J Med Syst (2010) 34:251–259
DOI 10.1007/s10916-008-9236-7

ORIGINAL PAPER

Donor Research and Matching System Based on Data Mining in Organ Transplantation

Ali Serhan Koyuncugil · Nermin Ozgulbas

Received: 11 March 2008 / Accepted: 20 November 2008 / Published online: 7 December 2008

Abstract It is very important to identify the appropriate donor in organ transplantation under the time constraint. Clearly, adequate time must be spent in appropriate donor research in that kind of vital operation. On the other hand, time is very important to search for other alternatives in case of inappropriate donor. However, the possibility for determining the most probable donors as fast as possible has an great importance in using time efficiently. From this point view, the main objective of this paper is developing a system which provides probabilistic prior information in donor transplantation via data mining. While the sytem development process, the basic element is the data of successful organ transplantations. Then, the hidden information and patterns will be discovered from this data. Therefore, this process requires the data mining methods from its definition. In this study, an appropriate donor detection system design based on data mining is suggested.

Keywords Data mining · Donor matching · Organ transplantation · Health information systems · Electronic patient/medical records

A. S. Koyuncugil (✉)
Capital Markets Board of Turkey, Department of Research,
Eskisehir Yolu 8. km., No: 156, Balgat,
06530 Ankara, Turkey
e-mail: askoyuncugil@gmail.com

N. Ozgulbas
Faculty of Health Sciences,
Department of Healthcare Management, Baskent University,
Eskisehir Yolu 20. km.,
06810 Ankara, Turkey
e-mail: ozgulbas@baskent.edu.tr

Introduction

Data mining is one of the big gifts of the Information Technology since 1990's and still an actual phenomena. Advancements in IT has been made by the use of computers in every part of life. All processes has been realized by computers or with the help of computers. It have been made by collecting large amount of data. It has made life easier, but some problems has occured as well. One of these problems is huge data sets, in addition to this, reaching accurate knowledge in huge data sets. It triggered the idea called 'Knowledge Discovery' in that big amount of data. Therefore, data mining has been giving a chance to turn these big problems about data into a big strategical tool. Data mining is the core of knowledge discovery process, which is mainly based on statistics, machine learning and artificial intelligence. According to the Cabena et al. data mining is the process of extracting previously unknown, valid and actionable information from large databases and then using the information to make crucial business decisions [1]. Data mining is an evolutioniary area. Therefore, there is no single definiton for data mining but the given one is generally acceptable.

Every field of science and business search the way of use data mining in their domains. Mainly, data mining has been used in banking, finance, telecommunication and health because of produced large amount of data in very large range. Some of them only deal with data mining to increase profits in their business but some of them are only interested in usage of data mining to make life more comfortable or easier.

Nowadays, nearly all processes about patients and hospitals have been done with computers. Unfortunately, data mining applications have not become widespread in health sector, because most of the health and hospital data are not stored by datawarehouse logic. On the other hand, there has been increasing effort to apply data mining in health care and

medical cases. Healthcare researchers use data mining applications for many areas like physician practice patterns by measuring clinical, quality, customer satisfaction and economical indicators; clinical performance across multiple perspectives to optimize resource utilization, cost effectiveness, pathway development and evidence-based decision-making; identifying high-risk patients and to proactively intervene and optimize care across populations: data management and analysis to support internal and external comparisons and reporting requirements: clinical research and outcomes analysis to generate new knowledge and to optimize clinical care; approaches to uncover trends and patterns in clinical errors.

This study deals with only searching the way of contribution to save life via developing a system for donor searching and matching system in organ transplantation. Every field of healthcare as well as medical science experienced advancements. Most of the unsolved cases have reached solutions. One of the most important revolutions in medical science is organ transplantation. Organ transplantation gives second chance in life via operations. Most important problem in organ transplantation is finding appropriate donors, or in other words donor matching. Of course, there are a lot of medical ways for donor matching but time is very important constraint in that fight for live. This situation has been coincided the idea of using data mining in organ transplantation cases.

Some of recent studies in medical informatics and organ transplantation via analytical techniques and mostly data mining are presented in Table 1 below.

In this study, a donor research and matching system is developed for organ transplantation based on data mining. A-Priori algorithm was used as a data mining method in the system.

