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Medicine Recommendation Technique by Using Dempster-Shafer Theory

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Abstract: This paper presents Dempster-Shafer Theory for pharmaceutical market,which considered all symptoms of diseases and recommends the most appropriate medicines by using web oriented sites or other information programs. Medicines used to cure, halt, or prevent disease, ease symptoms or help in the diagnosis of certain illnesses. Advances in medications have enabled doctors to cure many diseases and save lives.Sometimes it seems like there are more medicines than there are diseases, and it can be hard to keep them straight. Some medications can be bought over the counter at pharmacies or other stores. Others require a doctor's prescription. A few medicines are available only in hospitals. Therefore, in this research we used Dempster-Shafer Theory only for medications which are available in pharmacies without doctor's permission and chose only frequent diseases, in which people don't need the doctor's prescription. For calculation part we took only four frequent diseases, such as headache, toothache, flu and fever in ord er to show how works theory of Dempster-Shafer.

Keywords: Dempster-Shafer Theory, pharmacy market, medication, disease.

1 Introduction

Pharmacists are medication experts ultimately concerned about their patients? health and wellness. The principal goal of pharmaceutical care is to achieve positive outcomes from the use of medication which improves patients? quality of life with minimum risk. A pharmacist's duty is not simply preparing the medications which are prescribed by a general practitioner or other health professional. It is to deliver optimal pharmaceutical care, by assessing the suitability of the medication for a particular patient, taking into account their medical history, as well as possible side effects and interactions with other drugs that are being used. But there are times when, due to lack of knowledge, either because of fatigue or dependency from evening shifts at work, pharmacists can make mistakes. And although many errors are minor, some of them can be extremely grave. To get rid of such cases in foreign countries, experts a long time have been working on these issues, created different systems like expert systems using artificial intelligence such as DoseChecker, PharmADE and Microbiology by using different logical rules[1].

Nowadays, on the pharmaceutical market we can observe a lot of different systems that work with storing and extracting the data. For example, in Kazakhstan there are some web-oriented systems like vidal.kz, i-teka.kz and eurapharma.kz, which allow searching medicines[2], sorting the search results by price and give some special information about these medicines. These types of systems use only data management and processing. But in the most cases the pharmacists and clients need more intelligent results and recommendations about the proposed medicine. For instance, the relevance certain type of tablets for people with some contraindications by health. Also as noted above, pharmacist?s life like feeling tired or lacking of information that may lead to make an error in medicine selecting or dispending. That is why the creation of systems like expert systems by using Dempster-Shafer Theory in Kazakhstan?s pharmacy market will be useful for pharmacists, minimizing their efforts and time. In other words, system will greatly facilitate the decision making process of the pharmacists, especially in unusual situations when the selection needs to be more accurate and complete[3].

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2 Some concepts of Dempster-Shafer Theory (DST)

Dempster-Shafer Theory is a mathematical theory of evidence which can be interpreted as a generalization of probability theory in which the elements of the space to which nonzero probability mass is attributed are not single points but sets [4]. In traditional probability theory evidence is associated with only one possible event whereas in Dempster-Shafer Theory evidence can be associated with multiple possible events.

There are three important functions in Dempster-Shafer theory:

– the basic probability assignment function (bpa or m);
– the Belief function (Bel);
– the Plausibility function (Pl)[5].

Dempster-Shafer theory is based on several concepts. Assume, that for the set of hypotheses Θ exists some function m:P (A) ? [0,1] such that:

$$m(\text{ø}) = 0; \quad (1)$$

$$\sum_{A\subset\Theta}^{n} m(A) = 1 \quad (2)$$

This function is called basic probability assignment and it is denoted as bpa or m. Based on the basic probabilities can be calculated limit of the range, which determines the probability of a subset of hypotheses. The bpa, represented by m (formula 1), defines a mapping of the power set to the interval between 0 and 1, where the bpa of the null set is 0 and the summation of the bpa?s of all the subsets of the power set is 1(formula 2) [5], [6].

