Selection database is one of the main problem in designing Electronic Medical Record (EMR) Software, because that there are many different data with different types and format in it. This work provide an approach for select suitable Data Base Management System (DBMS) with Fuzzy Analytical Hierarchical Process that gives capabilities of requirements to electronic medical record software. Criteria are choose based on capabilities of requirements which including supporting from type of operating system and programming language, maximum of table size, indexing, replication and access control. In addition, alternatives are database considered as PostgreSQL, MySQL, Oracle, DB2 and Microsoft SQL Server. Owing to the application
Electronic Medical Record is the foundation of all activity in healthcare information technology [1]. Actually, without development of an electronic medical record software which includes health’s data and information related to humans’ population and that is able to access in every time and place for clinic, hospital, and any healthcare organization, other activities can’t be done. Patient records one of the information resources that contains very large data volume with many different data types which cause storage approach in EMR to be faced with some of challenges [1, 9].

For solving these challenges and problems, numerous storage approaches and database DBMS are proposed that each one has strengths and weaknesses. Software engineering or designer, according to requirements and capabilities of expected from EMR, from between exist methods chooses suitable DBMS. In this work, one of the Fuzzy Multi Criteria Decision Making (FMCDM) methods called FAHP is used for select DBMS. In FAHP, decision maker have a set of alternatives and a set of criteria that appropriate alternative is chosen according to the pairwise comparison between alternatives and criteria [2].

HELLMAN and et al [3] have been used AHP to select appropriate DBMS for Erlang programming language which PostgreSQL, MySQL, Berkeley DB, and Ingres are alternatives and set of criteria include Safety, Large Data, Replication, Mint Logical Constraint, and Erlang Interface. The priorities which obtained based on AHP in the work [3] are as follows: Berkeley DB< MySQL< PostgreSQL< Ingres.

In the present study, the criteria are Operating System, Indexes, Access Control, Size of Table, Replication and Programming Language and alternative are include PostgreSQL, MySQL, DB2, Oracle, and Microsoft SQL Server. In fact in the above-mentioned work all comparison and all scales considered as crisp number. To compare different criteria such as $C_1$ = Operating System, $C_2$ = Indexes, $C_3$ = Access Control, $C_4$ = Size of Table, $C_5$ = Replication, $C_6$ = Programming Language, it is better to use fuzzy scales and linguistic terms. Therefore, for covering the subjective uncurtaining of decision maker for evaluation of criteria and alternative we propose FAHP.

Based on our best knowledge, this work is the first study for ranking different DBMS to EMR software based on FAHP. In this work for the first time criteria are considered operating system, indexes, access control, size of table, replication, programming language. In fact the previous work just introduce Safety, Large Data, Replication, Mint Logical Constraint, and Erlang Interface. Furthermore, PostgreSQL, MySQL, DB2, Oracle, SQL are added as alternatives.

Fuzzy AHP

One Multi Criteria Decision Making technique, the Analytic Hierarchical Process (AHP), has been commonly used in industry to aid in concept selection [10]. Saaty (1981) first developed the AHP method for decision making. Marsh et al (1991) developed a more direct method specifically for design decision-making [6]. This AHP has three steps ordering the factors of a decision such that most important ones receive the greatest weight. Zahedi (1986) provides an extensive list of references on the AHP methodology and its application [2].

The fuzzy AHP method, which combines AHP and fuzzy logic, allow a more accurate description of the decision making. Fuzzy set theory a mathematical theory pioneered by Zadeh which is design to model the vagueness or imprecision of human cognitive processes [4]. What is important to recognize is that any crisp theory can be made fuzzy by generalizing the concept of a set within that theory into the concept of fuzzy set. Fuzzy set theory and fuzzy logic have been applied to a great variety of applications. Amongst the numerous application of fuzzy set theory, engineering design emerges as an important activity for organization that have previously lacked tools to manage the large amount of imprecise information that they usually encounter [2].