Organ transplantation in Turkey

Solid organ transplantation in Turkey began with two heart transplantation in 1969, both of which unfortunately were unsuccessful. In 1975, Mehmet Haberal and his team performed the first living-related renal transplant in Turkey. This was followed in 1978, by the first deceased donor kidney transplantation, using an organ supplied by Eurotransplant. In 1979 the law on harvesting, storage, grafting, and transplantation of organs and tissues was enacted; later that year, the first local deceased donor kidney transplantation was performed by Mehmet Haberal. In 1988, another groundbreaking event in Turkey was successfully achieved; the first cadaveric liver transplantation; and in 1990, the first pediatric living-related segmental liver transplantation in Turkey and in the region by Mehmet Haberal [21, 22].

First regulation about organ transplantation made On June 3, 1979. The Turkish Transplantation Law with number 2238 on harvesting, storage, grafting, and transplantation of organs and tissues were enacted. On January 21, 1982 some new articles were added to Law 2238, with the enactment of Law 2594. An amendment was also made in favor of organ and tissue retrieval from cadavers in 1982. Organ and tissue retrieval is divided into two parts; (1) Organ and tissue retrieval from living human beings, (2) Organ and tissue retrieval from a dead body (cadavers).

According to The Turkish Transplantation Law with number 2238 On the Harvesting, Storage, Grafting and Transplantation of Organs and Tissues [23]:

- **Article 3**—The buying and selling of organs and tissues for a monetary sum or other gain is forbidden.
- **Article 4**—Except for the distribution of information having scientific, statistical, and new characteristics, all advertisement in connection with the harvesting and donation of organs and tissues is forbidden.
- **Article 5**—Harvesting organs and tissues from persons under the age of 18 or who are not of sound mind is forbidden.
- **Article 6**—In order to be able to harvest organs and tissue from any person over the age of 18 who is of sound mind, a protocol, which beforehand the donor has approved of in writing and subscribed to verbally before at least two witnesses, should be approved by a physician.
- **Article 11**—In connection with enforcement of this law, the case of medical death is established unanimously by a committee of four physicians consisting of one cardiologist, one neurologist, one neurosurgeon, and one anesthesiologist by applying the rules, methods and practices which the level of science has reached in the country.
- **Article 12**—The physician who will perform the transplant surgery cannot be among the group which pronounced the donor as dead (Article 11).
- **Article 15**—Those harvesting, storing, grafting and transplanting organs and tissues in a manner not conforming to this law, and those intermediating in such actions as the buying and selling of organs and tissues and those brokering same, in the case that it does not require any heavier punishment, shall be sentenced to punishment of two (2) to four (4) years, and of 50,000 to 100,000 Turkish Lira.

According to Transplantation of Organs and Tissues Law No. 2594 Addendum (January 21, 1982) [24]:

- **Article 1**—In the event of any accident or natural death, provided that the cause of death is not in any way related to the reason for organ harvesting and according to the conditions stated in Article 11, the suitable organs and tissues can be transplanted into persons whose lives depend upon this procedure without permission from the next of kin.

In 2001, the health ministry established the National Coordination Center as an umbrella organization to pro-

mote transplantation activities, especially for deceased donor organ procurement. Transplantation activities are accelerating day by day all around the country, but deceased donors are still far below the desired rates. It still must be mentioned, however, that although cadaveric organ procurement is a great idea in theory—as is the case in many other countries—there are plenty of patients but not enough organs. Improvements in the fields of education and coordination should increase the quality and the quantity of transplantation activities.

According to the Organ Transplant Coordinators Association (ONKOD), kidney, liver, heart, kidney–pancreas, cornea, bone marrow, and a few heart and lung transplantations are performed in 13 province with 34 transplantation centers (heart transplantation in 12 centers, liver transplantation in 13 centers, kidney transplantation in 23 centers, cornea transplantation in 23 centers, bone marrow transplantation in 15 centers) and 60 hospitals with enough facilities for transplantation in 2007 [25]:

