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LOGICAL MODEL AND SOFTWARE FOR DETERMINING THE RELATIONSHIP BETWEEN DISEASES AND THEIR SYMPTOMS

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Abstract. In this article, a system of logical equations is created using logical functions through methods of expressing the relationship between symptoms of diseases and the diseases themselves in the language of logical algebra. The purpose of this task is to identify obvious connections between diseases and their symptoms and apply it to a specific patient. Development of a software project using the object-oriented design method based on an algorithm for solving this problem and a calculation algorithm using modern programming languages. Using the software developed on the basis of the project, specific solutions to the problem were obtained.

Keywords: algorithm, diseases, disjunction, logical function, symptoms of diseases, system of logical equations.

Kasallik belgilari va kasalliklar o‘rtasidagi bog‘liqlikni aniqlashning mantiqiy modeli va dasturiy ta’minoti

Annotatsiya. Mazkur maqolada kasallik alomatlari va kasalliklar o‘rtasidagi bog‘liqlikni mantiq algebrasi tilida ifodalash usullari orqali mantiqiy funksiyalar yordamida mantiqiy tenglamalar sistemasi hosil qilinadi. Qo‘yilgan masalaning maqsadi, kasalliklar va ularning alomatlarining oshkor bog‘liqliklarini aniqlashdan iborat va uni aniq bir bemorga tadbiq etishdir. Ushbu qo‘yilgan masalani yechish algoritmi va zamonaviy dasturlash tillari yordamida hisoblash algoritmi asosida obyektga yo‘naltirilgan loyihalash usulidan foydalangan holda dasturiy vosita loyihasini ishlab chiqish. Loyiha asosida ishlab chiqilgan dasturiy vositadan foydalanilgan holda qo‘yilgan masalaning aniq yechimlari olinadi.

Kalit so‘zlar: algoritm, dizyunksiya, kasalliklar, kasallik alomatlari, mantiqiy tenglamalar sistemasi, mantiqiy funksiya.

Логическая модель и программное обеспечение для определения связи между заболеванием и их симптомами

Аннотация. В данной статье система логических уравнений создается с помощью логических функций посредством способов выражения связи между симптомами болезней и самими заболеваниями на языке логической алгебры. Цель данной задачи – выявить очевидные связи между заболеваниями и их симптомами и применить ее к конкретному больному. Разработка программного проекта с использованием метода объектно-ориентированного проектирования на основе алгоритма решения данной задачи и алгоритма расчета с использованием современных языков программирования. С помощью программного обеспечения, разработанного на основе проекта, получены конкретные решения поставленной задачи.

Ключевые слова: алгоритм, дизъюнкция, логическая функция, симптомы заболеваний, система логических уравнений, заболевания.

I. Introduction. Methods of reasoning are important in describing processes for studying a number of important areas, such as biology, medicine, management, in order to study not only their important parameters quantitatively, but also their logical connections. The examination of medical or technical diagnostic problems of objects and phenomena can be reduced to the problem of expressing them through systems of logical equations and solving them. The problem of determining the solutions of a system of logical equations is also used in medical diagnostics and, in general, involves determining the presence of logical connections using the method of logical recognition.

It is known that various diseases are accompanied by symptoms of one or another disease. This relationship is established experimentally on the basis of many years of medical examinations of thousands of patients. Using these relationships, it is possible to systematize the problem of medical diagnostics using the apparatus of logical functions, which can clearly determine the potential consequences [1-3].

This article deals with the analysis of a specific problem. Based on the observed relationships between inflammatory diseases and disease symptoms, a system of logical equations is constructed and its solution is obtained. A description is given of the relationship between disease symptoms and diseases by solving the system of logical equations and analyzing the results of the solution.