The Belief function (denoted as bel) is a measure of reliability of the hypothesis A and also it is the sum of the basic probabilities of all non-empty subsets which are belong to the set A:

$$bel(A) = \sum_{B\subseteq A} m(B) \quad (3)$$

Plausibility function (denoted as Pl) is the sum of all non-empty subsets that intersect the set A:

$$Pl(A) = \sum_{B\cap A=\text{ø}} m(B) = 1 - bel(\bar{A}) \quad (4)$$

The relationship between belief function, plausibility function and uncertainty clearly illustrated below (figure 1):

The Dempster?s rule of combination for combining two sets of masses, m1 and m2 is defined as follows[7]:

$$m_{12}(\text{ø}) = 0; \quad (5)$$

$$m_{12}(A) = \frac{1}{1-k}\ ; \quad (6)$$

$$\sum_{B\cap C=A=\text{ø}} m_1(B)m_2(C); \quad (7)$$

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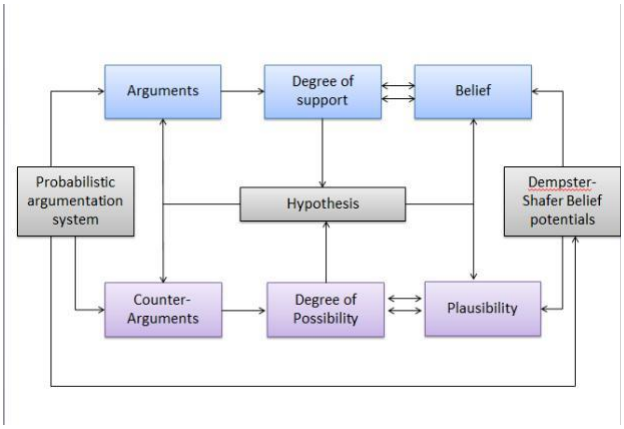

Fig. 1: Probabilistic argumentation system

$$k = \sum_{B \cap C = \emptyset} m_1(B) m_2(C); \quad (8)$$

Here k is a measure of the amount of conflict between two evidences. If k = 1 the two evidences cannot be combined because their cores are disjoint. This rule is commutative, associative, but not idempotent or continuous.

3 Using of DST for medicine recommendations

In this research, we used Dempster-Shafer Theory which considered all symptoms of diseases and recommends the most appropriate medicines. Below, in table 1 we used bpa values according to the opinions of experts. We asked some pharmacists and experts about what diseases are considered permanent in our country and what medicines people often buy and also what kind of medicines as an alternative they can recommend. Moreover, we considered a list of medicines that are produced without doctor's prescription, as well as we paid attention to the prices of medicines, that is, mostly people from the average status cannot buy expensive medicines. Comparing all the obtained data and results, we stopped on the diseases such as headache, toothache, flu and fever. Also we took six medicines which are used frequently and medications which are available in pharmacies without doctor's permission. **Disease #1 ? Headache**

According to experts, mainly people with a headache are used analgin tablets. There are sometimes cases when the headache is due to a cold or because of pressure, in these cases, people generally buy tablets such as aspirin paracetamol and antigrippin. Therefore, Analgin {An}, Aspirin {As}, Antigrippin {Ant}and Paracetamol {Pr} are used in the treatment of pains of different origin and variable intensity like headache with basic probability assignment 0.65[8]:

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$$m_1\{An, As, Ant, Pr\} = 0.65$$

$$m_1\{\Theta\} = 0.35$$

Table 1: Basic Probability Assignment

No.	Diseases	Medicines	Basic Probability Assignment
1	Headache	Analgin Aspirin Antigrippin Paracetamol	0.65
2	Toothache	Analgin Tempalgin	0.55
3	Flu	Antigrippin Paracetamol	0.55
4	Fever	Paracetamol Coldrex	0.60

Disease #2 ? Toothache

In toothache, pain may be felt in the affected tooth. However, in some people, the pain may feel like it is coming from head, sinuses, jaw or ear. Most people describe the pain as throbbing and continuous. Sometimes pain and swelling in the jaw can be a sign of a tooth infection or abscess. With the above signs of pain, pharmacists basically recommend tablets like analgin, tempalgin, ketanol, etc. But for the calculation we took two tablets like analgin and tempalgin as the most sought-after among people with bpa value 0.55:

$$m_2\{An, T\} = 0.55$$

However, if these medicines are not suitable to this disease or system has no information about this type of disease or medicines, i.e.:

$$m_2\{\Theta\} = 0.45$$

Combination of m_1 and m_2 to calculate the new bpa values for m_3:

Table 2: Combination of m_1 and m_2

	$m_2\{An, T\} = 0.55$	$m_2\{\Theta\} = 0.45$
$m_1\{An, As, Ant, Pr\} = 0.65$ $m_1\{\Theta\} = 0.35$	$\{An\} \rightarrow 0.36$ $\{An, T\} \rightarrow 0.19$	$\{An, As, Ant, Pr\} \rightarrow 0.29$ $\{\Theta\} \rightarrow 0.16$

