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DESIGN AND IMPLEMENTATION OF AN INFORMATION SYSTEM FOR SELF-CONTROL OF BRONCHIAL ASTHMA BY PATIENTS

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***Abstract*: The aim of this article is to develop information system for people with bronchial asthma. The main function of the information system described in the article is enabling self-control of bronchial asthma by patients. By controlling asthma correctly, patients can reduce the symptoms of asthma. The most important task solved before the information system design was a selection of the asthma parameters which can be monitored and implemented in it. The information system consists of two main elements: a database and an application. The article describes the technologies used to create these elements. Moreover, the article provides information about connection between the database and the application. The article also includes basic information about asthma and describes the information system work.**

***Index Terms*: asthma control, asthma parameters, application, database, Java, JDBC, medical informatics, information system.**

I. INTRODUCTION

The main objective of this article is to design an information system for people with asthma. The problems of people with asthma are described and solutions to them are considered. It also includes information about disease statistics and the technologies used in the information system.

Informatic technology is widely used in medicine. In summary, computer science is used in the field of medicine because it solves problems related to the analysis, processing, acquisition, integration, and visualization of data. A good example of the use of computer science in medicine is a computer tomograph. This device is available today only because computer signal and image analysis exist. Finally, the goal of medical informatics is to improve the quality of healthcare [3, 4].

Throughout history, people have struggled with many incurable diseases, and bronchial asthma is one of them. This article proposes a useful information system that will help a sick person in everyday life. It is important for people with asthma to respect the fact that they themselves influence the course of the disease. The goal of every sick person is to control the disease in order not to feel the symptoms on a daily basis or to reduce them significantly. The described problem applies to people of all age groups because asthma accompanies a person throughout his life. An information system consists of two related elements: a database and an application. An application is implemented in the mobile version and for desktop computers. The interface of the application was designed based on the fact that it should be simple and intuitive, as its user can be a person of any age who suffers from asthma. A very important aspect of the information system is the simplicity of its use, but also an easy access to the collected data. The information collected by the system is securely available anywhere using access through Internet. The information system works not only on data collected from the patient, but also offers data collected from external services that may be useful for the patient. The system can be used in a very large group of people because, according to WHO, over 339 million people in the world are living with asthma [1]. The WHO also estimated that over 400.000 people worldwide died from asthma in 2016 [1]. Over 80 % of asthma-related deaths occur in low and lower-middle income countries. Asthma is the most common chronic disease among children worldwide [1].

II. PROBLEM STATEMENT

The Asthma is a heterogeneous disease. This means that many different factors can affect its course. The disease may be different for each person. Therefore, the sick person does not need to use every aspect of disease control implemented in the information system.

The first problem for asthmatics is to save measurements and present them. Normally, measurements from, for example, a peak flow meter, are saved on paper, but by the information system, they can be accessed electronically using graphs or tables. Another problem for asthmatics is the need to call for help as soon as possible during an asthma attack. Next problem for asthmatics is that they need to avoid polluted places and bad weather. The last asthmatics problem to be solved by the system is medicines monitoring and taking care of their regular intake.

Mentioned peak flow meter is shown in Fig. 1. It should be remembered that the system offered in the article is only to facilitate the day-to-day functioning of the sick person and cannot replace a consultation with a doctor. This system can also help in assessing the condition of the disease but cannot be used to diagnose it.

Fig. 1. An example of a peak flow meter

III. INFORMATIC PARAMETERS OF ASTHMA

Asthma is an incurable disease, and sick people can only alleviate the symptoms of the disease. According to GINA (Global Initiative for Asthma) it is possible to present three states of this disease: controlled asthma, uncontrolled asthma, partially controlled asthma. To describe this disease the best option will be to use the GINA definition:

"Asthma is a heterogeneous disease, usually characterized by chronic airway inflammation. It is defined by the history of respiratory symptoms such as wheeze, shortness of breath, chest tightness and cough that vary over time and in intensity, together with variable expiratory airflow limitation" [2].

