an HOTM system relying on centralized or decentralized processes?

the researcher proposed a certain structure for the HOTM system of her own, derived from her own vision and from the scarce available data and information gathered till this point in time. Following, the researcher presents the proposed structure and institutional components of the HOTMS in Egypt from her own point of view. The main interest of the following proposed HOTMS structure and model is concerned mainly with a deceased donor donating his organs to unrestricted recipients and not the case of a living donor donating a part of his organ to one of his/her relatives.

4.3.1. Egypt's Administrative Regional Divisions

From an administrative point of view, Egypt has been divided in seven main regions, each region covers some of the 27 governorates. The following figure shows the regional divisions, while the table contains the different governorates in each region.

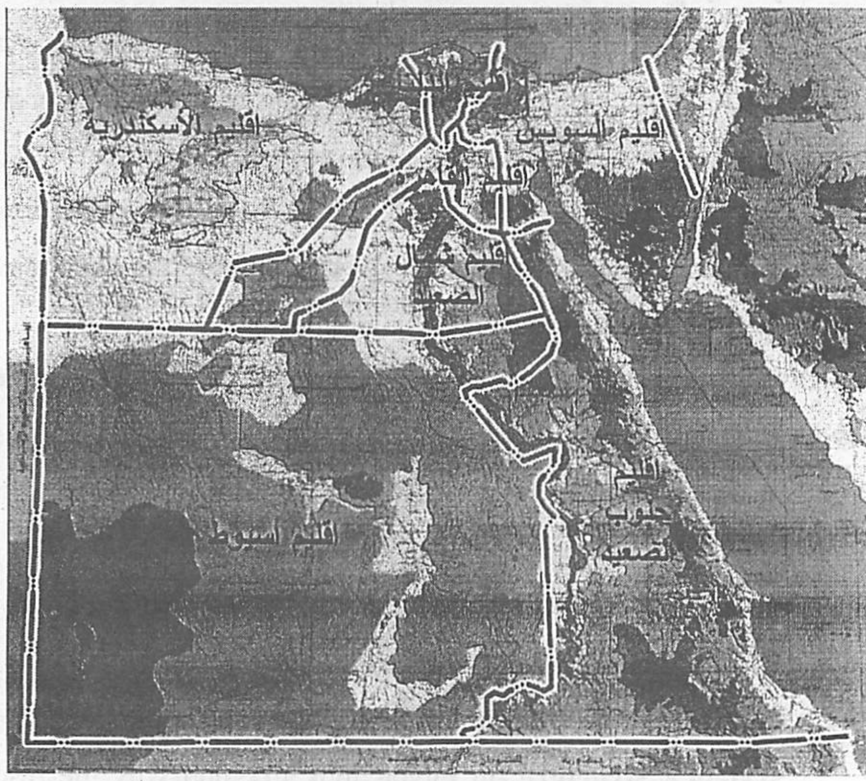

Figure 4-3Egypt's administrative regional divisions map

Regions	Governorates
Cairo	Cairo, Giza, Kaliubeya
North Upper (Shamal al Saeeid)	Fayum, Menia, Bani Suef
Delta	Dakahleya, Garbeya, Menufeya, Dumiat, Kafr Al Sheikh
South Upper	Luxor, Aswan, Suhag, Red Sea, Kena
Suez Kanal	Suez, Sharkeya, PortSaied, Sina, Ismaileya
Asiut	Asiut, Al Wadi al Gadid
Alexandria	Alexandria, Marsa Matrouh, Albehera

Table 4-1 Egypt Regions & Governorates

4.3.2. The Proposed HOTMS Structure in Egypt

The researcher, while designing the HOTMS's structure followed the regional distribution of Egypt's governorates, believing that it could be of great help concerning the easiness of services, communications and predefined administrative relations. The following figure shows the researchers own vision through the researcher's proposed HOTMS's structure.

As viewed in the figure, the system is structured in different levels or layers;

1. The National Level
2. The Regional Level
3. The Governmental Level
4. The Decision Making Level
5. The Services level

All levels are connected together exchanging data, information and knowledge. Each of these levels contains different organizations and institutions cooperating and collaborating with themselves and with other levels components to achieve their targets. Each has its own responsibility and plays a certain role that will be performed through some tasks and activities.

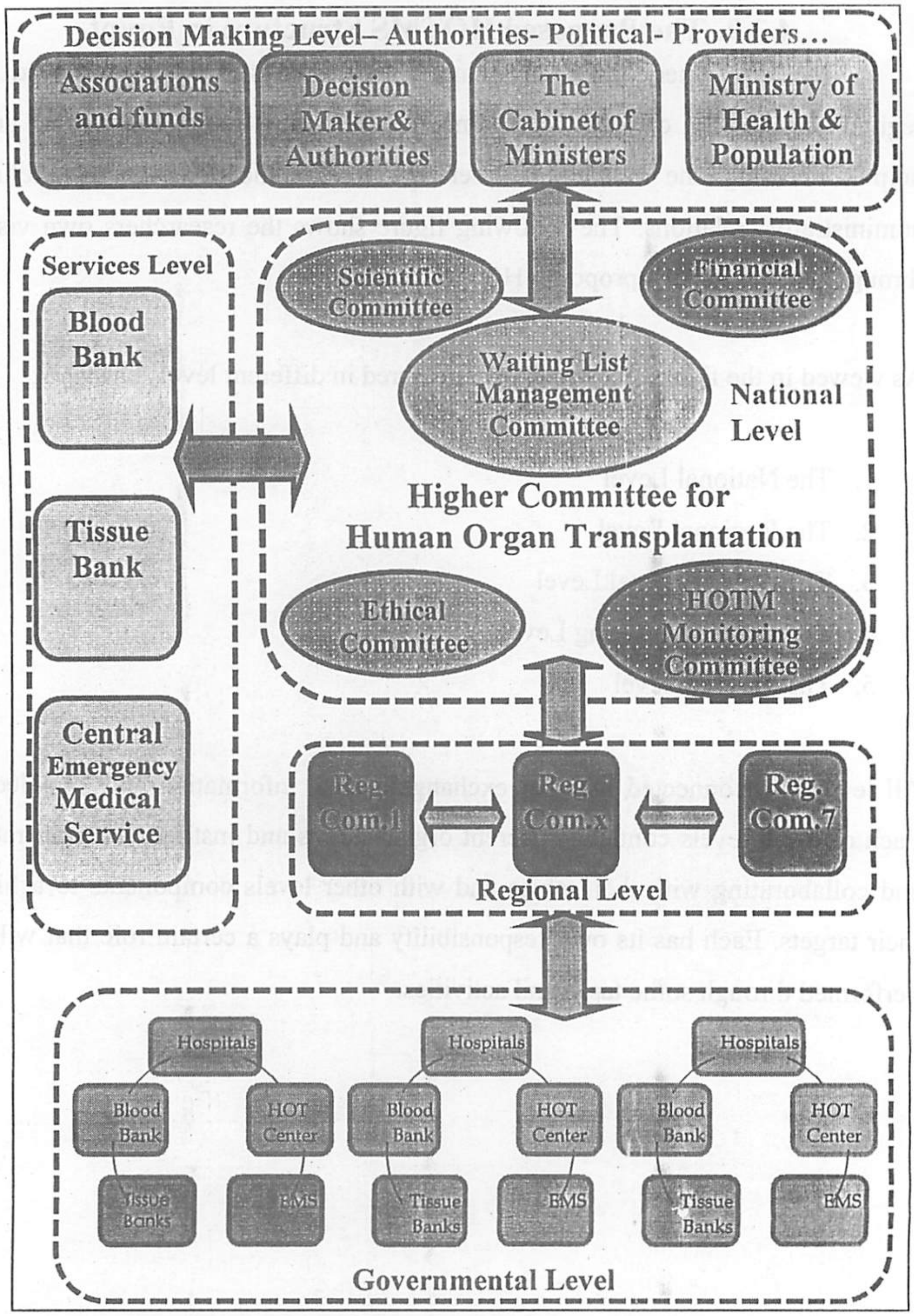

Figure 4-4 The Proposed HOTMS's Structure in Egypt

4.3.2.1. The Proposed HOTMS's National Level

The national level contains the higher committee of HOTM in Egypt under the auspices of the cabinet of ministers. It is considered as the central, highest and strongest official authority responsible for any human organ transplantation actions all over the country. Its main target is to save as much lives as possible by managing the human organ transplantation processes by effective and efficient resource allocation methods. It is supposed that it will be the only authenticated institution that allocates the donor organs and allows the transplant surgery. It has the power of monitoring and observing all the players involved in the HOTM giving permission or prohibiting actions. Its main roles are summarized as follows in some sub-processes:

- Recipients selection (from patient waiting lists and patients records)
- Organ/Tissue allocation (based on organ and tissue records and analysis)
- Ensuring adherence to legislation
- Following approved protocols and guidelines
- Preparing delivery plans (planning the transporting route, facility and team) [Navi.2005]

All this involves some tasks like:

- Assuring the seriousness and adherence of all the involved players, providers and persons to the rules and laws
- Be up to date of all recent data, information and records concerning organs at tissue banks, recipient's waiting lists, donor's waiting lists...
- Observing and monitoring the HOTM centers and Tissue Banks to fulfill the requirement and commitments made by the higher committee of HOTM
- Registering all the incidents concerning a specific organ
- Coordination of the organ transport from one center to the other [Caba.2003].

The higher committee of HOTMS has been established including five sub-committees, each one has a certain role that fulfills the main target partially. As one is not sure about the actual definitive tasks and activities of each, the researchers wants to assume some identifications briefly:

The Financial Committee: is responsible of getting the money and collecting finance from different associations and funds to support any HOT operation, as it is very expensive. It also has to control all financial transactions at any phase and check for its legality preventing the organ non-legal trade.

The Scientific Committee: is concerned with scientific and research aspects. It also should encourage for the international knowledge and experience exchange through training courses, scholarships, Tele-learning, online surgeries or any medical materials offered to medical personnel.

The Ethical Committee: is responsible of fetching each recipient's social condition to agree for example to have a free of charge HOT operation. It should also observe and monitor the system fairness through managing the waiting list and emergency list without any corruption. Which means each recipient saves his turn as long as he/she is the best fit for an organ.

Other ethical and moral issues have been raised worldwide due to the shortage of available organs. Following are some interesting issues discussed abroad (maybe some of them could be issued in Egypt later on, as long as it doesn't contradict with our believes and religions) :

- *"Should those who have a better chance for survival be given priority over other patients needing organ transplants?*
- *Should parents of young children be given priority?*
- *Should those whose lifestyle choices (smoking, drinking, drug use, obesity, etc.) damaged their organ(s) be given the opportunity of an organ transplant?*
- *Should incentives, either monetary or non-monetary, be offered in order to encourage organ donation? Should those who made the decision to donate organs of a loved one who has been declared dead receive any kind of financial compensation?*
- *Does "transplant tourism" – the concept of traveling to developing countries to obtain organs exploit the poor and what does this mean for distributive justice?*
- *Should prisoners on death row be given the option of donating organs upon their death, or even be offered the option of trading a kidney or bone marrow in exchange for a life sentence in prison without parole?*
- *Should everyone be required to indicate their wishes regarding organ transplantation on either their income tax forms or drivers license" [copied from www.}?*

The Monitoring and Licensing Committee: the role of this committee is of great importance, as it is concerned with observing and monitoring the different hospitals, either as an observer of the HOT Centers after been accredited or to give the centers not accredited yet, the license if they have fulfilled all the requirements and conditions spelled in the law (ISO, medical equipments, intensive care units, Sterilization ...).

The Waiting List Management Committee: is mainly concerned with managing the waiting list, registering the recipients and donors. It is supposed that its main role be very much involved in the recipient's selection and the organ/tissue allocation processes.