II. Statement of the problem and method of solution.

2.1. Problem statement. Assume that n diseases $T_1, T_2, \ldots, T_n$ and m symptoms $S_1, S_2, \ldots, S_m$ exist. Take into account the following boolean variables. $(i = 1, \ldots, m;\ j = 1, \ldots, n)$

$$y_i = \begin{cases} 1, & \text{if the i-symptom is detected in the patient;} \\ 0, & \text{otherwise} \end{cases}$$

$$x_j = \begin{cases} 1, & \text{if the patient is diagnosed with j-disease ;} \\ 0, & \text{otherwise} \end{cases}$$

Then, using the language of logical algebra, the relationship between illness symptoms and diseases can be articulated. The Boolean function $y_i \to (x_1 \wedge x_2 \wedge \text{L} \wedge x_m)$ is exactly equal to 1 if the illness $T_i \left(i = \overline{1,n}\right)$ is always accompanied by symptoms $S_1, S_2, \ldots, S_{m_1}$ $(m_1 \le m)$. Also, if symptoms $S_1, S_2, \ldots, S_{m_1}$ are detected, then the disease T_i must be detected, and vice versa, the disease always manifests itself in the indicated symptoms. Therefore, the Boolean function of the following form is identically equal to 1: $x_1 x_2 \text{L}\ x_{m1} \leftrightarrow y_i$ Often one j-th symptom (for example, high temperature) accompanies many diseases, a Boolean function in this case: $x_j \to (y_1 \vee y_2 \vee \text{L} \vee y_{n_1}) = 1$ [4-5].

Thus, a system of logical equations of the following form is formed:

$$\begin{aligned} &f_1(x_1, x_2, \ldots, x_m, y_1, y_2, \ldots, y_n) = 1; \\ &f_2(x_1, x_2, \ldots, x_m, y_1, y_2, \ldots, y_n) = 1; \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &f_k(x_1, x_2, \ldots, x_m, y_1, y_2, \ldots, y_n) = 1; \end{aligned} \tag{1}$$

$f_1, f_2, \ldots, f_k$ -logical functions are complex reasoning about the cause-and-effect relationships between the symptoms of diseases and the diseases themselves. Therefore, the following conclusion follows from equations (1):

$$f_1 f_2 \ldots f_k = 1. \tag{2}$$

Equation (2) represents the latent relationships between $y_1, y_2, \ldots, y_n$-diseases and $x_1, x_2, \ldots, x_m$-symptoms of disease. The purpose of the problem is to determine the latent relationships between diseases and their symptoms and apply it to a specific disease [5].

2.2. Method of solving the problem. The algorithm for solving this problem consists of the following steps:

1. Let us assume that we are given the following relationship between a disease and its symptoms, based on many years of medical examinations of several patients:

Table 1. Relationships between diseases and symptoms of the disease are determined through observations.

	T_1 disease	T_2 disease	…	T_n disease
S_1 symptom of disease	+	+	…	-
S_2 symptom of disease	-	+	…	+
…	…	…	…	…
S_m symptom of disease	+	-	…	+

When a S_i symptom appears in a T_j disease, a "+" symbol is positioned here, $(i=1,\dots,m;\ j=1,\dots,n)$.

2. Based on Table 1, construct a system of equations of the form (1) expressing the latent relationships between $y_1, y_2, \dots, y_n$-diseases and $x_1, x_2, \dots, x_m$ - symptoms of disease.

3. Determine the solution to the system of equations (1).

4. Provide diagnostic conclusions based on the analysis of the solution of a system of equations (1);

If in system (1) for all values of $(x_1 \wedge x_2 \wedge \text{L} \wedge x_m)=1$ of the $x_1, x_2, \dots, x_{m_1}$ $(m_1 \le m)$- variables (group of symptoms) there is always $y_i=1$ (i-disease), then i-disease is always observed with $x_1, x_2, \dots, x_{m_1}$ symptoms. Otherwise, additional symptoms need to be checked for i-disease.

To determine the relationship between symptoms and inflammatory diseases, we construct Table 2 based on a standard yes (+)/no (-) response. Symptoms were taken as indicators that could indicate the presence of progressive inflammation and unfavorable prognostic factors.

Table 2. An observational relationship between inflammatory diseases and symptoms of disease.

diseases/symptoms of disease	x_1	x_2	x_3	x_4	x_5	x_6
y_1	-	+	-	-	+	+
y_2	+	+	+	+	+	+
y_3	+	+	+	-	+	+
y_4	-	+	-	-	+	+
y_5	-	-	-	-	-	+
y_6	-	+	-	+	+	-
y_7	+	+	-	+	+	-
y_8	+	+	-	+	+	+

This includes the following definitions:

y_1 — chronic bronchitis; y_2 — pneumonia; y_3 — tuberculosis; y_4 — carcinoma of lung; y_5 — hydatid disease of lung; y_6 — bronchial asthma; y_7 — acute bronchitis; y_8 — COVID-

19; x_1 — temperatures; x_2 — wet cough; x_3 — spitting up blood; x_4 — leucocyte; x_5 — blood sedimentation rate; x_6 — radiologic abnormality [5].