Based on the presented definition we know the symptoms of the disease. From the point of view of the information system, the factors that cause these symptoms are more important. The most important factors influencing asthma attacks are: genetic factors, air pollution, stress, obesity, physical effort, cold air, medications, allergens in the workplace, dust, plants pollen, mites, pet dander, tobacco smoke, fungus or cockroach allergens. With the help of the system, a sick person can only control some of these factors. The factors that can be controlled by the system are the following: air pollution, stress, obesity, plants pollen, cold air and medications. The description of the implementation of these functionalities can be found in next part of article. An important test for the diagnosis of asthma is spirometry. However, the test result depends on the patient's current condition. Therefore, people with asthma often measure their maximum exhaled air daily with a peak flow meter. A peak flow meter is a cheap and readily available device. Very often, asthma attacks are preceded by a decrease in the values read from the peak flow meter. The peak flow meter wears out after three years of use. Other devices that can be used by people suffering from asthma are the following: pulse oximeter, air humidifier, air purifier, devices for measuring body weight and pulse. The pulse oximeter measures blood saturation and heart rate. An air purifier is a device that removes air pollution from the room. An air humidifier is a device for increasing the humidity in a given place. It is worth remembering that the correct air humidity is between 40 and 60 percent. Each patient should have an individually prepared treatment plan by his doctor. Asthma patients also use an inhaler on a daily basis. Most medications for asthmatics are inhalants because they are safer and more effective [5], [6].

IV. DESIGN OF INFORMATION SYSTEM FOR PEOPLE WITH ASTHMA

Anyone can create an account in the system by an application as shown in Figure 2. Remember that the account is related to the measurements assigned to it, therefore the e-mail address for each account must be unique. The user account is stored in the database and allows you to log in using the desktop or mobile application. The user password is encrypted with the MD5 algorithm for security reasons.

Fig. 2. The registration of patient fragment located in the desktop application

For example, if the user enters the password zaq1@WSX during registration, the password in the database is 9e38e8d688743e0d07d669a1fcbcd35b. It is important to provide correct data when registering. The data entered in the registration process are used by the system to assess the patient's condition. This data can be modified later in the application.

After registration and logging in, the user can choose from categories shown in Fig. 3. Most of the categories are designed to solve the problems of the asthmatics mentioned earlier. Categories named PEF, BMI, BPM, and Saturation are similar and are intended to operate on the measurements collected from the user. These categories allow the user to add, delete and view measurements. These four categories measure four different values. However, the PEF category has an additional functionality showing the time to wear of the peak flow meter because the peak flow meter wears out every three years. The air condition category allows the sick person to obtain information about the weather conditions, air pollution, and about

dusty plants. A category called medication allows the user to monitor the status of his medications. The last functionality allows the user to quickly send an asthma attack notification to the selected e-mail addresses with predefined content. A category called settings allows the user to configure the information system to his needs. For example, the user can select other formulas to calculate values in the BMI tab or change user password.

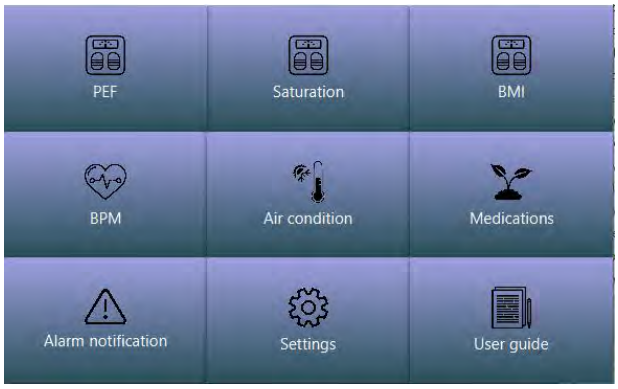

Fig. 3. Fragment of the system containing the categories available to the user.

V. INFORMATION SYSTEM DATABASE ORGANIZATION

All the above-mentioned categories use the database in a smaller or larger way. The database includes many tables shown in Figure 4, that store not only information collected from the user but also data necessary for the functioning of the system, such as, for example, coordinates of measuring stations.