The higher committee of HOTM cooperates with decision making level components to aid them by making decisions. One can observe that the main roles and tasks of the higher committee of HOTM are mainly contained in the procurement phase with its three main processes; Match Making, Route Planning and Medical Team Scheduling, which have been identified as very difficult and complex processes. Therefore the researcher believes that the higher committee should make the final decision depending on a complete, well organized and powerful work of some other committees collaborating, coordinating, communicating and negotiating to fulfill the higher committee of HOTM main targets. These committees should be distributed all over the country and be able to easily communicate and exchange data and information. We will follow the administrative regional divisions of Egypt as shown in the previous figure and table.

4.3.2.2. The Proposed HOTMS's Regional Level

The researcher believes that the higher committee can't mange the complex and difficult HOTM processes (recipients selection, donor allocation, route planning, medical scheduling and monitoring and observing) solely without being supported. Because of the distributive problem characteristics, there is a huge need to distribute the complex problem into smaller distributed problems to get them easily solved. Therefore, the researcher thought it will be more efficient and effective to establish seven HOT Regional Committees emerging from the Higher Committee for HOT. They should follow Egypt's administrative regional division. Each of these regional committees will be responsible of the governorates and zones contained into its region. These regional committees should cooperate and coordinate with the national level as well as the governmental one. They should help the higher committee to make the right decision on the national level and at the same time observe the governmental level, while all the regional committees should proceed on their on level and make a decision to be presented at the higher level in kind of simplifying and fastening the selection and allocation processes. The seven regional committees should be connected together through a network to easing the communication and information exchange.

4.3.2.3. The Proposed HOTMS's Governmental Level

This level contains all the normal hospitals as well as the HOTM centers, wish are allowed to make organ transplant at a certain region. It also should include blood banks, tissue banks, emergency medical services. The different governorates should easily communicate their corresponding regional committee. Even though Egypt doesn't have an HOT center at each region, we should still plan for the future –ideal- structure.

4.3.2.4. The Proposed HOTMS's Decision Making Level

It's the level or layer representing decision makers, politician, authorities…that will aid and help during the procurement phase. It plays also an important role for strategic planning and national and international issues.

4.3.2.5. The Proposed HOTMS's Services level

It represents different services needed all over the time during the HOTMS (Blood banks &Tissuee bank, emergency units, medical equipments…)

4.3.3. Scenario "What happens if a Deceased Donor has been detected"

The **"Deceased Donor Detection"** Scenario proposed by the researcher considers the proposed HOTMS's Structure and relational framework of the different institutions. Under the assumption that we deal just with deceased donors donating their organs to anybody who is compatible. It is assumed first of all that these persons will declare a legal document explaining their desire to donate their organs after their death.

Upon detecting a donor, a certain scenario according to the proposed structure should take place. If the donor is detected at an accident scene or detected at home, it will be sent immediately to the nearest Hospital. If the donor dies at the hospital he will be already there. After communication with the nearest HOT center, either the donor will be transported to the nearest HOT center or a specialized surgical team will be sent immediately to the donor's hospital (depends on the means of transportation and distance...). In either case the donors ID and initial organ evaluation should be forwarded to the corresponding regional committee as well as the nearest HOT center. Then the regional committee quickly forwards this information to all the other six regional committees to perform their **Match Making Processes** and of course to the higher committee of HOT (as a monitoring side). The regional committees perform parallel Match **Making Processes** for each organ of the donor's organs considering the regional committees waiting list and emergency list only. This means each regional committee will address the recipients of their region only including the corresponding governorates. At the same time and if the donor had the chance to reside at the HOT center, then an **HOT Match Making Process** should be done there taking into consideration the HOT centers waiting lists and emergency lists only. The **HOT Match Making** process for recipient selections, outputs the best fitting recipient from the HOT centers waiting list. This output should be also forwarded to the corresponding regional committee. The seven regional committees forward the output of their **Match Making processes** to the higher committee. Each output contains a smaller list (not more than three recipients) presenting the three best fitting recipient for one organ. This happens in parallel for the different organs of the same donor. As an example the regional committee of Suez should send for instance five lists for five different organs of the same dono Each of these lists contains three best fitting recipients. The higher committee should perform a **Combined Match Making Process** taking into consideration the seven regional committees output; this means it should perform a normal **Match Making Process** for each organ, the recipient selection will take in consideration just the 21 presented recipients (3 persons from the 7 regional com.) outputted from the regional committees although it has control on the whole countries waiting and emergency lists. The **Combined Match Making Process** then will take in considerations the regional different outputs and the complications of the **Transport Routes Planning** and **Medical Team Scheduling Processes.**

Of course one of the main selection strategies and rule is to search first at the emergency list (people who need the organ in less than 24 hours) and then give the priority to the order of the waiting list as long as two recipients are evaluated equally after diminishing the **Transport Routes Planning** and **Medical Team Scheduling Processes** contradictions (combined Match Making). The **Combined Match Making** process will contain some **Negotiations** that will be explained later in the research.

After the Combined Match Making process has been performed the organ has been assigned to the best fitting recipient and the HOT center in a certain region will be decided to the transplantation operation.

The following figure shows the proposed flow diagram of the HOTMS after detecting a deceased donor.

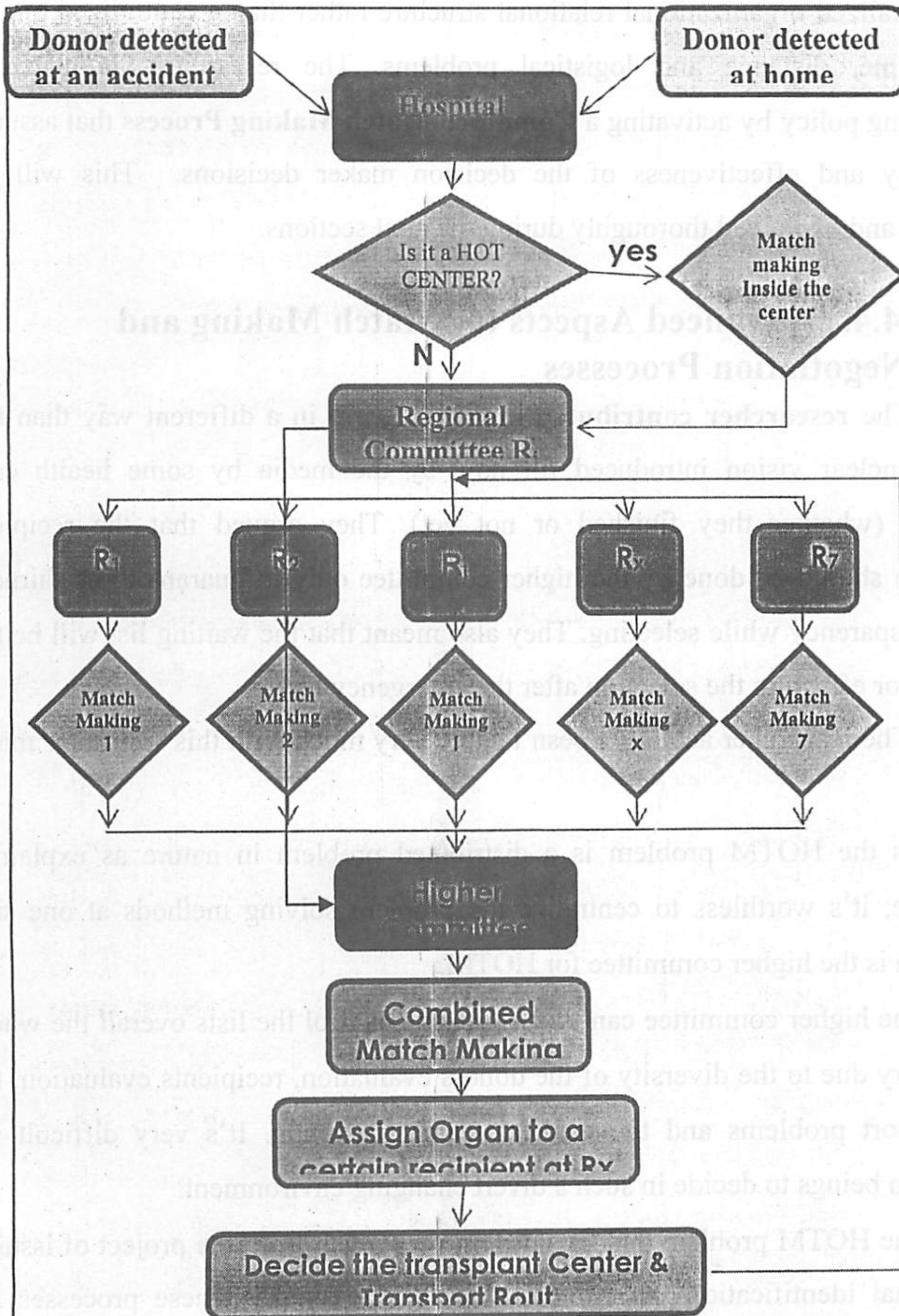

Figure 4-5 Proposed Flow Diagram of the HOTMS after detecting a Deceased Donor

During section 4.3 the researcher answered the researches first two questions by presenting the proposed HOTMS structure in Egypt and how it could look like to avoid many problems and challenges of the distributed nature of the HOTM processes. At the same time the researcher emphasized the importance of adopting a decentralized organizational relational structure rather than a centralized one to avoid time, distance and logistical problems. The researcher initialized a monitoring policy by activating a **Combined Match Making Process** that assures efficiency and effectiveness of the decision maker decisions. This will be clarified and explained thoroughly during the next sections.

4.4. Advanced Aspects for Match Making and Negotiation Processes

The **researcher contributed** in this scenario in a different way than the vague unclear vision introduced till now by the media by some health care officials (whether they finished or not yet). They argued that the recipient selection should be done by the higher committee only to guarantee the fairness and transparency while selecting. They also meant that the waiting list will be the first factor effecting the selection after the emergency list.

The researcher actually doesn't agree very much with this vision for many reasons:

- As the HOTM problem is a distributed problem in nature as explained before, it's worthless to centralize the problem solving methods at one side which is the higher committee for HOTM.
- The higher committee can't by all means control the lists overall the whole country due to the diversity of the donors evaluation, recipients evaluation, the transport problems and the medical team scheduling. It's very difficult for human beings to decide in such a divert changing environment.
- The HOTM problem and lists differs very much from the project of issuing national identification number cards for all Egyptians. These processes are affected by different factors and human evaluations (surgeons, specialists...) that affect the final solution.
- Assume there are really one million liver patients waiting for an organ transplant, as mentioned lately. Is it possible for a committee of three persons or even ten specialists to decide the bet fitting recipients taking in consideration all the factors affecting. It's not so easy to depend on a central program fetching one list regardless of the human specialist's interaction and advice at each phase and level.

The researcher recently got very much informed about issues and subjects relating to the HOTM from literature, journals, research articles and books. She was very much influenced by the lot of work of pioneers in that field like (Moreno, Cortes, Navidad and others, see references).