Problem Definition

The problem is defined using of a hierarchical, including of objective, criteria and alternative. In other words at the beginning of decision process, selector according to alternative, criteria and objective, implies the relationship between these elements is expressed in terms of hierarchy. Figure 1 shows hierarchical or definition for problem of DBMS selection. As the showing in figure 1, objective is choice suitable DBMS from
between of PostgreSQL, Oracle, MySQL, DB2 and SQL based on Operating System, Indexes, Access Control, Size of Table, Replication, Language Programming.

The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set. A fuzzy set is defined by a membership function. The membership function maps elements in the universe of discourse to elements within a certain interval, which is usually \([0, 1]\) [5]. Fuzzy concept are used for comparison between DBMS based on criteria which these concepts are expressed by Linguistic Terms. There are different methods scoring that these are different from each other in number of point or linguistic terms such as scoring method with 5, 7, 9 or 11 point [2] that in this work is used from 9 point scoring method. In this study, triangular fuzzy numbers are used to represent subjective pair-wise comparisons of selection process (Table 1).

Table 1: Linguistic Term and Corresponding fuzzy number [6]

<table>
<thead>
<tr>
<th>Fuzzy Number Linguistic term</th>
<th>(1,1,2) Equally important</th>
<th>(2,3,4) Moderately more important</th>
<th>(4,5,6) Strongly more important</th>
<th>(6,7,8) Very strongly more important</th>
<th>(8,9,10) Extremely more important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuzzy Number</td>
<td>(1,1,2)</td>
<td>(2,3,4)</td>
<td>(4,5,6)</td>
<td>(6,7,8)</td>
<td>(8,9,10)</td>
</tr>
</tbody>
</table>

A triangular fuzzy number denoted as \( M=(l,m,u) \) where \( m, u \), has the following triangular-type membership function [2]:

\[
\mu(x) = \begin{cases} 
0 & x < l \\
(x-l)/(m-l) & l \leq x \leq m \\
1 & m < x \\
(u-x)/(u-m) & m \leq x \leq u \\
0 & x > u
\end{cases}
\]

Alpha-cut concept is used to perform mathematical operations such as multiplication, division and subtraction, which \( \alpha \) is value in \([0, 1]\). Alpha-cut for triangular number is obtained by using the formula 2:

\[
\alpha \text{cut} = \begin{cases} 
n(l) = (l^\alpha, m^\alpha, u^\alpha) \\
n(l) = (l^\alpha, u^\alpha, m^\alpha)
\end{cases}
\]

Actually, \( \alpha \)-cut result is interval and mathematical operation are performed on this interval. The main operation for positive fuzzy number such as \( M, N \) are shown in formula 3, 4, 5 [11]:

\[
M \cdot N = (m_L^\alpha, m_R^\alpha), (3)
\]

\[
M \div N = (m_L^\alpha, m_R^\alpha), (4)
\]

\[
M = (m_L^\alpha, n_L^\alpha, m_R^\alpha), (5)
\]

\[
N = (n_L^\alpha, n_R^\alpha), (6)
\]

The selection steps of suitable alternative by using of FAHP it can be summarized follow [2]:

Problem definition: the first, objective, alternative and criteria are identified and they are shown in the hierarchical diagram (Figure 1).

Pairwise comparison criteria matrix: this step has a matrix which in it the importance of each criteria relative to each other is expressed by linguistic terms, and relative to it, entries of matrix will be filled. Eigen value obtained in this step, show the weight of criteria.

Pairwise comparison alternative matrix based on criteria: at this step, number of matrix is equal to the number of criteria and all of the alternative are be compared with each other based on all of the criteria. Calculation of Eigen Value for all matrixes: for each of matrix in step 2, 3, Eigen Value is calculating. Thus the, the first for all rows, the geometric mean is calculate by the formula 7 and then for any matrix, the value obtained are normalized and are placed in a separate column.

Selection suitable alternative or determine priority of alternative: finally, priority of alternative for selection is determined. In order to do this, weight vector obtained in step 2 be multiplied by the all of the Eigen value column in step 3.