As seen in Table 2, in 2007, 1,318 kidney, 451 liver, 53 heart, 12 pancreas, two heart and lung, 258 cornea, one intestine, 28 cecum, totally 2,123 transplantations performed in transplantation centers. Also, Organ Transplant Coordinators Association reported that there were 89 donors from transplantation centers, 134 donors from the other hospitals and 223 donors in total in 2007. After establishing the National Coordination Center in 2001, transplantation coordination system made a good start at increasing cadaveric transplantation. Despite the increasing number of patients on the waiting lists, 15,787 patients have waited for the transplantation [26], the total numbers of donors are still far below the desired rates. When we consider the statistics, it is possible to say that Turkey needs a new system and reorganization for a larger organ pool, matching and shorter waiting lists. From that view of point a new system is proposed for the elimination of these problems and especially for time saving.

Data, method and system

Data source

The variables can collect into three main groups:

1. Demographic data like:
   - Gender,
   - Age,
   - Geographical Location,
   - Marital Status etc.
2. Medical records

Medical history of the all patients will be transformed into electronic records as structured data.

3. Life condition

Variables about the patients' daily habits and life conditions will be taken as structured data.

The method: A-priori Algorithm

The main method that will be used in our system is A-priori Association Rule Algorithm. Therefore, firstly the definition of association rules will be given then A-priori will be determined. Association rules is one of the most efficient methods for extracting patterns in transactional databases. Amir et al. defines association rule extraction as the process of finding frequent patterns, associations, correlations, or causal structures among sets of items or objects in transaction databases, relational databases, and other information repositories [27].

An association rule is an expression between two variables or subset of variables and it can be written in the form $A \rightarrow B$, where A and B denote subsets of variables. It basically shows a if–then rule and means if A occurs, then B occurs.

The strength of an association rule is commonly measured using support, confidence and lift, also known as measures of a rule's 'statistical interestingness' [28]. These 'statistical interestingness' measures are given below where $A \rightarrow B$ *denotes an association rule,* $N_{A \rightarrow B}$ denotes number of transactions which satisfy the rule and Ndenotes total number of transactions [29]:

$$\text{support}\{A \rightarrow B\} = \frac{N_{A \rightarrow B}}{N}$$

$$\text{confidence}\{A \rightarrow B\} = \frac{N_{A \rightarrow B}}{N_A} = \frac{N_{A \rightarrow B}/N}{N_A/N} = \frac{\text{support}\{A \rightarrow B\}}{\text{support}\{\text{A}\}}$$

$$\text{lift}\{A \rightarrow B\} = \frac{\text{confidence}\{A \rightarrow B\}}{\text{support}\{B\}} = \frac{\text{support}\{A \rightarrow B\}}{\text{support}\{A\}\text{support}\{B\}}$$

An association rule model should include these three interestingness measures and their values can imply the importance of the knowledge which is discovered. On the other hand, the amount of possible rule sets can be very large. Therefore, some strategies must be developed for reducing the rule sets have minor importance. Then, the possible data models will be selected from these reduced rule sets [29, Koyuncugil, A. S. (2006). Fuzzy data mining and its application to capital markets, Unpublished doctoral dissertation, Ankara University, Ankara, Turkey].

According to the Han and Kamber, the most representative association rule extraction algorithms are [30]:

- Apriori,
- DHP,
- Trie Data Structures,
- Iceberg queries.