Therefore the researcher proposed this structure and believed of two main advantages of such a structure and a scenario as follows:

1. **Decentralizing** the whole process is of great importance to keep the patient's information security regulations all over the world. Each entity maintains its own data, HOT centers know their patients medical records, the surgeons schedules and the operating theatre availability. Providing decentralization will enable to work with such distributed process in which many entities must keep their own identity, meaning their own rights, norms, private information. The centralized approach could break the authority and control of the activities and information flow at the hospitals. It's also well known that the decision maker anywhere shouldn't be loaded with tons of data and information rather than to be introduced with the most powerful and affecting part of information they need. So, I think it is much easier, quicker and more efficient that the higher committee selects the recipient out of 21 or even 35 rather than to select out of million under the assumption that all the regional Match Making Processes provide fairness and transparency following the legislative rules beside the medical ones. Even when talking about a computerized proposed Multi-Agent HOTMS it is more professional that each agent keeps its own data and represents its institutions role autonomous regardless of others.
2. **Negotiation Process**: while we experience now a new arena of HOTM processes, it will be very surprising to think about negotiations during the HOTM processes. Even though and after reading and getting informed it was astonishing, how negotiation could be presented to such a problem. Previously we presented the different factors affecting the selection process. Actually all these factors can be considered and understood easily, but as a matter of fact as learned from the predecessors that allowed for HOTM

operations long time ago like Spain, Switzerland and the European Union, they reported that for the same case there could be different medical point of view, which means that a specialist could evaluate the organ as viable for a certain recipient, while another could evaluate it as nonviable for the same recipient. Therefore many researchers, organizations proposed systems like CARREL or ASPIC "Argumentation Services Platform with Integrated Components" developed systems, to allow less human organs to be discarded and lost. The following is extracted from [Tolc.2007]

> *"What may be sufficient reasons for discarding an organ for some qualified professionals may not be for others. Contradictory conclusions may be derived from the same set of facts. For example, suppose a donor with a smoking history of more than 20-30 packs a year and no history of chronic obstructive pulmonary disease (COPD). The medical guidelines indicate that a donor's smoking history is a sufficient reason for deeming a donor's lung as non-viable. However, there are qualified physicians that reason that the donor's lung is viable given that there is no history of (COPD) [Tolc.2007].*

3. Therefore, the researcher adopted the **Negotiation Method** that coincide very much with the **decentralized** HOTMS's proposed structure. Under the assumption, that the higher committee for HOT will perform the **Combined Match Making Process** taking in consideration seven regional committees negotiating and competing on one organ and by that assure a monitored transparent decision.

Through this section the researcher tried to answer the third research question concerning the availability of a negotiation and match making process during the HOT management. At the same time the researcher believes that these two processes should be maintained through intelligent systems for each by relying on AI techniques. Building these intelligent sub-systems is beyond the research's scope, as it needs full analysis, design and implementation of prototype and testing. This could be performed in a forthcoming research, anyhow the researcher suggests to make use of Case-Based Reasoning, Expert

Systems, IDSS & Intelligent Database Management systems for the Match Making processes and Intelligent/Multi-Agent systems for the Negotiation Processes to implement these subsystems in the future.

4.5. Efficiency and Effectiveness of using Multi-Agents during the HOTMS

During this section the researcher will examine the fifth question of the research concerning the ability to rely on techniques and technologies from the AI domain generally and the agent technology specifically as a main contributor of an **IDSS** during the **Human Organ Transplantation Management Processes.**

From the basic characteristics of agents and their properties introduced in chapter two and the nature of the HOT management processes mentioned previously and the examples of intelligent decision support systems and agent applications in the medical and the health care domain of chapter three, one can conclude the emerging importance and need of using multi-agent systems in the HOTMS.

From one side it's well known, that the HOTM domain involves a large number of individuals in different locations. All theses participants; patients, donors, families, physicians, surgeons, anesthetists, nurses, managers, health providers and others have to cooperate and provide services, tasks and information to increase percentages of successful transplant. The time factor and the information correctness and reliability play an important role during the HOTM different phases. Communication, coordination and negotiation between the different directions and parties like the HOT centers, regional committees or higher committee of HOTM with all the involved parties are of great importance. From the other side, we find that the nature and properties of agents promise to support the distributed work groups in the HOTM domain with the needed information that facilitates their coordination and communication needs because they can autonomously act in behalf of their users to fulfill their tasks and are able through their social property to communicate, cooperate and negotiate with each other and with human agents to get the best solutions. They are also able to introduce reliable, required information and data to the right persons at the required time. Proactively they can take the initiatives to determine their beliefs and maintain certain tasks.

As a conclusion one can say, that integrating agents during the HOTM processes and using the agent technology within its different phases, can result in effectiveness and efficiency in the whole medical care process. It promises to fulfill the domain's main requirements, tasks and help to achieve the systems main goals. It also has the power to integrate the medical and clinical information, knowledge and experience to provide solutions and support the decision-makers at the different processes and tackle many of their problems and complications. If we allow it and simply saying, integrating the agents during the HOTM processes, it will result in automating the HOTM processes or even half-automate it within a certain range.

Out from the researcher's belief in the suitability of using the agent technology during the HOTM processes, the researcher proposed an initial generic Multi-Agent Human Organ Transplant Management System's "HOTMS" Generic Model to aid the decision makers during HOTM process as follows in the next chapter.

Chapter Five

5. The Proposed Multi-Agent HOTMS

During this chapter, the researcher will try to answer the last two research questions by introducing the proposed **Multi-Agent HOTM System,** its architecture, different scenarios and the various contained agent types and roles. But before introducing the systems architecture, the researcher will explain the different processes more precisely.

From the previous chapter, one can notice the characteristics of the HOTM various scenarios. As mentioned before, it is assumed to perform in a constantly changing environment, in which constraints could be added or removed anytime; while a recipients registers there could be a donor or more detected. The tasks could also conflict or contradict for example they could leave the choice of the "best fitting recipient" to be able to save an emergency list recipient. It would also be preferred to use a multi-criteria selection decision aid, which means to change the criteria to exclude as many as possible persons from the matchmaking process to speed up the selection. If a donor has a rare blood group for instance, it will be faster to choose the blood group as the first criteria of selection while in other cases other criteria could be more efficient. The decision should be made in a timely advanced fashion and the selection of the recipients has to be done in the shortest time possible. So it's obvious that traditional software tools are not appropriate or adequate as the solution should provide great flexibility and simulate human behaviours in taking decisions.

Thus using intelligent techniques during the different sub-systems as well as intelligent agents and multi-agent based systems can be much more efficient in terms of time, money and organizations. A multi-agent system offers a distributed platform in which individual entities can be modeled with individual agents that guarantee the rights of the entity and are responsible of a given process. In addition agents can model other important tasks, such as administrative tasks, (gather information of a patient), logistics (how to address the problem of patient transport from one hospital to another),etc. Agent's communication and negotiation abilities are appropriate to improve the whole process. The communication of the data can be done very quickly and the information represented to the decision maker is done in a more convenient way. The MAS allows the maintenance of the current organizational structure within a hospital or among different hospitals and the complexity of the application gives the opportunity to investigate a highly distributed problem with different levels of coordination and decision-making[More.2003] [Fuzz.2005] [Navi.2005].

Influenced by the whole work done in the field of organ transplant by the University of Catalonia and the University of Rovira I Virgili, as well as the Switzerland organ transplantation model –which is stricter - and the work on CARREL, ASPIC and the ProClaim Model (an argumentation based framework), the researcher adopted some ideas and adapted them to follow the proposed Egyptian HOTM structure.

5.1. The Proposed Multi-Agent HOTMS Processes

Concluding, multi-agent systems could reproduce the human behaviour during the tasks that could be performed automatically. The proposed multi-agent HOTMS can perform through the following processes:

1- **Recipients Registering and Admission**: every patient that needs an organ can register in the recipient waiting lists due to an accredited HOT center.
2- **Donors Registering and Detection**: all the donors information should be available at the system to allow for an efficient Match Making process
3- **Automatic Intelligent Match Making Process**: this process is one of the most important processes of the system, as the best match between donor and recipient should be done. The system will be provided with mechanisms to follow, rules to respect and constraints to satisfy according to the human decision criteria in addition to the medical history of similar cases. Some intelligent aids can be used at this phase like Medical Expert Systems, Case-Base Reasoning or Online Medical Knowledge and Guidelines.
4- **Decision Supporting**: the proposed multi-agent system won't ever replace the human player but it rather provides a fast and efficient aid to make the right decision. For example when performing the match making process the

system could present the three best matches leaving the last control and decision to the human specialist.

5- **Coordination Support**: while choosing the recipients, other constraints should be taken into account like the logistic transport route plan and medical scheduling which could be very much solved by a multi-agent providing qualified resource allocation. (Note that this aspect wont be dealt with inside this research) [Fuzz.2005].

5.1.1. The Match Making, Combined Match Making and Negotiation Processes

Match Making Process: is the most complex part of the solution. There are different points of views for performing match making activities in a multi-agent system. There are also different levels of match making starting with very simple match making to a more complex combined match making ending up with match making followed by negotiation.

When a donor is detected, the process starts by trying to find the most compatible recipient that matches the donor. This compatibility is determined according to some attributes or parameters defined in forehand, whose values must be under strict constraints. As mentioned before it could be the difference between the donors and receivers age not exceeding a certain value. Or in case of heart transplant the patient should not be elder then a certain age, as well as the blood type compatibility according to certain rules like follows;

Donor	Recipient
O	O, A, B, AB
A	A, AB
B	B, AB
AB	AB

Table 5-1 ABO table of blood compatibility [More.2003]

All these constraints and other can be used during the match making process. The proposed match making transplant specialist agent is responsible first for finding the compatible patients, second to analyze the compatible candidates' characteristics that depends upon the degree of compatibility between the two persons. So the match making transplant specialist agent either at the HOT center or at the regional committee will perform first the **filtering** process and then the **ranking**. Parameters could be quantitative as well as qualitative values like; inadequate, feasible, good, optimum for the weight or maybe >20, >17, >11 for the age or different, similar and identical for the Antigens.

For these process to be well performed, different techniques could be used as follows:

- **MCDA multi-criteria** decision aids which include many different methods, like mentioned in [More.2003] ; linguistic aggregation, clustering or tuple techniques.
- **Expert system** could be used to provide rule based criteria for filtering and ranking
- **Case Based Reasoning** is a great facility to learn from past experiences and previous similar cases
- **Neural network** can be trained if there are a great no of parameter values
- ...

The Combined Match Making Process: In the proposed system the researcher used the **Combined Match Making Process** which is a kind of simple match making process taking into consideration the parameters of the other main two processes; **Transport Route Planning** and the **Medical Scheduling** like distance between hospitals, surgeon time table, theatres availability...

This kind of match making is also so important, from one side you can select the best fitting recipient with a 95 % compatibility, but all of the sudden you are challenged with the distance between hospitals "Cairo-Aswan" needs a huge no. of hours if you transport by ambulance cars for instance while an organ may last just for 4 to 6 hours what implies discarding this organ. From the other side, you may transplant the organ to a 75% compatible recipient in the same hospital, but it doesn't work as the body may reject the organ. Thus it is a very difficult and tough balance to perform.

The Negotiation Process: the researcher in the proposed system thought of adopting and adapting the technique introduced in ProCLAIM model to deliberate over the ability of a human organ. It will be used to negotiate about an organ rather than claiming it as non-viable.

Each one of the seven Regional Committee Donor Negotiation Agents will compete and negotiate according to the different arguments they receive from the match maker specialist. Their target is to win the organ. The proposed system will contain seven negotiators which will negotiate and compete about any organ. By doing this they can make use of

- Argument Scheme Repository
- Guideline Knowledge
- Case- Based Reasoning Engine
- Argument Source Management [Tolc.2007].

Summing up, there are two main approaches providing match making technique. The first one, is the "one by one" search of the recipient list, which will be a very efficient search when applied to a small amount of potentials. The second one lets the agent who represents the recipients hospital negotiates among each other to find the best fitting recipient and gain the organ. If the competition is well organized, all the requirements of fairness can be respected. The negotiation process is very much like the actual reality of doctors trying to save their patients life as much as possible.

5.2. The Proposed Multi-Agent HOTMS Architecture

Before representing the initial proposed Multi-Agent HOTM Systems Architecture, one has to mention that planning, analyzing, designing and implementing such a system or even a preliminary prototype of such a system is considered a national project that needs huge resources; human experts, technology, financing, time...etc. and above all tremendous amount of data that could represent the data repository. This will include many forms and kind of data and information like mentioned before. As well as various definitions and relations that should be considered. For instance it will contain:

- The electronic patient record of the donor and the recipient
- The data and information of the donated organ
- The match-making and negotiation techniques of each organ
- Authorized persons to use these systems and their degree of authentication
- ...

