Providing a Basic Model in the Medical Diagnosis and Decisions by Using Bayesian Networks

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Abstract: The main purpose of this article is to presents a method of analysis in the field of medical decisions based on the analysis of processes and phenomena. In this article, the using of a model for medical decision support systems will be discussed. Therefore in the introduction, we present the issue that related to the Impingement syndrome which is accompanied with shoulder and proximal pain during the abduction of shoulder (45-160) and its treatments such as assessing the effectiveness of using nitroglycerin 2% ointment by using of statistical method and SPSS software. Finally, by using of Bayesian networks, one of the methods of artificial intelligence, modeling and measuring the effectiveness of this medicine will be presented.

Key words: Medical decision systems, artificial intelligence network, Bayesian network.

1. Introduction

The development of methods for the acquisition, modeling and reasoning is, therefore, useful to exploit the large amount of temporal data recorded daily in Patients care. In this context, a Medical Decision Support System can be developed to help physicians to better understand the patient's temporal evolution and thus to take decisions. This paper aims to unify all these qualitative models in a probabilistic relational model that enables to provide not only qualitative recommendations but also a quantitative evaluation of risk. Each of these main phases are modeled using a Bayesian network pattern (derived from cognitive engineering) that captures the different causal influences of activity inputs (technical but also organizational) with regards to the activity failure modes and outputs. These Bayesian elementary networks are aggregated according to the causal flows identified in the previous qualitative analysis [1].

Impingement syndrome is a disease that characterized by the pain of shoulder and proximal during the abduction of shoulder in the range of 45-160 degrees and outside this range, the pain is reduced. Because of this symptom it called “painful are syndrome”. In this syndrome, the active movements of shoulder are limited and painful especially in the anterior raise and internal rotation of shoulder. The initial injury, such as slight rupture of tendons and calcium deposits in tendons, can be the causes of this syndrome. Generally this disease is associated with frequently activities in over head condition. Treatments for these activities, Physiotherapy, using of no steroidal anti-inflammatory drug and injection that none of these treatments has not been entirely effective. It is over 100 years that topical Glysine-3-nitrate is used for treatment of the angina and its mechanism is due to NO production which in Iraq uses as vascular
relaxing factor. Nowadays it has been observed that NO effects on the production of fibroblasts, collagen and reconstruction of tendons. In this article, we use the Bayesian network which has been introduced in 1980 and since 1990 it has been used to discover the medical decisions and also we use a model which was presented by Peter Lucas for optimizing the use of antibiotic for pneumonia patients in ICU.

2. Research Methodology

This descriptive-analytical study has been done from Apr. to Aug. 2011. Sixty patients referred to the orthopedic hospitals for Islamic Azad University Tehran medical branch and the method of sampling has been gradual-random method. The criteria for entry into this study are (1) age: over 18 years old, (2) the duration of symptoms should be more than three months and it should be in shoulder area. The patients who referred to the orthopedic clinic with diagnosed shoulder pain symptom were selected and they were randomly divided into two groups of intervention and control (30 patients in intervention group and 30 patients in control group) [2]. The Demographic information and history and examination findings of patients in a questionnaire that was designed for this purpose, is recorded and then in intervention group, the nitroglycerin 2% topical ointment is applied twice a day (1 cm) in a painful area of shoulder and control group was used topical Vaseline by the amount of 1cm and twice a day, then patients were follow up in the 4, 8, 12, 24 weeks and re-examination was performed and patient satisfaction were evaluated in the treatment. The data gathering tool was a questionnaire, interview and observation and Data analysis was performed by SPSS software and the modeling is done by one of the methods of artificial intelligence which is “Bayesian network”.

3. Findings

The discussed cases include: age, sex, occupation, smoking habits, the duration and amount of tobacco consumption, type and history of previous treatment, disease recurrence, shoulder strength (0-10) in abduction and rotation modes before treatment and in 4, 8, 12, 24 weeks, the amount of pain in rest duration (1-10) before treatments an in mentioned weeks, Supraspinatus tendon strength (it has been studied in three groups of good, average, poor or no response. The summary of mentioned items is described in Table 1.