Table 1 Summary of literature review

Authors	Year	Country	Method	Area Of application	Results	Ref. No
Aldea, A., Lopez, B., Moreno, A., Riano D., Vals, A.	2001	Spain	Multi Agents	Organ Transplant Coordination	Presented the design of a intelligent decision support system in a multi-agent architecture for organ transplant coordination	[2]
Yuan, Y., Feldhamer, S., Gafni, A., Fyfe, F., Ludwin, D.	2001	Canada	Fuzzy Logic	Organ Transplantation	Developed a fuzzy logic expert system which was used for kidney allocation	[3]
Staes, C., Huff, S. M., Evans, R. S., Narus, S., Tilley, C., Sorensen, J. B.	2005	USA	Model Designing	Organ Donor	Developed a model for storing information of transplant patients in electronic medical records	[4]
Mcdonald, J.M., Brosette, S.,Moser, A.	1998	USA	Pattern Recognition, Data Mining	(Pathology) Information Systems	Presented data mining to discover new patterns that provide new knowledge in health care	[5]
Vason, B. J.	2004	USA	Data Mining	Infection Control Surveliance	Provided strategies for infection surveillance include data mining	[6]
Blatt, R. J.	2000	USA	Data Mining	Biological Banking	Provided an overview of key policy of biological banking	[7]
Rodriguez, A., Carazo, J. M., Trelles, O.	2005	Spain	Data Mining (Association Rules)	Biological Databases	Developed a new algorithm which specialized on bioinformatics and discovered low magnitude similarities in biological databases. Also, introduced a new and promising application of the rule extraction algorithm on gene expression databases	[8]
Pool, R., Esnayra, J.	2000	USA	Database Preparation	Bioinformatics	Presented database integrity, curation, interoperability, and novel analytic approaches	[9]
Han, J., Kamber, M.	2001	USA	Data Mining	Bioinformatics	Gave an introduction to the bridge between data mining and bioinformatics	[10]
Liew, C., Yan, H., Yang, M.	2005	Germany	Data Analysis, Knowledge Discovery	Bioinformatics	Analyzed microarray data and microarray technology used for genome expression study, image analysis for data extraction, and data analysis for pattern discovery	[11]
Liew, C., Yan, H., Yang, M.	2005	USA	Data Mining	Bioinformatics	Presented applications of data mining in bioinformatics	[12]
Tse, B., Hume, D., Chen, Y.P.	2005	Germany	Data Mining	Bioinformatics	Mentioned the issues in motif recognition and motif detection strategies	[13]
Toldo, L., Rippmann, F.	2005	Germany	Data Mining	Bioinformatics	Developed a method that automatically assigns putative functions to DNA sequences	[14]
Ken, M., Garfield, S., Morris, N.	2006	Great Britain	Knowledge Discovery-Text mining	Bioinformatics	Discussed the way of tackling the fragmentation of knowledge problem in living systems.	[15]
Sumathi, S., Sivanandam, S.,N.	2006	USA	Data Mining (Sequential Pattern Analysis, Similarity Search)	Biomedicine	Gave examples about usage of data mining	[16]
Shah, S., Kusiak, A., Dixon, B.	2003	USA	Data Mining (Decision Rules and Decision Trees)	Kidney Dialysis Treatment	Elicited knowledge about the interaction between kidney dialysis treatment variables and patient survival.	[17]

Kusiak, A., Dixonb, D., Shah, S.	2005	USA	Data Mining (Decison Rules And Decision Trees)	Kidney Patients	Discover knowledge about the interaction between many measured parameters for kidney patients and patient survival	[18]
Jiang, D., Jian, P., Ramanathan, M., Lin, C.	2007	USA	Dvata Mining (Cluster Analysis)	Gene Coherent	Presented two algorithms which names are Sample-Gene Search and the Gene-Sample Search to mine data set	[19]
Ramon, J., Fierens, D., Güiza, F., Meyfroidt, D., Blockeel, H., Bruynooghe, M., Van Den Berghe, G.	2007	Belgium	Data Mining	Intensive Care Patients	Described the application of data mining methods for predicting the evolution of patients in an intensive care unit	[20]

Apriori implements an iterative process where k—itemsets are used, in order to discover (k + 1)—itemsets [31]. Apriori algorithm starts from the simplest rules and proceeds by adding items. The algorithm starts by selecting a subset from selected itemset or variables according to the predefined threshold value t. If the value of support for subset passes the t value then subset are selected else discarded [Koyuncugil, A. S. (2006). Fuzzy data mining and its application to capital markets, Unpublished doctoral dissertation, Ankara University, Ankara, Turkey; 32].

The main logic of A-priori and the other association rules algorithms as well are based on Conditional Probability calculations as seen above. But the principal attribute of Association Rules Algorithms is the ability to set a limitation value. This limitation value provides to ignore weak possibilities and then focusing the most probable matches. Actually, this is the most strong property of the A-priori Algorithm and it makes taking into account the major relations but ignoring the minor relations. On the other hand, Algorithm's most strong property is the most weak property at the same time for donor cases. Because the algorithm ignores the minor relations. Therefore, in case of a donor matching not observed before will not be taking into consideration until it has frequent observation according to presetting limit. In addition, it is possible to put a lower limit but it makes to deal with a lot of combinations and a lot of possible matches. Therefore, the user defined limitation values is very important for searching and matching process.