Pairwise Comparison of Criteria

Criteria considered include:

- Different operating system that database can implementation on them. About tis criteria, many more operating system for a DBMS means less important is the choice operating system for it.
- Number of indexing method that database can supported: more methods of indexing for a DBMS means more important of indexing in it.
- Number of access control method that database provides: most of access control methods for a DBMS means more important of access control in it.
Maximum size of table that can be created in the database: larger size of table in the database show supporting of large data is more important in it.

Different type of mechanisms for replication: more mechanism of replication in a DBMS means that replication is more important in it.

Programming language that can be supported: more programming language which a DBMS can be supported show less important of programming language in it.

At first, criteria matrix is created. In this matrix, fuzzy number is allocated to entries based on some of analysis relative to expected feature from EMR software. For example, one of the important features that the software should have, is support for large amounts of data. Therefore importance of information or data replication and capability to implement distributed is more than type of operating system or programming language which software implement by them. So, priority of replication relative to operating system can be expressed as extremely more important and fuzzy number that placed in (REP, OS) is (8,9,10), and its inverse i.e. (1/10,1/8,1/9), placed in (OS, REP). Similarly, another entries are all set (Table 2). The last column of the matrix represents Eigen value that Eigen value in the criteria matrix same weight.

Table 2: Matrix of pairwise comparison of criteria

<table>
<thead>
<tr>
<th>Eigen Value LP</th>
<th>REP</th>
<th>SOT</th>
<th>AC</th>
<th>IND</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0/018,0/024,0/037)</td>
<td>(1,1,2)</td>
<td>(1/10,1/9,1/8)</td>
<td>(1/8,1/7,1/6)</td>
<td>(1/8,1/7,1/6)</td>
<td>(1/10,1/9,1/8)</td>
</tr>
<tr>
<td>(0/154,0/226,0/334)</td>
<td>(8,9,10)</td>
<td>(1/8,1/7,1/6)</td>
<td>(2,3,4)</td>
<td>(4,5,6)</td>
<td>(1,1,2)</td>
</tr>
<tr>
<td>(0/097,0/138,0/159)</td>
<td>(8,9,10)</td>
<td>(1/8,1/7,1/6)</td>
<td>(4,5,6)</td>
<td>(1,1,2)</td>
<td>(1/6,1/5,1/4)</td>
</tr>
<tr>
<td>(0/061,0/089,0/138)</td>
<td>(6,7,8)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1,1,2)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1/4,1/3,1/2)</td>
</tr>
<tr>
<td>(0/553,0/448,0/716)</td>
<td>(8,9,10)</td>
<td>(1,1,2)</td>
<td>(4,5,6)</td>
<td>(6,7,8)</td>
<td>(8,9,10) REP</td>
</tr>
<tr>
<td>(0/017,0/023,0/036)</td>
<td>(1,1,2)</td>
<td>(1/10,1/9,1/8)</td>
<td>(1/8,1/7,1/6)</td>
<td>(1/10,1/9,1/8)</td>
<td>(1,1,2) OS</td>
</tr>
</tbody>
</table>

Pairwise Comparison of Alternative Based on Criteria

As stated before purpose is selection suitable database for EMR software. All alternative together are compares on the basis of criteria.

Matrix for compared alternative based on OS:

Information related to create this matrix from [7] is taken. The number of operating system that are supported by each DBMS, value of relative compare and Eigen value for any rows are shown in table 2. For example, number of OS for Oracle is 5 and for SQL 1. So, degree of OS criteria importance for SQL compared to Oracle is expressed with strongly more important (Table 1) and (4, 5, 6), (1/6, 1/5, 1/4) are placed in (Oracle, SQL) and (SQL, Oracle).