<table>
<thead>
<tr>
<th>Vaseline ointment</th>
<th>Nitroglycerin2% ointment</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.479</td>
<td>47.56</td>
<td>Average of age</td>
</tr>
<tr>
<td>Male:66.3%</td>
<td>Male: 66.7%,</td>
<td>Sex</td>
</tr>
<tr>
<td>female: 36.7%</td>
<td>female:33.3%</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>26.7%</td>
<td>The amount of smoking</td>
</tr>
<tr>
<td>Dominant: 86.7%</td>
<td>Dominant:63.3</td>
<td>Pain of shoulder</td>
</tr>
<tr>
<td>Recessive: 10% in</td>
<td>Recessive:13.3% in</td>
<td></td>
</tr>
<tr>
<td>the both hand: 3.3%</td>
<td>the both hand: 23.3%</td>
<td></td>
</tr>
</tbody>
</table>
| Good: 33.3%       | Good                     | Response to the previous treatments:20%
| Average           | average:80%              |                          |
| No response to treatment:66.7% | No response to treatment:20% |                     |

| Good              | Good                     | Supraspinatus tendon strength (after 4 weeks) |
| Average: 70%      | Average:73.3%            | (after 8 weeks)                          |
| Poor: 30%         | Poor: 26.7%              |                                          |
| untreated         | untreated                |                                          |
| Good              | Good: 6.7%               | Supraspinatus tendon strength (after 12 weeks) |
| Average: 76.7%    | Average: 86.7%           | (after 24 weeks)                        |
| Poor: 23.3%       | Poor: 6.7%               |                                          |
| untreated         | untreated                |                                          |
| Good              | Good: 30%                | Supraspinatus tendon strength (after 24 weeks) |
| Average: 80%      | Average: 70%             | (after 24 weeks)                        |
| Poor: 20%         | Poor                     |                                          |
| untreated         | untreated                |                                          |
| Good              | Good:73.3%               | Supraspinatus tendon strength (after 24 weeks) |
| Average: 83.3%    | Average:25.7%            | (after 24 weeks)                        |
| Poor: 16.7%       | Poor                     |                                          |
| untreated         | untreated                |                                          |
According to the t-test between the groups (user of nitro glycerin 2% ointment and Vaseline) and the intensity of the abduction & rotation in 12 and 24 weeks and patient satisfaction there is a significant relation between recovery rates (nitro glycerin2%) in the first group \( (P < 0.05) \), and according to the K test there is a significant relation between Supraspinatus Tendon strength and the groups in 12 and 24 weeks.

### 4. Simulation

In this part, in order to simulation from a scientific perspective we study the base of quantification of phenomena. In fact, finding the reason is the main point of forming knowledge. Now if all the elements of a phenomenon to be fully identified, in this case its occurrence can be explained unambiguously. But in the real world the causes of phenomena is not entirely clear and is associated with uncertainty [3]. Generally for expressing the uncertainty in the occurrence of a phenomenon, the possibility of an occurrence is used. The theory of expressive possibilities of mathematical is for representing the uncertainly in phenomena. With a full expression we can say that the uncertainty is synonymous with insufficient knowledge and normally in current world, the perfect knowledge is unattainable for the human. But by understanding a causal relation, a partial recognition with a particular phenomena, can be achieved. The Bayesian network analysis is based on identifying the factors. Accordingly, the two main focuses in this analysis include:

1. Important factors in the occurrence of the phenomenon;
2. Conditional probability of factor.

Therefore the Bayesian network is a combination of certainty and the uncertainty. Here we define the Bayesian network.

### 5. Bayesian Network

#### 5.1 Classification with Bayesian Networks

Bayesian networks are widely used to perform classification tasks, with the following advantages:

- Based on probability theory;
- Not a black box approach;
- Allows rich structure;
- Can mix expert opinion and data to build models;
- Backwards reasoning—in addition to predicting outputs given inputs, we can use output values to infer inputs.