Anyways, this is now beyond this research's scope by all means but it still could be done in a forthcoming study when starting to implement a prototype. However the researcher will present through the following sections how the systems architecture will look like and which agents will be contained within it and which roles will be presented. The initial proposed Multi-Agent HOTM System Architecture will be introduced stressing on the necessity to proceed with this work trying to build an initial prototype.

The following two figures show the proposed Multi-Agent HOTMS's architecture with its different contained agents in different sites; the first figure represents mainly the HOT Center, while the second figure introduces the architecture covering the Regional Committee and the Higher Committee for HOT.

The next two figures focuses on the establishment of the architecture of the multi-agent system and the interaction between the agents that are part of the multi-agent HOTMS. Arrows indicating the information and data flow over the architecture and represent interactions among the agents. Agents are represented with rounded squares. To represent more than one agent from the same type, other rounded squares are repeated behind the first one. The different agents have their specified roles and their specialized tasks according to their services and duties. The red lines represent the recipient registering scenario, the blue dashed lines represent the donor detecting scenarios, while the green dotted line indicates the final assignation and allocation result after performing different match making and negotiating processes and techniques. It's supposed that the HOTMS is a dynamic system that works through the changing environment at the HOT center, the regional committee and the higher committee. Thus it contains agents that keep sensing all the varying states along the whole process. The most important agents and what they do will be briefly explained through explaining two different scenarios like follows:

5.2.1. The Proposed Multi-Agent HOTMS "Recipient Registration Scenario"

Upon an arrival of a patient at the HOT center, certain activities and tasks of different agents will be performed like follows:

1- The patient will be welcomed by one of the reception staff, who initiates a patient electronic record PER through its HOT Center Recipient Admission Interface Agent. The record will be send and stored at the data base of the registered patients. It will simultaneously be sent to the HOT Center Surgeon Interface Agent.

2- The specialist surgeon examines the patient and decides if he/she needs organ transplantation or not. If yes he decides the urgency level and the corresponding selection function. He enters the required information through his interface agent to update the PER

3- The updated PER will be forwarded to the HOT Center Coordinator Agent who directly asks the HOT Center Advisor Agent for his advice. The Advisor Agent, autonomously access different facilities and techniques like expert systems, medical data bases or case-based reasoning to verify the surgeon's request. Accordingly, the HOT Center Advisor Agent initiates a recipient electronic record RER containing all the data and information available (Id, Name, Organ Request, Selection Function...) and forwards this record to the HOT Center Coordinator Agent.

4- The HOT Center Coordinator Agent orders the HOT Center Waiting List Information Agent to update the Waiting lists or Emergency List of the HOT Center.

5- Immediately it sends the verified RER and its ID to the Reg. Com. Recipient Admission Agent automatically to get registered at the corresponding region.

6- The Reg. Com. Recipient Admission Agent checks first the ID of the HOT Center Coordination Agent to assure if it's authorized to register or not. Then it forwards the verified RER automatically to the Reg. Com. Coordination

Agent that orders the Reg. Com. Waiting List Agent to register at the regional waiting lists containing the recipient's waiting list of the whole region.

7- The verified RER will be forwarded to the Higher Com. Recipient Admission Agent, which checks for the authorization rights and forwards the RER to be stored at the higher committee's waiting list, by first passing it through the Higher Com. Coordination Agent and next to the Higher Com. Waiting Lists Agent. The higher committee waiting list will contain the recipient's names all over the country. This doesn't imply that it will be used at the Combined Match Making or Negotiation process as long as the HOTM won't be centralized. It just means that it enables a monitoring and observing facility any time when required.

At this point the patient has been easily registered and its full information, data and request are now stored at the three main waiting lists at the HOT Center, Regional and Higher committee. Although it looks like it's a long procedure but in fact human intervention was the least just at the HOT Center reception and then at the surgeon examinations, while all other tasks have been performed automatically. Which saves time, undesired load; many personnel working at different stages, patients don't have to bother traveling to the capital carrying their files to register. And it saves by all means money (traveling money, personnel salaries…).

5.2.2. The Proposed Multi-Agent HOTMS "Deceased Donor Detection Scenario"

This scenario is the complementary scenario, which will be very much similar to the scenario explained previously; the main difference comes from integrating more agents through the whole process. Every Agent plays a certain role and performs specific behaviour to achieve its required targets. Like mentioned before, when a deceased donor will be detected at the HOT Center,

1- The HOT Center Donor Interface Detection Agent checks immediately the Donors Record according to the ID number.

2- The HOT Center Donor Data Base Agent updates the donor record if it's already exists, or initiates a new one if it doesn't.

3- The medical consultant examines the donor to decide the organs viability. He evaluates the different organs conditions. And updates the donor's record through its interface HOT Center Consultation Agent, which forwards the organs conditions and the donor's record to the HOT Center Coordination Agent.

4- At the minute, this information will be received by the HOT Center Coordination Agent it will be forwarded to the Higher Com. Donor Detection Agent. Simultaneously the same will be sent to all the other regional committees to perform a match making process.

5- The match making process will be done by the HOT Center Match Maker Transplant Specialist Agent, which makes use of all the available mechanisms and systems like explained.

6- When getting an output for each organ; meaning the best fitting recipient for each organ (they could be 3 or five for each organ), the output will be forwarded from the seven regional committees to the higher committee which starts a Combined matchmaking process using the different regional committees output (the whole waiting list of the higher committee wont be used)

7- The Combined Match Making considers the logistic problems of transportation and medical team (not planned in this research).

8- At the same time the Reg. Com. Donor Negotiation Agents of all the seven regions begin to negotiate and compete for the organs they need. Their negotiation will start after receiving the output of the Reg. Com. Match Making in addition to the argumentation to this output. Notice that for each region there are an interface as well as a task Reg. Com. Donor Negotiation Agent. The interface agent allows the online interaction during the process either by adding, removing, questioning or answering any information and questions during the negotiation process. While their task agents will perform the negotiation process in behalf of the regional consultant.

9- By finishing the negotiation, the organ should be assigned to a certain recipient and transportation procedures should begin to enables the transplant operation.

As one can observe, the system will be half automated leaving the important last decisions for the decision makers while providing them with all data, information and facilities they need. So the final control will be forever at the human side. The multi-agent structure was of great help to save time, assure efficiency and guarantee fair resource allocation.