Donor research and matching system

The system is based on two main steps: Prior and the system steps. Prior steps are preperation steps of the system for providing necessary data to process. System steps are defining the core research and match system. The System is given in Fig. 1.

I. Prior steps

1. Development of electronic patient records: All variables about the patients will be tranformed into electronic patient records as structured data.
2. Development of hospital databases: Electronic patient records will be collected in the databases which is called as Hospital Databases (HDB).
3. Selection of organ transplantation records: HDBs will include all kind of patients' records. Therefore, only the records of patients who had a organ transplantation operation will be selected for further data migration. Assume that there are n hospital databases in different locations as HDB1, HDB2,..., HDBn. Only organ transplantation records from all HDBs will be selected for migration.

Table 2 Number of transplantations performed in transplantation centers (2007)

Transplantations	Cadaver	Live	Total
Kidney	344	802	1318
Liver	132	258	451
Heart			53
Pancreas			12
Heart and Lung			2
Cornea			258
Intestine			1
Cecum			28
Total	476	1060	2123

II. Steps of the system

1. Data migration to organ transplantation database: Data belongs to succesfull organ transplantation cases will be collected in a unique database which is called Organ Transplantation Database. All records in country (or world wide) will be collected in a central database. Organ Transplantation Database will be a web enabled and applications will be realized via internet.
2. Data preparation: Missing value, outlier and the other data problems will be solved.
3. Organ selection: The organ subject to query will be selected.
4. Determination of important variables

a. Implementation of A-priori algorithm for organ Yi: A priori algorithm will be implemented for determination of important variables in successful organ transplantation cases. Threshold value t will be determined according to the expert knowledge based on past experiences.

b. Determination of important variables for organ Yi: Most important variables and factors according to the organ correspondence will be determined via A-priori algorithm. In other words, data will be reduced. Reduced data set will be included rule set which identifies the most important variables and factors according to their importance level. Importance level will be considered as an occurrence frequency or in another words statistical interestingness. Therefore, three measures which are called as statistical interestingness will become the base of determination of important variables.

5. Determination of organ correspondence

a. Matching corresponding donor with determined important variables via SQL query: Important relations, rules and variables which discovered via A-priori algorithm will be selected for SQL query. Applicant of organ Yi will be subjected to SQL query for selected variables. Therefore, the organ that is subject to query will be compared due to relations, rules and variables