Support for missing data during learning and classification In short, the Bayesian network is a directed graph with a set of probability as the probability distribution or probability table. A simple example of this network is shown in Fig. 1 [1, 2].

Fig. 1 shows the structure of a Bayes classifier, which is the simplest form of useful Bayesian network classifier. (We use the term useful, as actually this is not the simplest possible classifier. We could perform classification using a model with no links; however a model of this type would have limited use) [4].

The links in Bayes model are directed from output to input, which gives the model its simplicity, as there are no interactions between the inputs, except indirectly via the output. Note however that directing links from output to input, is not a requirement for all Bayesian network classifiers.

One of the important features of Bayesian networks is the relationships between activities or phenomena that are displayed as nodes in the graph. Accordingly, the direction of arrows or arcs represents the relationship. The above structure with possibility of any phenomena can be used to predict the final phenomena. Of course the variables of center can be discrete or continuous. Thus the beginning of the arc represents the cause and the end of it indicates the effect.

![Bayesian Network Diagram](image)
of process. In some texts, they call the node of effect as parent and the effect node as child [4]. If no arc drawn between two nodes indicates that there is no relationship between them. To expressing more specialized and from perspective of probability of theory, each node is a random variable with a statistical distribution with both discrete and continuous form. By a mathematical approach, the Bayesian network can be defined as follows:

Bayesian network is a set of variables and a set of oriented paths (edges) so that
- Each variable accept the limited and independent number of states;
- Variables with an oriented path form a graph with no cyclic routes [1, 2];
- Between node A and its parental node such as Bₙ…B₁, there is a conditional probability relation, in other word, the possibility of A is depended on the occurrence of its cause. This means p(A|B₁, …, Bₙ)

It is necessary to mention that, one of the ways to determine the probability distribution of each node is probability tables in any different mode that we can see in Table 2.

### 5.2 Modeling by Using Bayesian Networks

The main components of the model by using Bayesian network can be outlined as follows:
- A Graph related to the cause and effect relationships between variables;
- A Set of possibilities related to the mode of relation between cause and effects;
- The Use of main Bayesian’ theorem alternatively for distribution based on Bayesian network. In this regard, the chain rule for Bayesian networks is used.

The main purpose of modeling with Bayesian networks is to obtain the assessment of a reliable occurrence of phenomena that they cannot be seen directly [5].

(1) Causal model;
(2) Diagnostic model.

In this study, the diagnostic model is used for modeling. Accordingly, this model or assumed variables are the cause of symptoms and signs which by recognition of them, the occurrence of assumed phenomena can be discovered. This approach can be used in detecting of disease; briefly we can say that the diagnostic model is following the discovery of causes [6].

### 5.3 Bayes Variable and Chain Relation for Bayesian Network

The relations conditional probability and also the main Bayesian theorem are as following: Relations conditional probability of two events of A and B [7]:

\[
P(A|B) = \frac{P(A \cap B)}{P(B)} = P(A|B)P(B)
\]

If C is another event, in this case we have

\[
P(B|A \cap C) = \frac{P(A \cap B \cap C)}{P(A \cap C)} = \frac{P(A \cap B | C)P(C)}{P(A | C)P(C)} = \frac{P(A \cap B | C)}{P(A | C)}
\]

The main Bayes’ theorem in probability theory:

If X and Y are the variables related to the event A and B, in this case we have [3]

\[
P(A|B) = P(A)
\]

\[
P(A \cap B) = P(A|B)P(B) = P(A)P(B) = P(B|A)P(A) \Rightarrow P(B/A) = P(B)
\]

### 5.4 General Bayes Chain Rule

If \( u = [A_1, ..., A_n] \) be a set of variable, so following relations for the probability of the normal distribution \( P(U) \) is established.

\[
P(U) = \prod_{i=1}^{n} p(A_i|P_a(A_i))
\]

In the above formula, \( \prod \) represents multiplied of involved factors and \( P_a \) is shows the parental variable (cause) for \( A_i \) variable [1, 2].