Table 3: Matrix for compared alternative based on OS [7]

<table>
<thead>
<tr>
<th>Eigen Value Number of OS SQL DB2 MSQL Oracle PSQL OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.054,0.064,0.1) 7 (1/8,1/7,1/6) (1,1,2) (2,3,4) (1/4,1/3,1/2) (1,1,2) PSQL</td>
</tr>
<tr>
<td>(0.1,0.118,0.179) 5 (1/6,1/5,1/4) (1,1,2) (4,5,6) (1,1,2) (2,3,4) Oracle</td>
</tr>
<tr>
<td>(0.024,0.028,0.041) 9 (1/10,1/9,1/8) (1/4,1/3,1/2) (1,1,2) (1/6,1/5,1/4) (1/4,1/3,1/2) MSQL</td>
</tr>
<tr>
<td>(0.076,0.085,0.143) 6 (1/6,1/5,1/4) (1,1,2) (2,3,4) (1,1,2) (1,1,2) DB2</td>
</tr>
<tr>
<td>(0.358,0.413,0.535) 1 (1,1,2) (4,5,6) (8,9,10) (4,5,6) (6,7,8) SQL</td>
</tr>
</tbody>
</table>

Matrix for compared alternative based on Indexes:

According to information available in [7] which different type of indexes method that any DBMS are supported is shown, can be compare alternatives based on indexes. Matrix of this comparison shows in table 4. As stated before, the DBMS that the number is more method for, importance of indexing is higher. For example, Posgresql is supported 10 methods for indexing, while the number of indexing method in MySQL is a 1. Therefore, indexing in Postgresql is extremely more important than MySQL. Also importance of indexing in DB2 and SQL is equal. So, (PSQL, MySQL) = (8, 9, 10) and (DB2, MySQL) = (1, 1, 2).

Matrix for compared alternative based on Access Control:

The number of access control methods that any DBMS are supported, in [7] are expressed. Number of more access control in a DBMS means which importance of access control is higher in it. For example, total access control method in Postgresql, Oracle and SQL is equal to 9, namely importance of access control in these three is equal. Against, about MySQL, number of access control method is 4. So, importance of access control in PostgreSQL, Oracle and SQL compare to MySQL can be expressed by very strongly more important. Therefor (Oracle, SQL) and (MySQL, Oracle) equal to (1, 1, 2), (1/8, 1/7, 1/6). Another entries are filled with this
Table 4: Matrix for compared alternative based on Indexes [7].

<table>
<thead>
<tr>
<th>Eigen Value Number of Indexes</th>
<th>approach</th>
<th>SQL</th>
<th>DB2</th>
<th>MSQL</th>
<th>Oracle</th>
<th>PSQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.327,0.529,0.81)</td>
<td>10</td>
<td>(6,7,8)</td>
<td>(6,7,8)</td>
<td>(8,9,10)</td>
<td>(2,3,4)</td>
<td>(1,1,2)</td>
</tr>
<tr>
<td>(0.173,0.283,0.445)</td>
<td>8</td>
<td>(4,5,6)</td>
<td>(4,5,6)</td>
<td>(6,7,8)</td>
<td>(1,1,2)</td>
<td>(1/4,1/3,1/2)</td>
</tr>
<tr>
<td>(0.026,0.033,0.445)</td>
<td>1</td>
<td>(1,1,2)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1,1,2)</td>
<td>(1/8,1/7,1/6)</td>
<td>(1/10,1/9,1/8)</td>
</tr>
<tr>
<td>(0.055,0.085,0.146)</td>
<td>4</td>
<td>(1,1,2)</td>
<td>(1,1,2)</td>
<td>(4,5,6)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1/8,1/7,1/6)</td>
</tr>
<tr>
<td>(0.042,0.061,0.12)</td>
<td>4</td>
<td>(1,1,2)</td>
<td>(1,1,2)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1/8,1/7,1/6)</td>
<td>(SQL)</td>
</tr>
</tbody>
</table>

Table 5: Matrix for compared alternative based on Access Control [7].