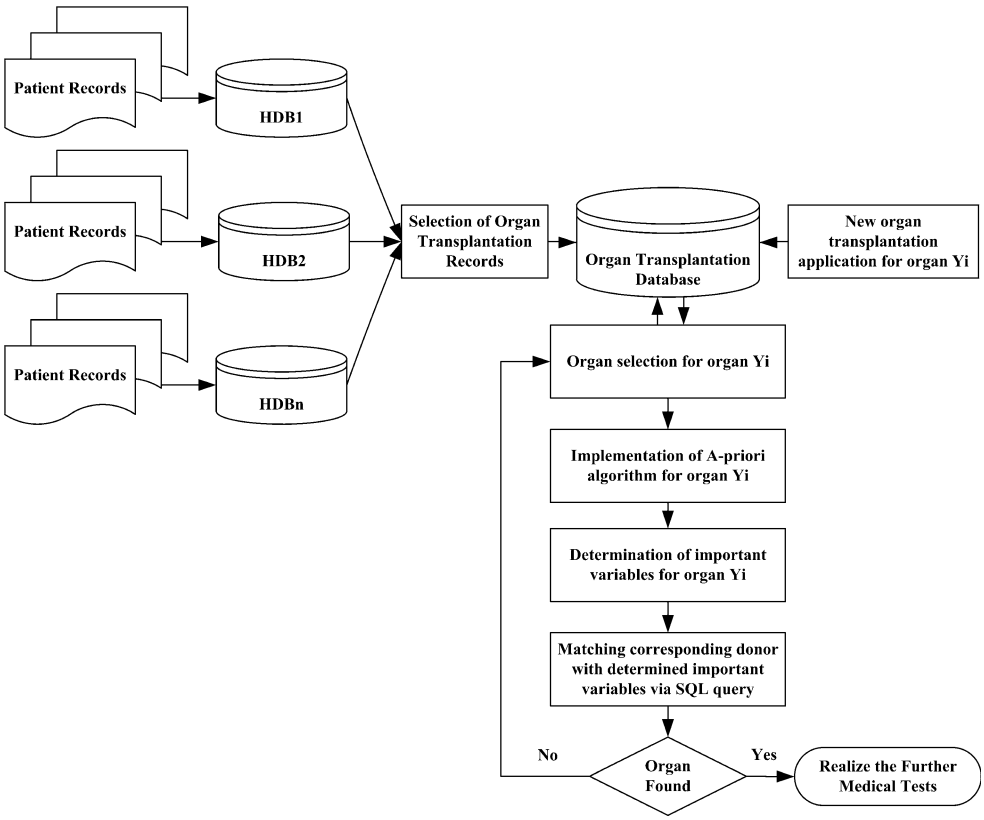

Fig. 1 Donor research and matching system

that were discovered, and then will be decided to correspondence probability as a prior information.

b. Organ found: If the prior information shows that the organ looks appropriate for the transplantation then further medical tests will be realized. If the prior information shows that the organ looks inappropriate for the transplantation then a new donor will be searched.

Limitations on implementation of the system with real data from Turkey

At the beginning of this study an implementation phase with real data has been planned as an example for the clarification of the System's accuracy. Therefore, it would be possible to show the real world results of the System. But at the application process Ministry of Health of Turkey (MOHT) was rejected to provide real data according to the Turkish Statistics Law Article 13 which is given below.

Statistics Law of Turkey (Number of the Law: 5429, Date of Approval: 10/11/2005; Published Official Gazette Date and Number: 18/11/2005 and 25997) [33].

- **Article 13**—Confidential data can be accessed only by the ones involved in the production of official statistics, to the extent that they need for performing their duties properly. If the number of the statistical unit in any cell of the data table formed by aggregating the individual data is less than three or one or two of the statistical units are dominant even if the number of units is three or more, the data in the concerned cell is considered confidential.

The confidential data compiled, processed and preserved for the production of official statistics cannot be delivered to any administrative, judiciary or military authority or person, can not be used for purposes other than statistics or as an instrument of proof. Civil servants and other staff in charge of compiling and processing these data are obliged to comply with this rule. This obligation continues after the related personnel leave their duties and posts.

The rulers of the institutions and organisations producing official statistics shall take all measures to prevent any illicit access, use or revelation of the confidential data. Data or information obtained from sources that are open to all people shall not be deemed confidential.

Data confidentiality ceases when a statistical unit gives written approval for the revelation of confidential data concerning itself.

Confidential data can be published only as combined with other data so as not to allow any direct or indirect identification.

Principles and procedures relating to data confidentiality and security shall be regulated through statutes to be issued in line with national and international principles and by soliciting the opinion of relevant institutions and organisations.

The authors of this study then decided to ask data from research hospitals for a Pilot study according to the reviewers comments but unfortunately this applications were rejected with the same reason of the MOHT.

Policy implications

In December 2003, the government of Turkey announced a new and comprehensive reform program, titled 'Health in Transition'. The health reform has aimed at organizing, financing and delivering the health services in an effective, productive and equal way. The major components of this program comprised the institutional strengthening of Ministry of Health, introduction of a universal health insurance, a reorganization of the health service delivery, development of the human resources in the health sector, quality assurance and accreditation of health facilities; establishment of a National Pharmaceutical and Medical Devices Agency and the development of a sound information system for the national health service [34].

Quality in health care, effectiveness, equity and patient safety are the primary goals of reform studies in health. When these objectives were considered in terms of organ transplantation and the number of patients in need of organ transplants, it was seen that Turkey needs a new system for donor research and matching. Donor Research and Matching System Based on Data Mining presented in this paper will ensure an equitable nationwide system for the distribution of transplantable organs. Beside these, this System provided some other advantages for the policy makers and health reform studies:

- Data warehouse and statistical analysis infrastructure,
- High quality data for strategic decision making process,
- Fast, accurate and reliable reporting base for health system,
- Evidence based medical processes,
- Measurable, objective, comparable and transparent results for higher patients safety,
- Ability to perform performance measures and benchmarking for the evaluation of transplantation centers by using System's data.