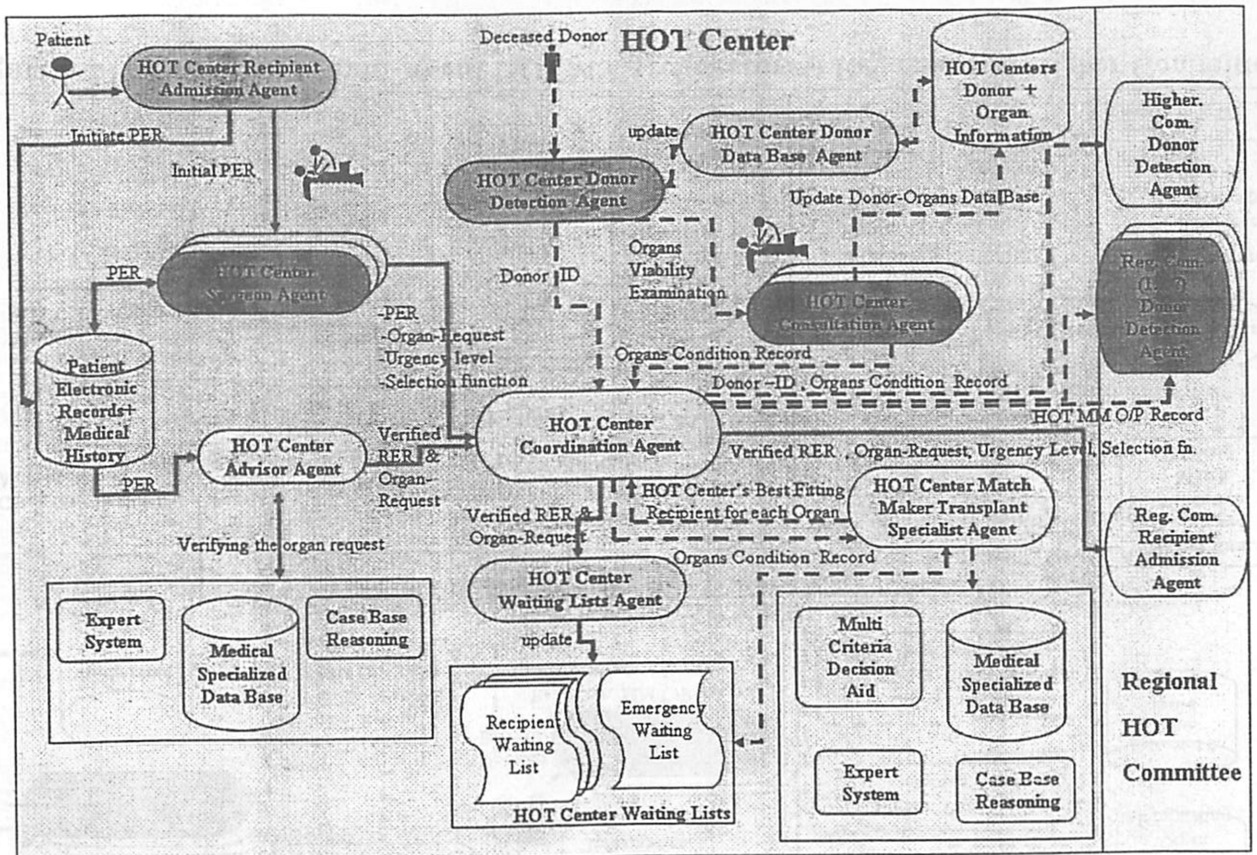

Figure 5-1 The Proposed Multi-Agent HOTMS Architecture –the HOT Center Side

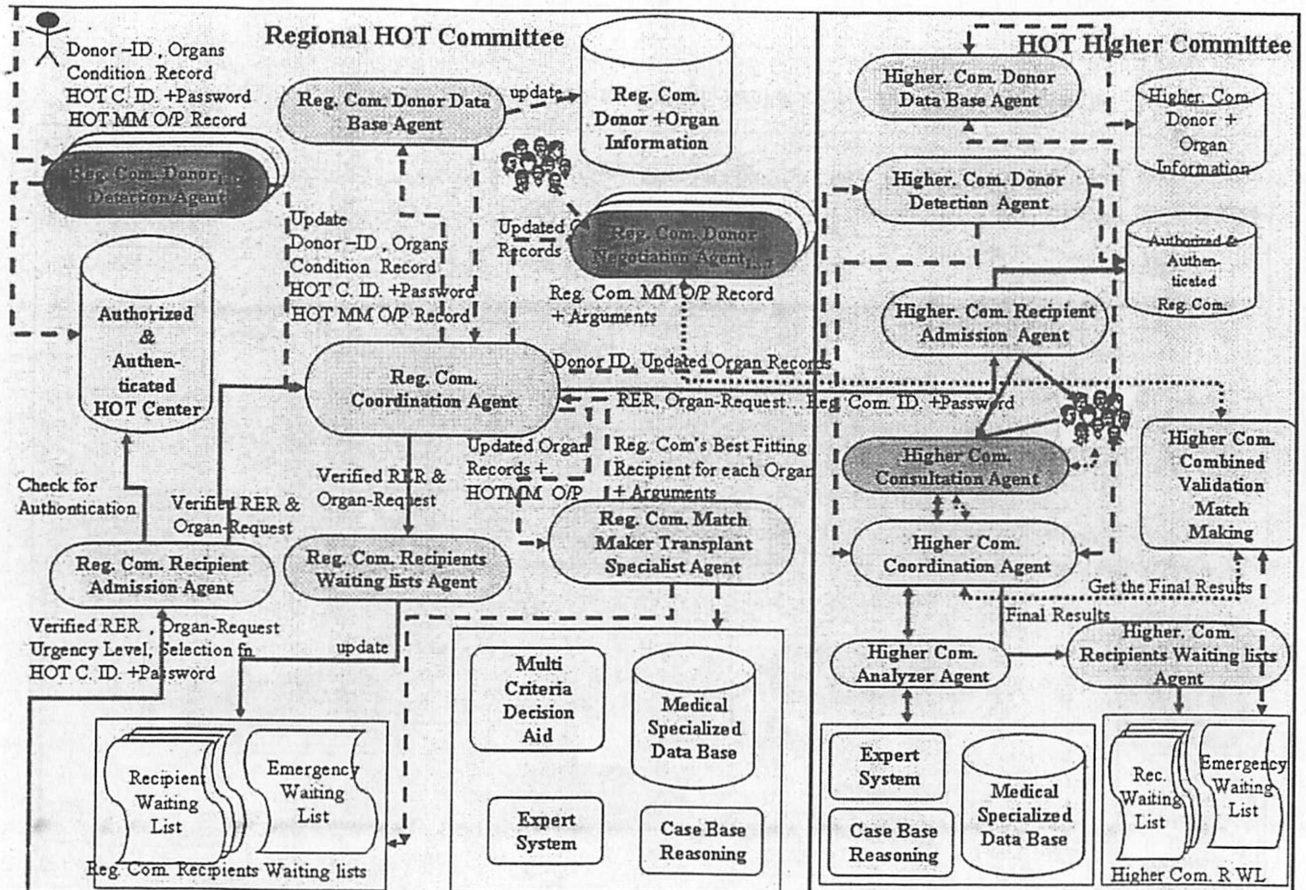

Figure 5-2The Proposed Multi-Agent HOTMS Architecture – Regional and Higher Committees

5.2.3. The Proposed Multi-Agent HOTMS Integrated Agent Types

During the previous sections we dealt with many agents with different roles, responsibilities and tasks. These are supposed to be of great help during the different processes of the system. The proposed multi-agent HOTMS contains different agent types varying from interface agents, task agents to information agents as follows:

Interface Agents: are personal assistance collaborating and communicating with the user to supply him with requests, information and commands. They represent some of the involved persons in the process, which means an interface agent for each of the different specialists during various phases of the system. Interface agents for recipients and donor registering persons, surgeons, HOT Center consultant, regional committee donor negotiators and the higher committee consultant. .. etc. All these agents supply their human actors with a proactive user interface to obtain their different needs and to get all the data and information in a best way among it. This interface could be a normal computer monitor but it also can be a kind of hand held device that informs its owner with the latest and recent changes and variations, PDA's or intelligent mobiles [Knub.2000].

Task Agents: are controlled by the interface agent and processes tasks in behalf of their users. They fulfill information processing activities, solve problems and terminate when finished. All the coordination, consultation, match maker and negotiation agents are main task agents that perform in a manner to execute the procurement phase and the whole HOTMS. [Brad.1997] [Knub.2000].

Information Agents: collect and provide various data and information from their distributed data sources easily and fast. They respond to information requests and have the ability to cooperate with other agents when needed to provide the user with his needs [Knub.2000]. The information-specific agents have to know how to access the databases and solve conflicts. Information strategies and protocols for coordination with relevant software agents are of great importance. Included in the architecture one can see many information agents. Their main role is to gather information to register, update or store different patients or recipient records to be used during the processes. The information agents in the proposed system are the entire data base and the waiting lists agents.

Following is a table with the agent names and types contained in the proposed architecture

Agent Name \ Agent Types	Interface Agent	Task Agent	Information Agent
HOT Center Recipient Admission Agent	X		
HOT Center Surgeon Agent	X		
HOT Center Advisor Agent		X	
HOT Center Coordination Agent		X	
HOT Center Waiting Lists Agent			X
HOT Center Donor Detection Agent	X		
HOT Center Donor Data Base Agent			X
HOT Center Consultation Agent	X		
HOT Center Match Maker Transplant Specialist Agent		X	
Reg. Com. Recipient Admission Agent		X	
Reg. Com. Coordination Agent		X	
Reg. Com. Recipients Waiting lists Agent			X
Reg. Com. Donor Detection Agent	X		
Reg. Com. Donor Data Base Agent			X
Reg. Com. Match Maker Transplant Specialist Agent		X	
Reg. Com. Donor Negotiation Agent	X	X	
Higher. Com. Recipient Admission Agent		X	
Higher Com. Consultation Agent	X		
Higher Com. Coordination Agent		X	
Higher Com. Analyzer Agent		X	
Higher. Com. Recipients Waiting lists Agent			X
Higher. Com. Donor Detection Agent		X	
Higher. Com. Donor Data Base Agent			X

Table 5-2 The Agent Types of the Multi-Agent HOTMS

After presenting the HOTM proposed system structure, properties challenge, different scenarios and the Multi-Agent HOTMS architecture one has to make clear that the proposed structure and architecture and all the surroundings is just an initial preliminary work that reveals the researchers own vision for the HOTMS under establishment and that advancement, enhancement and changes should be made in the future concerning the systems structure and architecture. New agent could be initiated and old agents could be killed after terminating their work. Some agents could be split and others may be merged according to the requirements and the targets. After going through all these advancement one can think about implementing a prototype containing well defined ontologies and specific agents behaviours.

5.3. Overview of the Multi-Agent System Development Approach

Although building a Prototype of the proposed HOTM system is out of the scope of this research, briefly the researcher explains the main general outlines to follow when building a prototype as a kind of a "multi-agent system development approache".

Planning, analysis, design and **implementation** are in fact the four fundamental phases for a software development lifecycle. An overview of a multi-agent development approach will be shown in the next fig. in which one can see that, the **planning** phase is the early stage of the system development and contains the initial assessment and the decisions made about the tools to be used in solving the application area problems and if an agent-based solution is the most appropriate tool among others or not. Here in our case and according to the definitions and research of previous chapters, literature and many applications of chapter 3, that showed that agent-technology has been successfully applied in the healthcare domain, we assume that a multi-agent system in the Human Organ Transplantation Management will be of great help and can successfully be applied in this field.

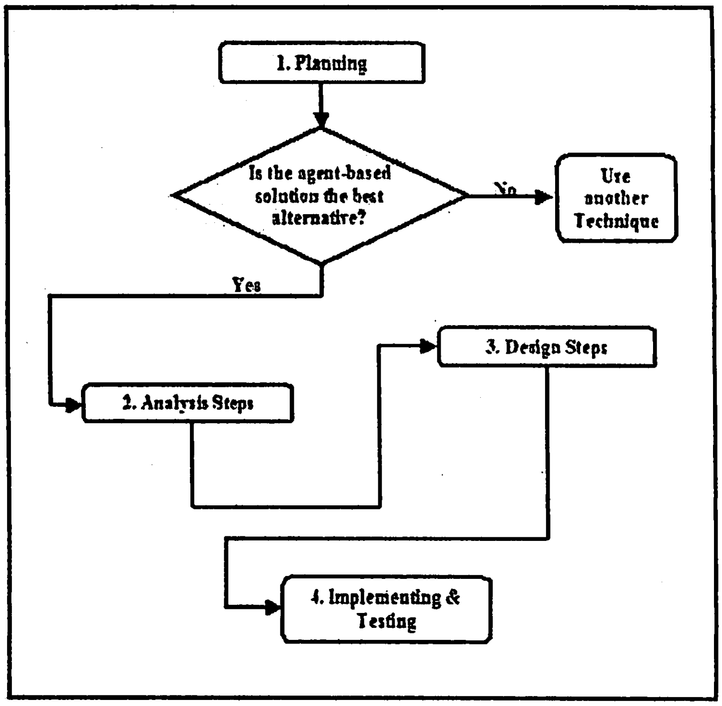

Fig 5-1 Overview of the Multi-Agent System Development Approach [Nikr.2006]

The **analysis phase** is general in nature and independent of the adopted platform, while the **design phase** specifically should assume a certain implementation platform as for instance JADE "Java Agent DEvelopment Framework", that focuses on classes and concepts provided by JADE. which is a robust and efficient environment for distributed agent systems. It follows the FIPA standards "Foundation for Intelligent Physical Agents[2]". Its main advantage is that it has a continuous development support; it's a distributed agent platform with message transport mechanism, and graphical tools for debugging. Simply saying it is an open source project, which follows the latest FIPA specifications. As observed in the overview, there is no strict boundary between the analysis and design phases so that the designer will be able to move forth and back between the analysis and design phase in an iterative way till finding the best design [Nikr.2006].

[2] FIPA, is an international organization dedicated to promoting the industry of intelligent agents by openly developing specifications supporting interoperability among agents and agent-based applications. Geneva, Switzerland. http://www.fipa.org/

During the **analysis phase**, the real world processes should be modeled, agent application scenarios & use cases should be detected as well as identification of initial possible integrated agent types, identification of agent roles, responsibilities &tasks. Also relations between different agents and collaborators will be defined; which has been done at some extent during this research. Depending on the implementation platform the design phase contains steps. If the researcher decides a JADE platform then it will start by splitting or merging the agents, specifying the interactions, defining interaction protocols, putting the message templates, deciding the agent & agent-resource interactions. As well as deciding the internal agent behaviours, defining the specific ontology and selecting the content language. After finishing the design phase, the **implementation & testing phase** begins, in which the developer develops the actual code.

If agents are going to communicate; a certain amount of information is transferred between agents by means of an ACL "Agent Communication Language" message. In order for agents to convert the contents of the ACL messages to meaningful information, and vise versa to convert other meaningful information into contents of outgoing ACL messages in a way that makes sense for them, they must share the same language, vocabulary and protocols. Defining the Ontology, it's essential to exploit JADE's content language and ontology supports. And for agents to talk and reason about "things and facts" related to given domain, JADE suggests going through five important steps:

- Defining an ontology including schemas for predicates, agent's action, and concepts.
- Developing proper Java classes for all types of predicates, agent's action, and concepts.
- Selecting a suitable content language.
- Registering the defined ontology and the selected content language to the agent
- Creating and handling content expressions [Mone.2005] [Cair.2002b].

An application-specific ontology describes the elements that can be used as content of agent messages. An ontology is composed of two parts, a vocabulary that describe the terminology of concepts used by agents in their space of communication, and the classification of the relationships between these concepts, and that describing their semantic and structure. The Multi-Agent HOTM system vocabulary consists of concepts, agent's action and concepts, which are the elements in the HOTM system domain, about which agents will communicate. These elements will be transferred during the agent's interaction in the Multi-Agent HOTM system. While this ontology, defines the set of schemas representing the structure of the elements from the related vocabulary; which means the semantic for the contents of the communication between the agents, for which JADE provides particular classes; dealing with concepts, agent's action and predicates [Mone.2005] [Vauc.2003].

5.4. General Requirements for establishing a Reliable, Consistent and High-Quality Multi-Agent HOTM System

For the proposed HOTM structure to be realized and the system after that to work properly, there are some requirements to be fulfilled:

- Providing highly intensive communication techniques as well as information exchange cooperation and coordination by

  - Establishing a network connecting all the governorates and their facilities on their level as well as connecting them with the regional committee.
  - Establishing another network connecting all the regional committees with the higher committee for HOTM all over the country.
  - Establishing internal networks within the different hospitals all over the country

- Facilitating and accelerating the procedures for issuing electronic patient records instead of paper patient records
- Developing and enhancing the national health insurance system will be of great help during the HOTM
- Awareness campaigns should be held to enhance the overall performance by increasing the number of donors and decreasing the number of discarded organs.
- Safety and security of the system should be assured
- Fairness and transparency should be guaranteed

Chapter Six

6. Conclusion, Contribution, Recommendation and Further Work

During this research and analysis, the researcher reached, discovered and made some conclusions, recommendations and future work

6.1. General Conclusions

- The research showed that the 21st century decision support systems could rely very much on intelligent systems generally and agent technology specifically to provide more flexible support and aid through dealing with large amount of knowledge, data and better dissemination and resolving different perspectives.