On the basis of Table 2, we will create a system of logical equations from 14 variables:

$$\begin{aligned}
&f_1 = x_1 \to (y_2 \vee y_3 \vee y_7 \vee y_8) && g_1 = x_2 \,\&\, x_5 \,\&\, x_6 \leftrightarrow y_1\\
&f_2 = x_2 \to (y_1 \vee y_2 \vee y_3 \vee y_4 \vee y_6 \vee y_7 \vee y_8) && g_2 = x_1 \,\&\, x_2 \,\&\, x_3 \,\&\, x_4 \,\&\, x_5 \,\&\, x_6 \leftrightarrow y_2\\
&f_3 = x_3 \to (y_2 \vee y_3) && g_3 = x_1 \,\&\, x_2 \,\&\, x_3 \,\&\, x_5 \,\&\, x_6 \leftrightarrow y_3\\
&f_4 = x_4 -> (y_2 \vee y_6 \vee y_7 \vee y_8) && g_4 = x_2 \,\&\, x_5 \,\&\, x_6 \leftrightarrow y_4\\
&f_5 = x_5 \to (y_1 \vee y_2 \vee y_3 \vee y_4 \vee y_6 \vee y_7 \vee y_8) && g_5 = x_6 \leftrightarrow y_5\\
&f_6 = x_6 \to (y_1 \vee y_2 \vee y_3 \vee y_4 \vee y_5 \vee y_8) && g_6 = x_2 \,\&\, x_4 \,\&\, x_5 \,\&\, x_6 \leftrightarrow y_6\\
&g_7 = x_1 \,\&\, x_2 \,\&\, x_4 \,\&\, x_5 \leftrightarrow y_7 && g_8 = x_1 \,\&\, x_2 \,\&\, x_4 \,\&\, x_5 \,\&\, x_6 \leftrightarrow y_8
\end{aligned} \tag{3}$$

Let the solutions of this system of equations be in the form of a table $T_{(k,m+n)}$. The first m columns of the $T_{(k,m+n)}$-table correspond to the presence value of the $x_1, x_2, \ldots, x_m$- symptoms of disease, the remaining n columns correspond to the presence value of the $y_1, y_2, \ldots, y_n$-diseases, k- (1) is the number of solutions of the system. That is,

$$\begin{aligned}
&T_{i,j} = \begin{cases} 1, & \text{if the patient has i-symptom of disease;} \\ 0, & \text{otherwise} \end{cases}\\
&(i = 1, \ldots, k;\ j = 1, \ldots, m),\\
&T_{i,s} = \begin{cases} 1, & \text{if the patient is diagnosed with j-disease ;} \\ 0, & \text{otherwise} \end{cases}\\
&(i = 1, \ldots, k;\ s = m+1, \ldots, n+m)
\end{aligned} \tag{4}$$

Now, to determine what combination of symptoms can occur with disease *s*, we need to print all columns $T_{i,j} = 1$ when $T_{i,s} = 1$.

III. Functional scheme of software and computational experiences results.

3.1. Software of supply functional scheme.

It is similar to a UML (Unified Modeling Language) diagram, which depicts different classes and their attributes, methods, and relationships between them. This diagram can be used to build a logical model for creating a software tool using an object-oriented design method based on a computational algorithm based on the relationship between a disease and its symptoms. Each class stores its own specific information and is used to diagnose diseases or perform computational processes when interconnected.

The software aims to create a database, determine the solution to a system of logical equations based on the relationships between diseases and symptoms of illness, create and process matrices based on them, create and generate power sets, analyze and file the results, and create (create) support departments.