Therefore, this system should take into consideration in the manner of Organ Tranplantation component of the information system for Health Transition program.

In addition, Turkish Statistics Law Article 13 or its implementation process should be changed for scientifical studies. Especially in health studies personal data always becomes the vital base. Therefore, restrictions on using personal data should be ignored at least in health studies.

Conclusion

In this study a system is proposed for donor research and matching. System is mainly based on A-priori algorithm and aims to reduce minor rules in organ transplantation and then to find important factors in major rules, and finally to match the correspondent donors according to the important rules via SQL query. Authors aim to shorten the necessary time for finding the corresponding donor and to make it available via internet.

It is possible to process the system in an only one hospital database, but to increase accuracy of the system, a unique nationwide or world wide transplantation database should be developed.

System was orientated for finding strick rules according to the predefined t value due to the past experiences. In further studies, fuzzy rules can be taken into consideration. Therefore, the system can find almost closer ones than exact one.

At the beginning of this study authors have been planned to process the system with real data. Unfortunately, system couldn't processed because of the Turkish Statistics Law. In furthere studies, the system can be processed with real data and according to results of the System some improvements can be made in the System.

However, data mining can be used as an aid for diagnosis in clinical trials and for obtaining cure alternatives. In addition, early warning and surveillance systems based on data mining can be developed for detection and control of communicative diseases as well.