<table>
<thead>
<tr>
<th>Eigen Value Number of Access Control</th>
<th>approach</th>
<th>SQL</th>
<th>DB2</th>
<th>MSQL</th>
<th>Oracle</th>
<th>PSQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.293,0.5,0.81)</td>
<td>9</td>
<td>(4,5,6)</td>
<td>(8,9,10)</td>
<td>(4,5,6)</td>
<td>(2,3,4)</td>
<td>(1,1,2)</td>
</tr>
<tr>
<td>(0.138,0.25,0.435)</td>
<td>9</td>
<td>(2,3,4)</td>
<td>(6,7,8)</td>
<td>(2,3,4)</td>
<td>(1,1,2)</td>
<td>(1/4,1/3,1/2)</td>
</tr>
<tr>
<td>(0.007,0.109,0.205)</td>
<td>4</td>
<td>(1,1,2)</td>
<td>(4,5,6)</td>
<td>(1,1,2)</td>
<td>(1/4,1/3,1/2)</td>
<td>(1/6,1/5,1/4)</td>
</tr>
<tr>
<td>(0.019,0.031,0.05)</td>
<td>8</td>
<td>(1/6,1/5,1/4)</td>
<td>(1,1,2)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1/8,1/7,1/6)</td>
<td>(1/10,1/9,1/8)</td>
</tr>
<tr>
<td>(0.067,0.109,0.205)</td>
<td>9</td>
<td>(1,1,2)</td>
<td>(4,5,6)</td>
<td>(1,1,2)</td>
<td>(1/4,1/3,1/2)</td>
<td>(1/6,1/5,1/4)</td>
</tr>
</tbody>
</table>

Matrix for compared alternative based on Size of Table:

Maximum size of table for DBMSs can be obtained in [8]. Importance of supporting the large data in a database is more important if it have to be large table. Results comparison and calculation of Eigen value are shown in table 6. For example, maximum size of table in oracle is very more than DB2, then importance of supporting large data in DB2 compared to Oracle is expressed by extremely more important, mean (DB2, Oracle)=(8,9,10).

Table 6: Matrix for compared alternative based on Size of Table [8].

<table>
<thead>
<tr>
<th>Eigen Value Maximum of Table Size</th>
<th>approach</th>
<th>SQL</th>
<th>DB2</th>
<th>MSQL</th>
<th>Oracle</th>
<th>PSQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.054,0.097,0.162)</td>
<td>32 TB</td>
<td>(2,3,4)</td>
<td>(1/10,1/9,1/8)</td>
<td>(1/6,1/5,1/4)</td>
<td>(2,3,4)</td>
<td>(1,1,2)</td>
</tr>
<tr>
<td>(0.021,0.034,0.06)</td>
<td>4 GB</td>
<td>(1/8,1/7,1/6)</td>
<td>(1/10,1/9,1/8)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1,1,2)</td>
<td>(1/4,1/3,1/2)</td>
</tr>
<tr>
<td>(0.091,0.149,0.252)</td>
<td>256 TB</td>
<td>(1/4,1/3,1/2)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1,1,2)</td>
<td>(4,5,6)</td>
<td>(4,5,6)</td>
</tr>
<tr>
<td>(0.343,0.558,0.886)</td>
<td>2 ZB</td>
<td>(2,3,4)</td>
<td>(1,1,2)</td>
<td>(4,5,6)</td>
<td>(8,9,10)</td>
<td>(8,9,10)</td>
</tr>
<tr>
<td>(0.093,0.159,0.283)</td>
<td>524272 TB</td>
<td>(1,1,2)</td>
<td>(1/4,1/3,1/2)</td>
<td>(2,3,4)</td>
<td>(6,7,8)</td>
<td>(1/4,1/3,1/2)</td>
</tr>
</tbody>
</table>

Table 7: Matrix for compared alternative based on Replication [8].