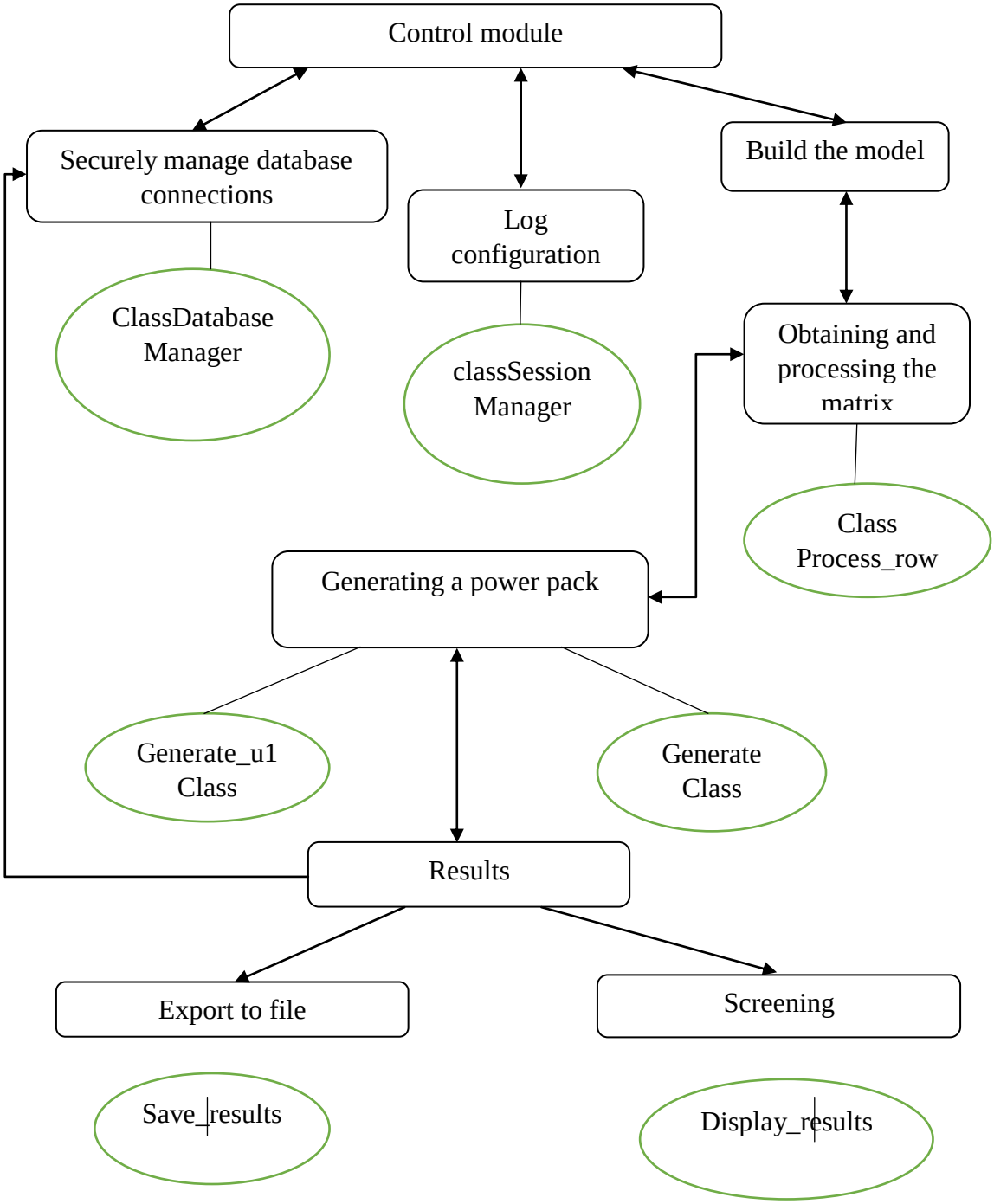


Figure 1. Functional scheme of the software

3.2. Implementation of the program. The interface and functional parts are developed using PYTHON, MYSQL, CSS programming languages, using modern caching algorithms that take into account environment settings and reduce system load.

The interface part includes the following:

- Login & Registration.
- A window for working with diseases.
- The user window.

Functional part includes the following:

- The main part;
- Journal configuration;
- Management of the database;
- Model construction;

- Matrix processing and calculation of results;
- Generating the power set and returning each subset;
- Save the results to a file;
- Display the results.

Let's analyze the diagram class by class. The software tool was developed using the following methods:

Logging configuration. Logging configuration organizes logging and registration.

class DatabaseManager: It organizes the management of the database.

class SessionManager: Manages sessions.

create_session(user_data: Dict):

- st.session_state.authenticated = True
- st.session_state.user_role = user_data['role']
- st.session_state.user_id = user_data['id']
- st.session_state.login_time = datetime.now()
- st.session_state.last_activity = datetime.now()

class AuthenticationManager: Organization of authentication and implementation of control.