- Intelligent software agents can support the decision-maker by :
  - Provide applicable tools
  - Organize and optimize his choice
  - Obtain the necessary data
  - Display uncertainties and assumptions
  - Execute services and display results
- Agent technology provides decision support systems with high intensive communication techniques as well as information exchange, cooperation and coordination, which is the main demand of these systems.
- It also enhances the decision making process in that it saves time, the information search time and supports the execution of the enormous decision making tasks.
- The main support of agent technology stems from the agents ability to execute the tasks more precisely and easily without to be prone to miscalculation, making mistakes, biased stress, mood swings and inability to make use of large amount of details and information.

6.2. Specific Conclusion

The researcher in the study concluded that the newborn Human Organ Transplantation Management "HOTM" domain is considered to be a real application of decision-making systems. Hence, using agent technology in any of its types will be of great support to the HOTMS. Moreover, the researcher believes that a multi-agent system could fulfill the HOTMS demands and requirements and solve some of the problems facing its different actors during the various phases of their work. The agent-based systems characteristics illustrate the benefits of using agents and multi-agents in the HOTM domain. The researcher's decision of using multi-agent system in the HOTMS was motivated by the following agent-based systems characteristics that have been mentioned during chapter 2:

- Distributed problem solving mechanism: the information that must be dealt with during the HOTMS is geographically distributed; HOT Center , insurance company, personal computers, regional/higher committee data bases , it needs a distributed AI approach to be dealt with. The proposed multi-agent system provides the distributed problem solving mechanism; its components can be running on different machines in different places, while each agent keeps the knowledge and information to solve his part of the problem (match making process on different levels). Different agents are distributed through various places, having their certain roles and performing specific tasks.

- Sociability: proposed agents can interact with each other (and possibly humans) in the future and at implementation time via some kind of agent-communication language to obtain their goals. They will be able to establish various messaging types and complex dialogues, to exchange information and data, negotiate and collaborate to coordinate actions, activities and solve problems.

- Responsiveness and Reactivity: agents perceive their environment, respond and act in a timely fashion to changes that occur at the perceived environment. For example the different coordination agents forward the recipients or donor organs information and keep them automatically actualized whenever there any change exists.

- Pro-activeness: agents do not simply act in response to their environment; they are able to exhibit goal-directed behavior by taking the initiative and make suggestions. They are able to perform tasks that maybe important for the user without waiting for his command. The negotiation process happens immediately after getting the entire preliminary match making processes output.

– Autonomy: agents operate without the direct intervention of humans or others and have some control over their actions according to their beliefs and information they receive from the environment; they can make their own decisions based on their internal state and the environmental information they receive. The proposed HOTMS provides the decision-maker with all the required kind of knowledge, information and the best probable solutions and decisions but leaves the final control with human actors.

Adopting the proposed HOTMS in the future to be established, will provide and fulfill the following during the HOTM domain:

1. Knowledge sharing and integration of information by gathering and handling medical and organizational information and data fast, easy, secure from various data sources.

2. Enhancement of the domain through improving information flow between the involved parties by introducing reliable and actual information.

3. Establishment of easy communication and coordination between the different parties during the process

4. Allow negotiations of the responsible directions targeting an optimal solution

5. Assisting decision makers in making their different decisions introducing the needed information, data, guidelines and suggested solutions [ElHaa.2008].

As an end conclusion, one can assume that using a Multi-Agent HOTM will be of great importance in this domain as;

- It improves the performance & efficiency of the system as a whole
- Due to autonomous nature of the agents, it lightens the work burden by automating some tasks & activities
- Eliminate information management problems
- Eliminate communication & coordination problems
- Eliminate resource allocation problems
- Help decision-makers to take the right decisions
- Provide proactively timely reliable information, save time and money

6.3. Contribution

The researcher contributed in that research through introducing:

- Tackling, studying and analyzing a very new area in the health care domain on the national level

- The researcher proposed a Human Organ Transplantation Management Systems structure with its various layers and communicational relations.

- The researcher adopted the use of intelligent technologies as the multi-agent technology believing that it will enhance the HOTMS Performance

- The researcher as a member of the "Institute of National Planning" proposed a multi-agent HOTMS architecture hoping it could be developed, implemented and used in the future to assist and help the decision-makers in this domain.

6.4. Recommendations

- From a medical and ethical point of view, encourage the people to donor their organs after death believing that saving lives is one of the gorgeous and everlasting act one can do.

- From a technological point of view, it is advised to make use of agent technology in the HOTM domain to improve the systems services quality and to make use of the agent-based systems properties.

- Encouraging the HOT managers and decision makers to build such systems to support them during decision making

- Dedicating certain budget to finance the development of a multi-agent HOTMS

- Providing technological and technical facilities concerning,
    - Software Programs and tools; GPS, Agent Environment Frameworks...etc.
    - Communication Techniques; networking, satellites...etc.
    - Hardware facilities; personal computers, PDA's,...etc.

- After building the system, maintenance should be continued; adjustment and modification must be done periodically.

- From a medical and ethical point of view, encourage the people to donor their organs after death believing that saving lives is one of the gorgeous and everlasting act one can do.

- Generally, there is a great need to encourage industries, organizations to built their agent-based systems to support achieving their goals

Further work

6.5. Further Work

Adopting the proposed HOTM system structure and multi-agent architecture:

- Reanalyze and study the domain thoroughly in the following period
- Analyze and study all the HOTM system phases
- Design, develop and implement a prototype
- Try to test the prototype and evaluate its performance
- Improve agents role by expanding its functions and allow for more interactions

Appendix

According to the World Health Organization's Glossary of Donation and Transplantations Terms and Definition, the following expressions have been and defined and extracted:

- ***Actual Organ Donor***

Deceased or living person from whom at least one solid organ or part of it has been recovered for the purpose of transplantation. Editorial Group

- ***Allocation***

Allocation is the assignment of human cells, tissues and organs to a transplant candidate, based on a set of rules. Editorial Group

- ***Brain Death***

Irreversible cessation of cerebral and brain stem function; characterized by absence of electrical activity in the brain, blood flow to the brain, and brain function as determined by clinical assessment of responses. A brain dead person is dead, although his or her cardiopulmonary functioning may be artificially maintained for some time. Glossary of UNOS

- ***Cardiac Death***

Death resulting from the irreversible cessation of circulatory and respiratory function; an individual who is declared dead by circulatory and respiratory criteria may donate tissues and organs for transplantation. Editorial Group

- ***Certification of Death***

Formal standardized documentation of death. Refer to both cardiac death and brain death. Editorial Group

- ***Compatibility testing***

Testing for the presence or absence of recipient antibodies to HLA antigens and to blood group antigens present on the transplant cells, tissues or organs. Editorial Group

- ***Deceased Donor***

A human being declared, by established medical criteria, to be dead and from whom cells, tissues or organs were recovered for the purpose of transplantation. The possible medical criteria are:

- Deceased Heart Beating Donor (Donor after Brain Death): Is a donor who was declared dead and
diagnosed by means of neurological criteria.

- Deceased Non-Heart Beating Donor (Donor after Cardiac Death) = Non-heart beating donor (NHBD): Is a
donor who was declared dead and diagnosed by means of cardio-pulmonary criteria. Editorial Group

- ***Distribution***

Transportation and delivery of cells, tissues or organs intended for human applications, after they have been allocated. Modified from EU Directive 2004

- ***Donor***

A human being, living or deceased, who is a source of cells, tissues or organs for the purpose of
transplantation. Modified from FDA. Human Tissue Intended For Transplantation.

- ***Donor evaluation***

The procedure of determining the suitability of a potential donor, living or deceased, to donate. Editorial Group

- ***Donor maintenance***

The process and critical pathways used to medically care for donors in order to keep their organs viable until organ recovery can occur.Adapted from UNOS

- ***Donor safety***

A minimization of living donor complications or adverse reactions related to donation Editorial Group

- ***Living Donor***

A living human being from whom cells, tissues or organs have been removed for the purpose of transplantation. A Living Donor has one of the following three possible relationships with the recipient:

A/ Related:

A1/ Genetically Related:

1st Degree Genetic Relative: Parent, Sibling, Offspring

2nd Degree genetic relative, e.g. grandparent, grandchild, aunt, uncle, niece, nephew, Other than 1st or 2nd degree genetically related, for example cousin

A2/ Emotionally Related: Spouse (if not genetically related); in-laws; Adopted; Friend

B/ Unrelated = Non Related: Not Genetically or Emotionally Related. Editorial Group

- ***Procurement***

The process that includes donor identification, evaluation, obtaining consent for donation, donor maintenance and retrieval of cells, tissues or organs. Editorial Group

- ***Recipient***

The human being into whom allogeneic human cells, tissues or organs were transplanted. Editorial Group

References

1- [Alde.2001] A. Aldea et al., "A Multi-Agent System for Organ Transplant Coordination", in Artificial Intelligence in Medicine, volume 2101/2001 of lecture Notes in Computer Science, pages 413-416. Springer-Verlag, Berlin, 2001

2- [Ande.2009] Elizabeth Rakus-Andersson and Lakhmi C. Jain, "Computational Intelligence in Medical Decision Making" : in "Recent Advances in Decision Making ",SCI 222, pp. 145–159. Springer-Verlag Berlin Heidelberg 2009

3- [Bern.2007] Eta S.Berner & Tonya J. LA Lande, Overview " Overview of Clinical Decision Support Systems".: in Clinical Decision Support Systems Theory and Practice, Springer Verlag,2007

4- [Brad.1997] Jeffrey M. Bradshow, "Software Agents". American Association for Artificial Intelligence, 1997

5- [Brah.2010] Sheryl Brahnam and Lakhmi C. Jain (Eds.) , " Advanced Computational Intelligence Paradigms in Healthcare 5", Springer Verlag Berlin Heidelberg, 2010

6- [Caba.2003] David Cabanillas et al., "Carrel: Secure Deployment of an Agent-Based Health Care Application":. in "Applications of Software Agent Technology in the Health Care Domain", edi Antonio Moreno, John Nealon, Birkhaeuser verlag PO. Box 133, CH-4010 Basel, Switzwerland ISBN 3-7643-2662-x, 2003

7- [Cair.2002] Giovanni Caire, "JADE Tutorial: Application-defined Content Language and Ontologies", TILab, Italy, JADE 2.6 edition, June 2002.

8- [Carl.2002] Christer Carlsson & Efraim Turban, "DSS: directions for the next decade" : in Decision Support Systems 33 (2002) 105-110, Elsevier Science B.V., 2002

9- [ElHa.2008] Basmah El Haddad, " Intelligent Agencies in Decision Support Systems", Ph.D. Thesis, Ain Shams University, Faculty of Engineering, 2008.

10- [ElHa.2011] Basmah El Haddad, "Comparative Performance-based Comparison of an Existing Resource Management System with an Analogous Agent-Based Competitive System", Fifth International Conference on Intelligent Computing and Information

Systems , ICICIS, Faculty of Computer &Information Science, Ain Shams University, 30 June-2 July, 2010

11- [Fran.1996] Stan Franklin & Art Graesser. "Is it an Agent, or just a Program?:A Taxonomy for Autonomous Agents", In Proceedings of the Third International Workshop on Agent Theories, Architectures, and Languages. Springer- Verlag, 1996

12- [Fuzz.2005] Rachele Fuzzati & Boi Faltings , "Organ Transplantation Management", EPFL Technical Report IC 2005/022, Swiss Federal Institute of Technology Lausanne (EPFL), 2005

13- [Glob.2009] World Health Organization "WHO", "Global Glossary of Terms and Definitions on Donation and Transplantation", Geneva, November 2009

14- [Gupt.2006] Jatinder N.D. Gupta et al., " Intelligent Decision-making Support Systems Foundations, Applications and challenges", Springer-Verlag London, 2006

15- [Jain.2010] Lakhmi C. Jain, Chee Peng Lim (EDs.), " Handbook on Decision Making: Techniques and Applications", Springer-Verlag Berlin Heidelberg, 2010.