To combine the two diseases, we can use a tabular form as in table 2. For each cell, take the corresponding

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focal elements from each item of disease, intersect them and multiply their corresponding basic probabilities. In the combined disease, there are two focal elements {An, As, Ant, Pr} and {An, T}. The combined mass function is calculated as follows:

$$m_3\{An\} = \frac{0.36}{1-0} = 0.36$$

$$m_3\{An, As, Ant, Pr\} = \frac{0.29}{1-0} = 0.29$$

$$m_3\{An, T\} = \frac{0.19}{1-0} = 0.19$$

$$m_3\{\Theta\} = \frac{0.16}{} = 0.16$$

The highest bpa value for this combination is the $m_3\{An\}$ which is equal to 0.36. It means system will require medicine Analgin to the diseases headache and toothache.

Disease #3 ? Flu

Antigrippine can be used to treat pain and fever caused by, for example, the flu or a cold. Also, Paracetamol is used to treat many conditions such as headache, muscle aches, arthritis, toothaches, cold or flu and fevers. It relieves pain in mild arthritis but has no effect on the underlying inflammation and swelling of the joint[10]. These medicines are available without a prescription. Moreover, herbal teas are a great way to treat cold/flu symptoms. There are people who most prefer treatment with herbs. Consequently, considering all this data and in agreement with experts, for third type of disease we took two tablets with bpa 0.55:

$$m_4\{Ant, Pr\} = 0.55$$

$$m_4\{\Theta\} = 0.45$$

Combination of m_3 and m_4 to calculate the new bpa values for m_5:

Table 3: Combination of m_3 and m_4

	$m_4\{Ant, Pr\} = 0.55$	$m_4\{\Theta\} = 0.45$
$m_3\{An\} = 0.36$	$\{\Theta\} \rightarrow 0.20$	$\{An\} \rightarrow 0.16$
$m_3\{An, T\} = 0.19$	$\{\Theta\} \rightarrow 0.10$	$\{An, T\} \rightarrow 0.09$
$m_3\{An, As, Ant, Pr\} = 0.29$	$\{Ant, Pr\} \rightarrow 0.16$	$\{An, As, Ant, Pr\} \rightarrow 0.13$
$m_3\{\Theta\} = 0.16$	$\{Ant, Pr\} \rightarrow 0.09$	$\{\Theta\} \rightarrow 0.07$

In this combination, there are four focal elements {An}, {An, T}, {An, As, Ant, Pr} and {Ant, Pr}.

$$m_5\{An\} = \frac{0.16}{1-0.30} = 0.23$$

$$m_5\{An, T\} = \frac{0.09}{1-0.30} = 0.13$$

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$$m_5\{Ant, Pr\} = \frac{0.16 + 0.09}{1 - 0.30} = 0.36$$

$$m_5\{An, As, Ant, Pr\} = \frac{0.13}{1 - 0.30} = 0.19$$

$$m_5\{\Theta\} = \frac{0.07}{1 - 0.30} = 0.10$$

The highest bpa value for combination of $m3$ and $m4$ is the $m5$ {Ant, Pr} which is equal to 0.36.

Disease #4 ? Fever

An elevated body temperature (fever) is one of the ways our immune system attempts to combat an infection. Usually the rise in body temperature helps the individual resolve an infection. However, sometimes it may rise too high, in which case the fever can be serious and lead to complications. Therefore, in our country in case of fever people mostly use medicines such as koldreks, paracetamol, teraflu, etc. And these medications are often recommended from pharmacists with bpa 0.60[11]:

$$m6\{C, Pr\} = 0.60$$

$$m6\{\Theta\} = 0.40$$

Combination for m7:

Table 4: Combination of $m5$ and $m6$

	$m_6\{C, Pr\} = 0.60$	$m_6\{\Theta\} = 0.40$
$m_5\{An\} = 0.23$	$\{\Theta\} \rightarrow 0.14$	$\{An\} \rightarrow 0.09$
$m_5\{An, T\} = 0.13$	$\{\Theta\} \rightarrow 0.08$	$\{An, T\} \rightarrow 0.05$
$m_5\{Ant, Pr\} = 0.36$	$\{Pr\} \rightarrow 0.22$	$\{Ant, Pr\} \rightarrow 0.14$
$m_5\{Ant, Pr\} = 0.19$	$\{Pr\} \rightarrow 0.11$	$\{An, As, Ant, Pr\} \rightarrow 0.08$
$m_5\{\Theta\} = 0.1$	$\{C, Pr\} \rightarrow 0.06$	$\{\Theta\} \rightarrow 0.04$