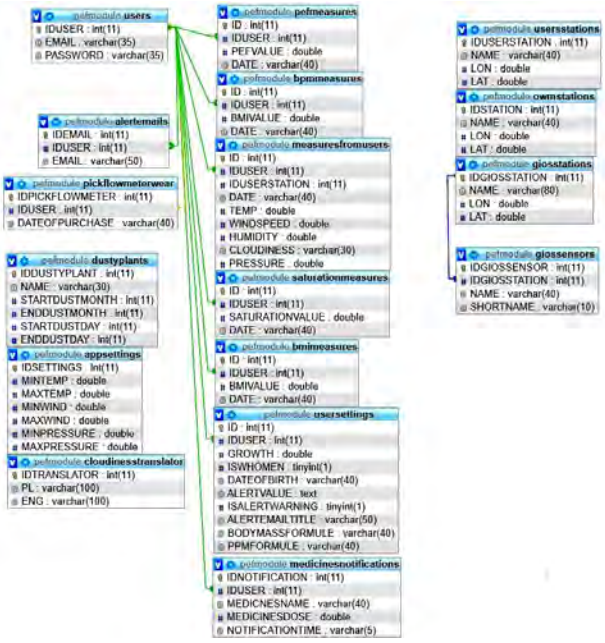

Fig. 4. Schema of the database used in the information system

The schema shows the connections between the tables. For example, it is impossible to delete a user without first deleting the related measurements or settings. All tables not related to the table named users cannot be modified by the application user and the only person who can modify them is the system administrator. For example, the system administrator can change, delete, or add measuring stations or modify the global settings of the application. The database is the most important part of the system mentioned in this article. A database is a collection of data stored in it according to certain rules [10]. The database will store patient data and make it available to them. By storing data in the database, the patient will have access to them from any place; the only condition is connection with the database. Software called a database management system is used to manage the database. In project, a database management system called MySQL, whose main advantage is speed and popularity, as well as the fact that it is available on most system platforms, was applied. In the information system, the XAMPP package was also used. It includes the mentioned MySQL. XAMPP is a free and multi-platform package consisting mainly of apache server, MySQL database and script interpretations written in PHP and Perl. The schema of the database shown in Fig. 4 was created by a database management tool called phpmyadmin included in the XAMPP package [8].

VI. CONECTION BETWEEN DATABASE AND APPLICATION

To connect the database with applications written in Java, system uses a programming interface called JDBC, created in 1996. JDBC means Java DataBase Connectivity. It enables communication between an application written in JAVA and the database using the SQL language. SQL or Structured Query Language is a structured query language developed in 1974 by IBM. This language is used to create, delete, and modify databases, but also to enter data into the database or download them.

If connection to the database is impossible, access to the system is also impossible and is blocked by the message shown in Fig. 5.

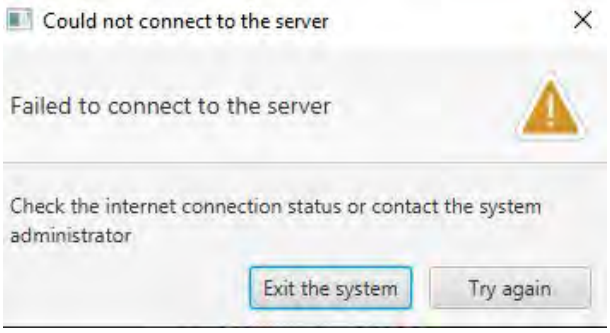

Fig. 5. Alert showing if it is impossible to connect to the base

If the connection with the database is working correctly, the user has an access to the previously entered data and can operate on them as shown in Fig. 6.

PEF Value	Date of measurement
750.0	23-11-2020 10:10
740.0	23-11-2020 10:11
690.0	01-12-2020 12:22
682.0	01-12-2020 12:22

Fig. 6. Example data in application when connection with database works correctly

VII. INFORMATION SYSTEM DESKTOP AND MOBILE APPLICATION

The application was the most difficult part of this project because the information system consists of two versions of the application with a different interface due to the use on other devices. The interface of the application must be simple and intuitive because the user of the application can be any person suffering from asthma of any age. Java version used in a project to create the application is 11. Java is a class-based object-oriented programming language developed by a working group led by James Gosling. The big advantage of this programming language is that programs written in it can be run on any system supporting java without recompilation. Currently, Java is one of the most popular and profitable programming languages [7]. Apart from the programming language, a programmer needs a programming environment to create an application. The programming environment is a program for creating, testing, and modifying software. In the case of the PC version, the development environment was IntelliJ IDEA, and in the case of the mobile version it was Android Studio. InteliJ IDEA is a software development environment created by JetBrains, developed since 2001. InteliJ IDEA gain easy access to SceneBuilder and GIT. The version control system (GIT) makes it easy to track changes to the source code of an application and to easily merge changes made to files by many people at any time. GIT is an example of a distributed version control system developed by Linus Torwalds [9]. Android Studio is a development environment based on Intel's IDEA designed to create applications for Android devices. Java FX is used to create the application interface for the personal computer version. Java FX is a library for creating a graphical user interface. With Java FX, it is possible define the appearance of the application in XML, and additionally gives the possibility to use SceneBuilder. XML is a universal markup language designed to write data in a form that is easy to read by both machines and humans, moreover, it is cross-platform which means that it will work on different systems. SceneBuilder is a tool for creating a user interface in Java FX using the drag and drop method.