16- [Luck.2003] Michael Luck, Peter McBurney and Chris Preist, "Agent Technology: Enabling Next Generation Computing A roadmap for Agent Based Computing", Technical Report, AgentLink II, January 2003.

17- [McCa.2007] John McCarthy, "What is Artificial Intelligence Basic Questions", http://www-formal.stanford.edu/jmc/whatisai/ , 2007

18- [Meil.2010] Yannick Meiller et al. , "Adaptive knowledge-based system for health care applications with RFID-generated information", Decision Support Systems 51 (2011) 198-207, Elsevier B.V., 2010

19- [Mone.2005] Dagmar Monett, "Agent-Based Configuration of (Metaheuristic) Algorithms", Ph.D. Thesis, Humboldt –Universität zu Berlin Mathematisch-Naturwissenschaftliche Fakultät, 2005

20- [More.2003] Antonio Moreno, John Nealon, "Applications of Software Agent Technology in the Health Care Domain". Birkhaeuser verlag PO. Box 133, CH-4010 Basel, Switzwerland ISBN 3-7643-2662-x, 2003.

21- [Navi.2005] A. Lopez-Navidad et al., " Using Arguing Agents to increase the Human Organ Pool for Transplantation", 3rd Workshop on Agents Applied in Health Care, IJCAI-05, 2005

22- [Nikr.2006] Magid Nikraz et al. "A Methodology for the Analysis and Design of Multi-Agent Systems using JADE", In International Journal of Computer Systems Science & Engineering special issue on "Software Engineering for Multi-Agent Systems", May 2006.

23- [Petr.2007] Charles J. Petrie, "Agent-Based Engineering, the Web, and Intelligence". In IEEE Expert, December,1996. http://www.cdr.stanford.edu/ Nextlink/Expert.html 2007

24- [Powe.2008] Daniel J. Power "Decision Support Systems: A Historical Overview" in Handbook on Decision Support Systems, Springer, 2008

25- [Qays.2010] Israa Al-Qaysi et al., "Medical Diagnosis Decision Support HMAS under Uncertainty HMDSuU" .: in " Advanced Computational Intelligence Paradigms in Healthcare 5",", Springer Verlag Berlin Heidelberg, 2010

26- [Slom.2010] Aron Sloman, "What is Artificial Intelligence", University of Brimingham, http://www.cs.bham.ac.uk/~axs/misc/aiforschools.html ,2010

27- [Sord.2008] M. Sordo et al.: An Introduction to Computational Intelligence in Healthcare: New Directions, Studies in Computational Intelligence (SCI) 107, 1–26 (2008), Springer-Verlag Berlin Heidelberg 2008

28- [Sugu.2002] Vijayan Sugumaran, "Intelligent Support Systems Technology: Knowledge Management", IRM Press, USA, Idea Group Inc., Library of congress cataloging-in-Publication-Data, 2002.

29- [Syca.1998] Katia P. Sycara, " Multi-agent Systems", American Association for Artificial Intelligence, 1998

30- [Tolc.2007] Pancho Tolchinsky et al. , "Argumentation-Based Agents to Increase Human Organ Availability for Transplants" , Whitestein Series in Software Agent Technologies, 65-93 , Birkhauser Verlag Basel/Switzerland , 2007

31- [Turb.1998] Turban E & Aronson J, "Decision Support Systems and Intelligent Systems.", New Jersy Prentice-Hall, 1998

32- [Vauc.2003] Jean Vaucher, Ambroise Ncho , " JADE Tutorial and Primer", University de Montreal, September 2003, http://www.iro.umontreal.ca/~vaucher/Agents/Jade/JadePrimer.html 2008.

33- [Weis.1999] Gerhard Weiss, "Multiagent Systems a modern approach to distributed Artificial Intelligence", MIT Press, Cambridge, Mass.,1999.

34- [Wool.2002] Michael Wooldridge, "An Introduction to Multi-Agent Systems", John Wiley & Sons LTD, 2002

35- [Wren.2005] Gloria E. Phillips-Wren, Lakhmi C. Jain, "Intelligent Decision Support Systems in Agent-Mediated Environments", IOS Press, Inc. USA, 2005.

36- http://en.wikipedia.org/wiki/ Distributed_artificial_intelligence ,2/2011

37- http://en.wikipedia.org/wiki/Case_based_reasoning , 3/2011

38- http://en.wikipedia.org/wiki/Fuzzy_systems , 2/2011

39- http://en.wikipedia.org/wiki/Genetic_programming , 2/2011

40- http://en.wikipedia.org/wiki/Organ_transplantation, 3/2011

41- http://legal-dictionary.thefreedictionary.com/Organ+Transplantation , 3/2011

42- http://www.ahc.umn.edu/bioethics/prod/groups/ahc/@pub/@ahc/documents/asset/ahc_75699.pdf , 2/2011

43- http://www.nd.com/apps/medical.html , 2/2011

44- http://www.nd.com/neurosolutions/products/ns/whatisNN.html , 3/2011

ملخص بحث

" إستخدام نظم دعم واتخاذ القرار الذكية فى بعض مجالات الرعاية الصحية "

Using Intelligent Decision Support Systems in Selected Aspects of Health Care

د. م. بسمه محرم الحداد

يهدف هذا البحث الي دراسة إمكانية إستخدام و الإستفادة من تكنولوجيا الوكلاء في دعم ومساعدة المسئولين و متخذي القرار لإتخاذ القرارات الصائبة بشكل عام في شتي مجالات الرعاية الصحية وخصوصاً أثناء عملية " إدارة زراعة الأعضاء البشرية HOTMS". حيث يعتبر السيناريو الصحي في هذا الإطار تطبيقاً واقعياً لعملية إتخاذ القرار. كما يؤكد البحث علي أن تكامل تكنولوجيا الوكلاء بأنواعها وأساليبها وتفاعلها تسهم في اتخاذ القرارات الصحيحة وحل المشكلات بطريقة متقدمة.

تناول البحث عرض تحليلي للمفاهيم الأساسية و العامة و الأدبيات الخاصة ببعض الموضوعات ذات العلاقة و المترابطة من "ذكاء إصطناعي " ، "تكنولوجيا الوكلاء" ، " النظم الذكية لدعم وإتخاذ القرار" كأساس لموضوع البحث الرئيسي "نظام إدارة زراعة الأعضاء البشرية HOTMS" و ذلك بهدف إبراز فاعلية إستخدام تكنولوجيا الوكلاء المتعددين أثناء عملية " HOTMS"، والتي تُعتبر من أهم إسهامات البحث الحديثة لمصر و العالم العربي. فتم عرض وتقديم مقترح و هيكل لنظام إدارة زراعة الأعضاء البشرية خاص بحالة مصر و ذلك في إطار ما أتيح من بيانات ومعلومات محدودة لحداثة الموضوع محل الدراسة و عدم وجود إطار تشريعي كامل و واضح حتي صدور هذا البحث . و قد ساعد البحث بتقديم و تصميم مقترحاً مبدئياً لنظام إدارة زراعة الأعضاء البشرية الذكي المعتمد علي تكنولوجيا الوكلاء المتعددين . فتم عرض معمارية و هيكل النظام المقترح و تحليل العديد من العوامل المؤثرة فيه ، وكذلك تم إستعراض الوكلاء المختلفين بأنواعهم و أشكالهم و أدوارهم المختلفة في إطار النظام ، علي أن تقوم الباحثة في وقت لاحق ببحث أخر يهدف للبناء التطبيقي للنظام المقترح و ذلك حالما تتوافر البيانات والمعلومات الأساسية بشكل أعمق و أدق يتيح تحليل و تصميم و بناء النظام المبدئي في الواقع العملي.

كما أبرز البحث أيضاً أهمية و فاعلية إستخدام النظام المقترح المبني علي تكنولوجيا الوكلاء المتعددين بالأساس ، بالإضافة لبعض التكنولوجيات الأخري (مثل الشبكات العصبية الاصطناعية ANN والحوسبة التطويرية، والمنطق الضبابي، والبرهنة المبنية علي الحالات ، التي تم تناولها في الفصول التعريفية فقط) لمساعدة متخذي القرار في هذا الشأن علي المستوي القومي

والأقليمي في عملية " HOTMS". والذي أدي إلي التوصية الخاصة بالاستعانة بهذا المقترح عند تفعيل قانون زراعة الأعضاء البشرية و الذي أقر مؤخراً بعد سنوات طويلة من الجدل حول مشروعيته.

و فيما يلي إستعراض سريع لما تم تناوله بفصول هذا البحث :-

نظراً لأن الرعاية الصحية تمثل أحد اهتمامات الحكومة الرئيسية للتحسين والتعزيز والتطوير، حيث تواجه الرعاية الصحية كثيرا من المشكلات والتعقيدات التي يتطلب كل منها اتباع أساليب التخطيط و الاستعانة بالتكنولوجيات الحديثة الذكية للمساعدة في إتخاذ القرارات وحل المشكلات بشكل ملائم ، فقد تم استعراض المقدمة و التي تتضمن مشكلة البحث و تساؤلاته و أهدافه و أهميته في الفصل الأول.
حيث بدأ الفصل باستعراض مشكلة البحث وتساؤلاته عن طريق تناول مشكلة تزايد عدد المرضي المحتاجين لزراعة أعضاء بشرية بشكل عام و علي وجه الخصوص مرضي الكلي و الكبد طبقاً لأحدث إحصاءات وزارة الصحة بمصر مما يتطلب إنشاء نظام فعّال لإدارة و تنظيم زراعة الأعضاء البشرية HOTMS و ذلك بعد الموافقة الرسمية علي زراعة الأعضاء البشرية و صدور القانون الخاص و المنظم لهذه العملية في مصر بشكل رسمي بعد جدل دام لسنوات طويلة.

و تتضمن أهم تساؤلات البحث تحديد ما هو شكل و هيكل النظام الإداري و التنظيمي الذي يُفضل إتباعه بالنسبة لحالة مصر و من ثم مناقشة كل القضايا ذات العلاقة سواء من حيث المركزية أواللامركزية ، العلاقات التنظيمية المختلفة و إحتمال الإعتماد علي مبدأ التفاوض من عدمه في حال البحث عن عضو معين بمواصفات معينة و كذلك كيفية تنظيم عملية البحث عن العضو المناسب للشخص المناسب و ضمان الشفافية و النزاهة . ومن ثم التأكد من إتخاذ القرار الأمثل في هذا الصدد. كما كان من تساؤلات البحث الرئيسية أيضا تحديد التكنولوجيات المختلفة المرتبطة بالذكاء الاصطناعي و التي يمكن الاعتماد عليها لبناء النظام المقترح وتحديد هيكله و معماريته لضمان الشفافية و العدل و الفاعلية.