$$m_7\{An\} = \frac{0.09}{1 - (0.14 + 0.08)} = 0.12$$

$$m_7\{An, T\} = \frac{0.05}{1 - 0.22} = 0.06$$

$$m_7\{Ant, Pr\} = \frac{0.14}{1 - 0.22} = 0.18$$

$$m_7\{An, As, Ant, Pr\} = \frac{0.08}{1 - 0.22} = 0.10$$

$$m7\{Pr\} = \frac{0.22 + 0.11}{1 - 0.22} = 0.42$$

$$m_7\{C, Pr\} = \frac{0.06}{1 - 0.22} = 0.08$$

$$m_7\{\Theta\} = \frac{0.04}{1 - 0.22} = 0.05$$

The highest bpa value is the $m7\{Pr\}$ which is equal to 0.42. It means system will require medicine Paracetamol

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to the diseases headache, toothache, flu and fever. Based on the result, we can say that Paracetamol is often recommended as one of the first treatments for pain, as it's safe for most people to take and side effects are rare. It should be noted that, during this work, we first divided all types of medicines into categories, i.e., in this part of calculation we used those medicines that have similar pharmacological properties, so that the system can recommend alternative medicines as substitutes for the main.

4 Implementation part

In our previous work we studied expert system development environments, logical rules and their applications, also general principles of creation knowledge base . As a result of work created web oriented system for the pharmacy market using if-then rule and fuzzy logic, which can greatly facilitate the decision making process[12]. As every knows, today, system developers have an opportunity to distribute their applications via Web also. The development of the most web based expert systems embodies a number of benefits. For instance, the use of an internet based database was effective in storing large amount of facts and data for web based expert systems, also using PHP or Java makes it easier to enhance the expert system user interface. By using web languages, logical rules and production model of the expert system we achieved approximately 70% of the efficiency of the system.

Furthermore, previous system worked using the classification by categorizing all the medicines. Also, in order to give recommendation system used if-then rule by counting the number of contraindications and fuzzy logic rule. For instance, if the number of contraindications in one drug more than others in selected category, then system will remove this type of drugs and recommends only one suitable drug with minimum number of contraindications by using classification[13].

Presently, in order to increase effectiveness and logical inference part of a system we decided to realize Dempster-Shafer Theory and we think that the logic of the system will work more effectively than previous one, at least 85-90 percent. In this case, system will recommend suitable medicines considering the type of disease. For example, in previous one we get recommendations through counting the number of contraindications by logical rules if-then and fuzzy[14], but this system using this theory of belief will recommend tablets which are common and appropriate for several diseases. As shown in calculation part, the highest bpa value got medicine Paracetamol. It means when pharmacist selects one type of disease, system will recommend one suitable medicine with high bpa value, also will show other pharmacological actions of recommended medicine which are suitable for other diseases (combination for m_7, table 4). Moreover, as we

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know, in some cases one tablet has a similar instruction with other tablets. By using Dempster-Shafer theory algorithms we will avoid such situations, for example in case when person by his health reasons cannot use some kind of drugs then he cannot use the tablets that have the same properties.

5 Conclusion

In the course of work performance have been studied the Dempster-Shafer Theory, which allows to obtain the result, based on a priori knowledge and offers an alternative to traditional probabilistic theory for the mathematical representation of uncertainty.An important aspect of this theory is the combination of evidence obtained from multiple sources and the modeling of conflict between them.The motivation for selecting this theory is characterized by the following reasons:

1. The relatively high degree of theoretical development among the nontraditional theories for characterizing uncertainty.
2. The relation of Dempster-Shafer theory to traditional probability theory and set theory.
3. The large number of examples of applications of Dempster-Shafer theory in engineering in the past ten years.
4. The versatility of the Dempster-Shafer theory to represent and combine different types of evidence obtained from multiple sources .

It is supposed that this work will be actual for pharmacists, minimizing their efforts, time and likelihood of making errors during the selecting and dispending medicines to clients. But as we know medicine is not staying in one place, it means, every day has been created new drugs and are included to the pharmaceutical market. Therefore, we are planning to make our system as a self-learning and working as experts in the future, as expert systems are software systems developed using different techniques of artificial intelligence that can ac t parallel to the ”human” experts. [15]. Furthermore we should think about how to connect it with hospitals, in order to get doctor?s diagnosis for other diseases, also to expand database part. Likewise, we hope that people will entrust their health to this system, how they are entrusted to the doctors during the inspection.

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