TabProcessor: This module processes the rows of the matrix and calculates the value of s for each row. It calculates the values for the columns with the value 1 in each row and adds the required elements to the list U1.

- **process_row(row: list)**: Processes a string and calculates the results.

PowerSetGenerator: This module generates the power set of the list U1. All subsets are generated through the power set.

- **generate_u1(row: list)**: Creates a list U1, which displays columns with a value of 0 in this row.
- **generate()**: Generates a power set and returns each subset.

ResultHandler: It calculates the results, processes the R, F, and TY sets, saves the results to a file, and displays them on the screen.

- **save_results()**: Saves the results to a file.
- **display_results()**: Displays the results.

(The software interface is displayed in Uzbek)



Figure 2. Disease management window

Figure 2 shows the program interface in Uzbek. The Uzbek words listed in the program interface correspond to the following: Kasalliklar bilan ishlash oynasi - Disease management window; ma'lumotlarni kiritish - enter data; ma'lumotlarni tahrirlash- edit data; Excelga eksport qilish- export to Excel; Nimani tahrirlash kerak? - What to edit? Kasalliklar – Diseases; Simptomlar – Symptoms; Qiymatlar – values; Kasallik qo'shish - Add disease.

The software project was developed in the form of several classes using the object-oriented design method based on a logical model calculation algorithm built on the basis of the relationship

between the disease and the symptoms of the disease. Figure 2 shows the window for working with diseases of the software.

Using the software developed on the basis of the project, the solution of the system of logical equations is obtained based on the relationships between inflammatory diseases and disease symptoms determined by observations.

3.3. Conduct analysis of results. In order to find a solution to the problems posed, a comparative analysis of the results obtained using a software tool developed using a number of existing algorithms listed above is presented in Table 3 below.

Table 3. Suitable solutions to the system of equations

x1	x2	x3	x4	x5	x6	y1	y2	y3	y4	y5	y6	y7	y8
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	1	0	0	0
0	1	0	0	1	1	1	0	0	1	1	0	0	0
0	1	0	1	1	1	1	0	0	1	1	1	0	0
1	1	0	1	1	0	0	0	0	0	0	0	1	0
1	1	0	1	1	1	1	0	0	1	1	1	1	1
1	1	1	0	1	1	1	0	1	1	1	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1

The following analytical results are obtained by applying (4) to these obtained solutions on the basis of the above-mentioned algorithms:

y1- disease: (x2, x5, x6) or (x2, x4, x5, x6) or (x1, x2, x4, x5, x6) or (x1, x2, x3, x5, x6)- observed with symptoms;

y2- disease: (x1, x2, x3, x4, x5, x6)- observed with symptoms;

y3- disease: (x1, x2, x3, x5, x6)- observed with symptoms;

y4- disease: (x2, x5, x6) or (x2, x4, x5, x6) or (x1, x2, x4, x5, x6) or (x1, x2, x3, x5, x6)- observed with symptoms;

y5- disease: (x6) yoki (x2, x5, x6) or (x2, x4, x5, x6) or (x1, x2, x4, x5, x6) or (x1, x2, x3, x5, x6) - observed with symptoms;

y6- disease: (x1, x2, x4, x5, x6) or (x2, x4, x5, x6) - observed with symptoms;

y7- disease: (x1, x2, x4, x5) or (x1, x2, x4, x5, x6) - observed with symptoms;

y8- disease: (x1, x2, x4, x5, x6) - it turns out that it can be observed with symptoms.

Based on these statements, it is required to identify the possible causes that could cause them (the patient's illness) based on the presented set of consequences (the symptoms observed in a particular patient).

IV. Conclusion. In conclusion, this research work examined the methodology for establishing the relationship between various diseases and their accompanying symptoms. Certain relationships between diseases and their symptoms were identified. Based on the structure of the statement regarding the cause-and-effect relationship between the symptoms of the disease and the diseases, a system of logical equations was modeled. A software tool was designed using the object-oriented design method based on the algorithm for solving the problem and the calculation algorithm using modern programming languages, and specific solutions to the problem were obtained using this developed software tool.

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