و قد تمثلت أهداف البحث في هدفين رئيسيين هما: الهدف الأول متمثلاً في توضيح أهمية استخدام النظم والتكنولوجيات الذكية فيما يتعلق بمفهومها العريض في مساعدة متخذي القرارات أثناء عملية اتخاذ القرار في إطار "نظام إدارة زراعة الأعضاء البشرية HOTMS" وعلي وجه الخصوص أن تكامل تكنولوجيا الوكلاء بأنواعها وأساليبها وتفاعلها تسهم في اتخاذ القرارات الصحيحة وحل المشكلات بطريقة متقدمة. أما الهدف الثاني المقدم يتمثل في اقتراح هيكل "HOTMS" وتطبيقه أثناء إنشاء النظام المصري لذلك في المستقبل القريب.
و ذلك بالارتكاز علي استعراض المفاهيم الأساسية للذكاء الاصطناعي و نظم دعم و اتخاذ القرار الحديثة بشكل دقيق و مبسط بحيث يخدم الباحثين غير المتخصصين في هذا المجال بشكل عام

بجانب الباحثين و العاملين بقطاع الصحة و الطب البشري لحثهم و تشجيعهم علي استخدام هذه التكنولوجيات الحديثة و الوثوق بها للعمل علي الاعتماد عليها لتنظيم أعمالهم انطلاقاً من الإتجاه الحديث لأهمية العلوم المتداخلة لبناء نظم فعالة ذات كفاءة. هذا إضافةً الي لفت انتباه متخذي القرار و المسئولين و القائمين علي نظام الرعاية الصحية في مصر الي أهمية استخدام النظم الحديثة و الذكية في المجال الطبي و مجال الرعاية الصحية عن طريق عرض العديد من الأمثلة والتطبيقات المختلفة في هذا المجال. وبالتالي تضمنت أهداف البحث وضع تصور لكيفية استخدام نظام عميل متعدد لإدارة زراعة الأعضاء البشرية في مصر حالما يتم التطبيق الفعلي للقانون المستحدث الجديد لضمان كفاءة وفعالية وجودة خدمات ذلك النظام.

و ترجع أهمية هذا البحث لحداثة الموضوع وأهميته و خاصة بالاعتماد علي التكنولوجيات الحديثة من إستخدام للوكلاء المتعددين و بعض تكنولوجيات الذكاء الاصطناعي والتي ترتبط بالحاجة الملحة لإنشاء نظام دعم قرار ذكي لإدارة زراعة الأعضاء البشرية بعد إصدار مجلس الشعب قانونا بذلك لمساعدة المرضي بصفة عامة ومرضي الكلي والكبد بصفة خاصة ، والذين يمثلون الشريحة الأكبر للمنتظرين نقل الأعضاء البشرية إليهم و ذلك من شأنه تحسين مؤشرات الصحة بشكل عام سواء من خفض معدل الوفيات أو زيادة عدد الأعضاء المنقولة بالإضافة لتقليل عدد الأعضاء المرفوضة و تحسين إدارة توزيع الأعضاء البشرية المتبرع بها.

و لتحقيق أهداف البحث فقد تم إتباع المنهج الوصفي التحليلي بالإرتكاز علي أحدث البيانات والمعلومات المتاحة في حينه و المراجع العلمية الأكاديمية الدولية في هذا المجال نظراً لعدم وجود أو توافر مراجع محلية في هذا الصدد.

أما الفصل الثاني و المعنون "القرن الحادي والعشرين: حقبة اتخاذ القرارات الذكية " يهدف الي عرض المفاهيم و الموضوعات التي تُعتبر هامه جداً لغير المتخصصين حيث أن الاستفادة الأساسية التطبيقية لهذه النظم ستكون من قِبلهم بفهمهم لها و اقتناعهم بتطبيقها. ومن ثم أشتمل الفصل علي موضوعات ذات طبيعة و أهمية خاصة لموضوع البحث منها: الذكاء والذكاء الاصطناعي ، عرض تاريخي لنظم دعم القرار المرتكز علي التعاريف المنبثقة من الأدبيات المنشورة عن هذا الموضوع ، وكذلك تضمن نظم دعم القرار الذكي المرتبط بالخصائص وأوجه عملية اتخاذ القرارات الذكية ، وأساليب تحديد اتخاذ القرارات الذكية التي تتضمن الشبكات العصبية الاصطناعية ANN والحوسبة التطويرية، والمنطق الضبابي، والبرهنة المبنية علي الحالات ، ونظم العملاء والعملاء الأذكياء والعميل المتعدد التي تم استعراضها من حيث الخصائص والمكونات ونواحي القوة.

بالنسبة للفصل الثالث و المعنون "الذكاء الاصطناعي والنظم الكمبيوترية في مجال الرعاية العلاجية والصحية" فإنه يوجه بالأساس للمتخصصين في مجال الرعاية العلاجية و الصحية لتشجيعهم و حثهم علي إستخدام مثل هذه النظم الذكية علي إختلافها في شتي مجالات الرعاية الصحية و الطبية. وبالتالي فقد تعرض لموضوعات مثل: اتخاذ القرارات الطبية والعلاجية الذكية

من حيث الأنواع والتشخيص ودعم اتخاذ القرار، وتصنيف نظم دعم القرار الذكية الكمبيوترية في مجال الرعاية الصحية. كما عرض أمثلة لبعض النظم و التطبيقات الذكية في مجالات مختلفة من الرعاية الصحية.

أما الفصل الرابع والمعنون "نظام إدارة زراعة الأعضاء البشرية الذكي: حالة مصر" فقد تعرض لموضوعات عديدة مرتبطة ارتباطاً وثيقاً بعملية إدارة زراعة الأعضاء البشرية HOTM. حيث بدأ بتحديد الأسباب العامة الرئيسية لنجاح زراعة الأعضاء البشرية بصفة عامة، من حيث أساليب الجراحة الحديثة والعلاج الطبي المطور علي المستوي العالمي ، وبينما يرتبط السبب الأول بالتقدم الطبي، فإن السبب الثاني يرتبط بظهور الهياكل التنظيمية والإدارية التي تنسق كل مراحل الهبات للأعضاء البشرية وعمليات زراعتها طبقا للأعراف والقوانين المحلية، والإقليمية، والقومية، والدولية.
استعرض الفصل بعد ذلك عملية "إدارة زراعة الأعضاء البشرية HOTM" بكل ما تحتويه من المراحل والعمليات المتضمنة والأبعاد الرئيسية المؤثرة علي زراعة الأعضاء البشرية من النواحي الطبية والمنطقية والإدارية والأخلاقية، والأطراف البشرية المتضمنة، وطبيعة وخصائص نظام إدارة زراعة الأعضاء البشرية والتحديات والمشكلات التي يواجهها النظام بشكل عام مما يُسلط الضوء علي أهمية تطويع التكنولوجيات المتاحة لحل مثل هذه المشكلات.
وبعد العرض العام للنظام تم استعراض و تحليل نظام إدارة زراعة الأعضاء البشرية في مصر كحالة خاصة و تم تقديم مقترحاً لهيكل النظام الإداري بعلاقاته المختلفة مرتبطاً بالتقسيمات الإدارية المصرية القومية والإقليمية وعلي مستوي المحافظات . كما تم تحديد سيناريو ما يحدث منذ اكتشاف المتبرع المتوفي حتي الوصول لأنسب متلقي لهذا العضو . وكذلك تم تحديد الأوجه المتقدمة لعملية مضاهاة الأعضاء المناسبة للمتلقيين المناسبين ، بالإضافة للإستعانة بعمليات تفاوضية تعتمد بالأساس علي تكنولوجيا العملاء المتعذدين للنظام المقترح لإدارة زراعة الأعضاء البشرية و التي تُعتبر إضافة و إسهام في البحث يخرج عن التصور التقليدي الذي يعتمد في الأساس علي كفاءة المضاهاة و قوائم الانتظارفقط.

و بالرغم من أن هذا الفصل قد أكد علي كفاءة وفعالية استخدام الوكلاء المتعددين أثناء مراحل وعمليات إدارة زراعة الأعضاء البشرية بشكل عام إلا أن الباحثة فضلت عدم التعرض للمقاييس والمعايير المحددة التي يجب أن توظف (بعد تطوير النظام المقترح) لتحديد قابلية استخدامه Usability و رأت عرض ذلك في دراسة قادمة تكون أكثر تحديداً بعد توفير البيانات و المعلومات المطلوبة لإنشاء مثل هذا النظام[١].

[١]تم عرض هذه المعايير في ورقة علمية قدمت من قبل الباحثة في المؤتمر الدولي الخامس للحوسبة و نظم المعلومات الذكية بجامعة عين شمس.

ويتناول الفصل الخامس و المعنون " نظام العميل المتعدد المقترح لإدارة زراعة الأعضاء البشرية " كل ما يتعلق بالنظام المقترح من العمليات الأساسية مع شرح مفصل لعمليات المضاهاة و المضاهاة المركبة و عمليات التفاوض داخل النظام. كذلك تعرض الفصل لمعمارية نظام العميل المتعدد المقترح و هيكله مع شرح تفصيلي لسيناريو تسجيل المتلقي وسيناريو اكتشاف المتبرع المتوفي و بالتالي خلص الفصل الي تحديد أنواع العملاء التي يمكن أن تتكامل و تتوافق مع نظام إدارة زراعة الأعضاء البشرية المقترح في السيناريوهات المختلفة في الأماكن المختلفة. و بالرغم أن هذا الفصل لم يتعرض لمنصة Platform معينة (حيث يتم تحديد ذلك في وقت لاحق عند بداية بناء النظام و هو خارج نطاق البحث الحالي) إلا أن الباحثه قدمت تصوراً كاملاً للوكلاء المحتملين بمسئوليات كل منهم من خلال مطابقتهم للواقع الفعلي للسيناريوهات المختلفة.

كما تعرض الفصل لمختلف أنواع الوكلاء مثل وكلاء واجهة التفاعل Interface Agents ووكلاء جمع البيانات و المعلومات Information Agents و وكلاء العمليات المختلفة Task Agents . والتي انبثق منها كل من وكيل منسق زراعة العضو البشري المعين Transplant Coordinator، ووكيل قاعدة البيانات Database Agent، ووكيل تكنولوجيا وجود مفاهيم زراعة العضو البشري والعلاقات بينها Ontology Transplantor الذي يرتبط بمنسق زراعة العضو البشري و غيرها. و يسهم هذا الجزء بشكل كبير في تحديد سيناريو أو إطار عمل للنظام المقترح في مصر.

و بالرغم من أن هذا البحث لا يتضمن البناء الفعلي للنظام المبدئي المقترح إلا نه قد تم عرض تصور لمنهجية تطوير و إنشاء و بناء مثل هذا النظام من حيث الخطوات المختلفة و البيانات والمعلومات المطلوبة. كذلك تم إيضاح وجود العديد من ال Platforms التي يمكن استخدامها عند بناء النظام. و أختتم الفصل بعرض المتطلبات و الشروط الرئيسية حتي يمكن تبني إنشاء هذا النظام المقترح في مرحلة قادمة بحيث يكون علي درجة عالية من الكفاءة و الفاعلية و المصداقية

أما الفصل السادس والأخير عن "النتائج و التوصيات و الإسهامات و الأعمال المستقبلية " فقد تطرق للاستنتاجات العامة والاستنتاجات المعينة و التي تنطبق علي النظام المقترح و بالتالي تحقق أهداف البحث. ثم تطرق البحث للمساهمات و التي أكدت علي أن الإسهام الأساسي في هذا الصدد هو التطرق لمثل هذا الموضوع الأكثر حداثة بالدراسة و التحليل و الخروج بمقترح يعد من أوائل المقترحات في مصر بعد صدور هذا القانون. و أنتهي الفصل بالتوصيات والعمل المستقبلي و الذي أكد علي ضرورة الإستعانة بمثل هذه الأنظمة بشكل عام و الاعتماد علي النظام المقترح في هذا الصدد بشكل خاص و من ثم توفيركافة الإمكانات لتحقيق ذلك (سواء شبكات ، قواعد بيانات، برمجيات الذكاء الإصطناعي، موارد مادية و بشرية ... الخ).

و الله ولي التوفيق

د.م. بسمه محرم الحداد