<table>
<thead>
<tr>
<th>Probability (%)</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>high</td>
</tr>
<tr>
<td>40</td>
<td>low</td>
</tr>
</tbody>
</table>
5.5 The Mode of Determining the Bayesian Network Components

In designing the Bayesian network, determining the variables (nodes) is essential, in these three categories, variables (nodes) can be defined:

(1) Assumed variables that are the target variables for making decision purposes are not usually visible;
(2) Variables of information that cannot be observed directly;
(3) Intermediate variables which are defined for specific purposes and mainly to establishes the condition of independence of variables or to facilitate the determining of conditional probabilities. As mentioned earlier, also the Bayesian network showing a relation between variables. But to define this relation depends on the designer approach; we can define different Bayesian networks that in this study; there are two methods:

(1) The rule of oriented separation based on pear [8];
(2) According to provided index by Lauritzen et al. [9] by using the theory of sets.

The rule of oriented separation: After determining the network components and their relations, it’s essential to define a specific probability for a distribution variable. It should be noted that there is a variety of techniques and algorithms and software for making a created Bayesian network which based on data and observation can make Bayesian network automatically. In this study, the Bayes server software is used for stimulating [3]. We consider the modeling of evaluation of effectiveness of a drug for 60 patients in orthopedic clinic in accordance with Table 3. Based on above information, the result of Bayesian network is shown Table 3, and analysis input data shown in Figs. 2 and 3.

With above network and using the conditional probabilities we can calculate the occurrence of probabilities if other variables (factors) occur [10, 11]. A hypothetical Bayesian network for modeling and evaluating of effectiveness of drugs are shown in Fig. 4. After defining and classification the relevant variables is necessary to determine the conditional probability tables based on the information or opinions and relevant experiences [12-14].

After determining the mentioned probability, Table 4 is achieved. According to Table 4, this study models should of science network by Bayes’s. Network of Bayes, the structure chart Perform probabilistic inference with those variables are displaying many variables and potential relationships.

### Table 3  Encoding data by using Bayesian network.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Class job</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;30</td>
<td>31-40</td>
<td>41-50</td>
</tr>
<tr>
<td>Age</td>
<td>Age</td>
<td>Age</td>
</tr>
<tr>
<td>Workers, nurses, employees, housewives, drivers and others</td>
<td>Class job</td>
<td></td>
</tr>
<tr>
<td>No, yes</td>
<td>Smoking</td>
<td></td>
</tr>
<tr>
<td>Male and female</td>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Dominant, recessive, both hands</td>
<td>Pain in hand</td>
<td></td>
</tr>
<tr>
<td>Good, moderate, no recovery</td>
<td>Response to previous treatments</td>
<td></td>
</tr>
<tr>
<td>Good, moderate, poor</td>
<td>Supraspinatus tendon strength (after 1 visit, 4, 8, 12, 24 weeks)</td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>The intensity of the abduction &amp; int. rotation (1 visit, 4, 8, 12, 24 weeks)</td>
<td></td>
</tr>
<tr>
<td>0-100</td>
<td>Rate of patient satisfaction</td>
<td></td>
</tr>
<tr>
<td>Nitroglycerid2% and Vaseline ointment</td>
<td>Group</td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 2  Plot of a model with input data (personal data of patient).](image-url)
between nodes indicates a causal relationship. To determine which is the most appropriate route, is also likely. One advantage of this approach is to model the progress of a disease over time, as well as interaction with other diseases, helps. The psychological of the ointment effects on the patient and the patient’s only [15]. If the node is disabled Right consider the severity of the disease and previous treatments and ultimately smoking and the effect of these factors depends on the age. If the node is disabled due to consider the length of treatment depends on the history of previous treatment.
6. Discussion and Conclusions

Evaluation of Bayesian networks and decision theory systems can play a decisive role in the power of prediction for a set of test data and patient data that help physicians to diagnose diseases predict result and select the appropriate treatment. Based on this, in analysis of Bayesian network it is possible that attitude of attitude and network parameters are needed to modify and improve independently. Indeed, one of the major strengths of Bayesian network analysis lies in this. And this method can well be used for modeling of diagnosis of disease [5, 12, 16].

References