<table>
<thead>
<tr>
<th>Eigen Value Number of Replication approach</th>
<th>approach</th>
<th>SQL</th>
<th>DB2</th>
<th>MSQL</th>
<th>Oracle</th>
<th>PSQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.052,0.058,0.186)</td>
<td>1</td>
<td>(1,1,2)</td>
<td>(1,1,2)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1/4,1/3,1/2)</td>
<td>(1,1,2)</td>
</tr>
<tr>
<td>(0.113,0.228,0.427)</td>
<td>2</td>
<td>(2,3,4)</td>
<td>(2,3,4)</td>
<td>(1/4,1/3,1/2)</td>
<td>(1,1,2)</td>
<td>(2,3,4)</td>
</tr>
<tr>
<td>(0.226,0.434,0.761)</td>
<td>3</td>
<td>(2,3,4)</td>
<td>(4,5,6)</td>
<td>(1,1,2)</td>
<td>(2,3,4)</td>
<td>(4,5,6)</td>
</tr>
<tr>
<td>(0.039,0.068,0.14)</td>
<td>1</td>
<td>(1/4,1/3,1/2)</td>
<td>(1,1,2)</td>
<td>(1/6,1/5,1/4)</td>
<td>(1/4,1/3,1/2)</td>
<td>(1,1,2)</td>
</tr>
<tr>
<td>(0.098,0.183,0.372)</td>
<td>2</td>
<td>(1,1,2)</td>
<td>(2,3,4)</td>
<td>(1/4,1/3,1/2)</td>
<td>(1,1,2)</td>
<td>(2,3,4)</td>
</tr>
</tbody>
</table>

Matrix for compared alternative based on Programming language:

Programming languages that each of DBMS supported, in [8] are mentioned. Number of language programming that DBMS can be supported, comparison between alternative and Eigen values are shown in table 8. Further programming language shows less important of it in DBMS. For example, Oracle can be supported 32 language, but in front of number of language for SQL is equal 6. Therefor importance of programming language comparison between SQL and Oracle is expressed with extremely more important and (SQL, Oracle) = (8, 9, 10), (Oracle, SQL) = (1/10, 1/9, 1/8).

Table 8: Matrix of compared alternative based on Programming Language [8].

<table>
<thead>
<tr>
<th>Eigen Value Number of Programming Language</th>
<th>approach</th>
<th>SQL</th>
<th>DB2</th>
<th>MSQL</th>
<th>Oracle</th>
<th>PSQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.251,0.394,0.627)</td>
<td>7</td>
<td>(1,1,2)</td>
<td>(4,5,6)</td>
<td>(6,7,8)</td>
<td>(8,9,10)</td>
<td>(1,1,2)</td>
</tr>
</tbody>
</table>
Finally, alternative priority for selection suitable DBMS is obtained with multiplication between weight vectors (Eigen values) of criteria pairwise comparison and any Eigen value rows of alternative pairwise comparison. In order to do fuzzy, Middle value in fuzzy number has been considered as the crisp number for it.

\[
(0.0648 \& 0.5298 \& 0.0978 \& 0.0852 \& 0.3940 \& 0.1182 \& 0.2828 \& 0.0346 \& 0.2283 \& 0.0250 \& 0.0852 \& 0.0852 \& 0.3990 \& 0.1098 \& 0.1498 \& 0.0520 \& 0.0520 \& 0.0520 \& 0.0520 \& 0.0520 \& 0.0520 \& 0.0520) 
\times

(0.0240 \& 0.1380 \& 0.0890 \& 0.4480 \& 0.0230) =

(0.3148 \& 0.2443 \& 0.2070 \& 0.1439 \& 0.1087)
\]

Finally priority that obtained is shown in table 10 that this is the form: DB2 < SQL < Oracle < PostgreSQL < MySQL.

Table 9: Total score of each DBMS

- MySQL: 0.3148
- PostgreSQL: 0.2443
- Oracle: 0.2070
- SQL: 0.1439
- DB2: 0.1087

As previously mentioned, purpose of this paper selection suitable DBMS for Electronic Medical Record with fuzzy AHP bases functionality requirement. According to alternatives and criteria considered and analyses been performed by FAHP, suitable DBMS for EMR is MySQL.

References

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