References

1. Cabena, P., Hadjinian, P., Stadler, R., Verhees, J., and Zanasi, A., *Discovering data mining: from concept to implementation*. Prentice Hall PTR, Upper Saddle River, New Jersey, USA, 1997. (pp. 195).
2. Aldea, A., Lopez, B., Moreno, A., Riano D., & Vals, A. (2001). Multi-agent System for Organ Transplant Coordination. Artificial Intelligence Medicine: Proceedings of 8th Conference on AI in Medicine in Europe, AIME 2001, Cascais, Portugal, July 1–4, 2001. Springer Berlin/Heidelberg, pp. 413.
3. Yuan, Y., Feldhamer, S., Gafni, A., Fyfe, F., and Ludwin, D., An internet-based fuzzy logic expert system for organ transplantation assignment. *International Journal of Healthcare Technology and Management*. 3:56, 2001.
4. Staes, C., Huff, S. M., Evans, R. S., Narus, S., Tilley, C., and Sorensen, J. B., Development of an information model for storing organ donor data within an electronic medical record. *Journal of American Medical Informatics Association*. 12:3357–363, 2005. doi:10.1197/jamia.M1689.
5. Mcdonald, J. M., Brosette, S., & Moser, A. (1998). Pathology information systems: Data mining leads to knowledge discovery. *Archives of Pathology & Laboratory Medicine*, May.
6. Vason, B. J., Mine data to discover infection control trends. *Nursing Management*. 35:646, 2004. doi:10.1097/00006247-200406000-00014.s.
7. Blatt, R. J., Banking biological collections: data warehousing, data mining, and data dilemmas in genomics and global health policy. *Community Genetics*. 3:204–211, 2000. doi:10.1159/000051140.
8. Rodriguez, A., Carazo, J. M., and Trelles, O., Mining association rules from biological databases. *Journal of. American Society for Information Science and Technology*. 56:5493, 2005. doi:10.1002/asi.20138.
9. Pool, R., Esnayra, J. (2000). *Bioinformatics: converting data to knowledge*. A Workshop Summary, National Academy of Sciences.
10. Han, J., Kamber, M. (2001). *Data mining: concepts and techniques*, Kaufmann.
11. Liew, C., Yan, H., Yang, M. (2005). *Microarray data analysis in bioinformatics technologies* Yi-Ping Phoebe Chen (Eds.). Berlin Heidelberg: Springer-Verlag, pp. 353–388.
12. Liew, C., Yan, H., Yang, M. (2005) *Data Mining for Bioinformatics in Bioinformatics Technologies* Yi-Ping Phoebe Chen ((Eds.), Berlin Heidelberg: Springer-Verlag.
13. Tse, B., Hume, D., Chen, Y.P. (2005). *Pattern matching for motifs in bioinformatics technologies* Yi-Ping Phoebe Chen (Eds.), Berlin Heidelberg: Springer-Verlag, pp. 299–312.
14. Toldo, L., and Rippmann, F., Integrated bioinformatics application for automated target discovery. *Journal of the American Society for Information Science and Technology*. 56:5483, 2005. doi:10.1002/asi.20137.
15. Ken, M., Garfield, S., and Morris, N., Recent trends in knowledge and data integration for the life sciences. *Expert Systems*. 23:5330, 2006. doi:10.1111/j.1468-0394.2006.00414.x.
16. Sumathi, S., Sivanandam, S. N. (2006). *Introduction to Data Mining and its Applications*, Berlin Heidelberg: Springer-Verlag, 828 pages, Chapter 21: Data Mining in Biomedicine and Science, pp. 499–627.
17. Shah, S., Kusiak, A., Dixon, B. (2003). Data Mining in Predicting Survival of Kidney Dialysis Patients. In *Proceedings of Photonics West—Bios 2003*, Bass, L. S. et al. (Eds.), *Lasers in Surgery: Advanced Characterization, Therapeutics, and Systems XIII*, Vol. 4949, pp.1–8.
18. Kusiak, A., Dixonb, D., and Shah, S., Predicting survival time for kidney dialysis patients: a data mining approach. *Computers in Biology and Medicine*. 35:311–327, 2005. doi:10.1016/j.compbiomed.2004.02.004.
19. Jiang, D., Jian, P., Ramanathan, M., and Lin, C., Mining gene-sample-time microarray data: a coherent gene cluster discovery approach. *Knowledge and Information Systems*. 13:3305–331, 2007. doi:10.1007/s10115-006-0031-9.
20. Ramon, J., Fierens, D., Güiza, F., Meyfroidt, D., Blockeel, H., Bruynooghe, M., and Van Den Berghe, G., Mining data from intensive care patients. *Advanced Engineering Informatics*. 21:3243–256, 2007. doi:10.1016/j.aei.2006.12.002.
21. Karakayalı, H., and Haberal, M., The history and activities of transplantation in Turkey. *Transplantation*. 37:7341–344, 2005.
22. Tokalak, I., Karakayali, H., Moray, G., Bilgin, N., and Haberal, M., Coordinating organ transplantation in Turkey: effects of the National Coordination Center. *Progress in Transplantation*. 15:3283–285, 2005 Sep.
23. The Turkish Transplantation Law On the Harvesting, Storage, Grafting and Transplantation of Organs and Tissues, Law No. 2238, June 3, 1979.
24. The Turkish Transplantation of Organs and Tissues Law No. 2594 Addendum, January 21, 1982.

25. Organ Transplant Coordinators Association (ONKOD): (consulted: September 2008): http://www.onkod.org/istatistik.php.
26. Ministry of Health of the Republic of Turkey (MoH): (consulted: September 2008): http://www.saglik.gov.tr.
27. Amir, A., Feldman, R., and Kashi, R., A new and versatile method for association generation. *Information Systems*. 22:333–347, 1999. doi:10.1016/S0306-4379(97)00021-5.
28. Hand, D. J., Mannila, H., and Smyth, P., *Principles of data mining*. MIT, Cambridge, MA, USA, 2001.
29. Giudici, P., *Applied data mining: statistical methods for business and industry.* Wiley, England, 2003.
30. Han, J. (2002). How can data mining help bio-data analysis? Proceedings of the 2nd ACM SIGKDD Workshop on Data Mining in Bioinformatics,1–2.
31. Agrawal, R., Srikant, R. (1994). Fast algorithms for mining association rules. In J. B. Bocca, M. Jarke, & C. Zaniolo (Eds.), *Proc.20th Int. Conf. Very Large Data Bases VLDB* (pp. 487–499), Kaufmann.
32. Hastie, T., Tibshirani, R., Friedman, J. H. (2001). The Elements of Statistical Learning. Springer.
33. Statistics Law of Turkey, Law No.5429, November 10, 2005.
34. Ministry of Health of the Republic of Turkey (MoH) (2002). Health Transformation Programme, Ankara: MoH.