Fig. 7. Fragment of mobile application version

It was important for the system from the user's point of view that both the desktop and mobile versions of the application were similar not only in terms of functionality but also appearance. This solution makes both versions of the application easy to use. The mobile version shown in Fig. 7 is similar in appearance to the desktop version of the application shown in Fig. 2. The similarity is indicated by the colors, the appearance of buttons and other interface elements, as well as their arrangement. The mobile version cannot be completely identical to the desktop version because many Java FX elements are difficult to transfer to Android or the screen size of mobile devices does not allow to do this. The differences in appearance also arise due to the fact that in Java FX the appearance of an element can be defined using CSS files, and in Android, files in xml format are used to define the appearance.

```
.button {
    -fx-background-color:
    linear-gradient(   #66FF00, #BFFF00);
   -fx-effect:
    dropshadow( three-pass-box ,
     rgba(0,0,0,0.6) , 5, 0.0 , 0 , 1 );
}
.button:hover {
   -fx-background-color:
    linear-gradient(   #7BB661, #66FF00);
}
```

Fig. 8. CSS file from the desktop version of the application

```xml
<?xml version="1.0" encoding="utf-8"?>
<shape xmlns:android="http://schemas.android.com/apk/res/android"
    android:shape="rectangle" >

    <gradient
        android:angle="45"
        android:centerX="35%"
        android:centerColor="#66FF00"
        android:startColor="#BFFF00"
        android:endColor="#BFFF00"
        android:type="linear"
        />
    <padding
        android:left="0dp"
        android:top="0dp"
        android:right="0dp"
        android:bottom="0dp"
        />

    <stroke
        android:width="3dp"
        android:color="#878787"
        />
</shape>
```

Fig. 9. File from mobile version of the application used to do similar button as shown in Figure 7

As shown in Fig. 8 and 9, a similar effect can be obtained, but usually it will not be completely identical. The presented files were used to create the green login button visible in Fig. 7.

VIII. DATA FROM EXTERNAL SERVICES, AVAILABLE FOR USER

One of the most important functions of the system is to provide information about the weather and pollution. The easiest way to get the listed data is to download it from external services. Weather data is often free and easily accessible. In the presented system, the data from external services comes from OpenWeatherMap and Chief Inspectorate of Environmental Protection. The system also uses data from the Environmental Allergen Research Center, containing information about plant pollen periods. The operations performed on the mentioned data emphasize that the database is the most important element of the system The system administrator can, for example, change pollen periods of any plant in the database or modify the measuring stations available to the user. The system also includes the possibility of exchanging weather information between system users.

The user has an access to various weather data like air temperature, wind speed, air humidity, cloudiness, atmospheric pressure as shown in Figure 10. The station finder shown in Fig. 10 works in a very intuitive way, refreshes the station list after each letter entered and highlights the station name in red if it does not exist, or in green if there are stations with that name.

In addition, the size of the letters entered in the station finder does not matter, and the coordinates are given to the user in the case of two stations in different places with the same names. The user can easily read or sort the data, however, they are sent to the system in the form of JSON.

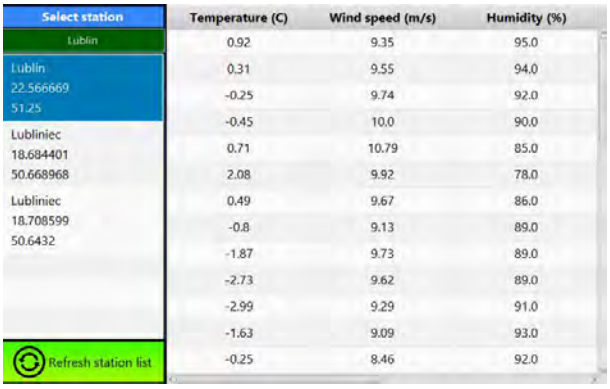

Fig. 10. Weather data in application

```
{
  "coord": {
    "lon": -122.08,
    "lat": 37.39
  },
  "weather": [
    {
      "id": 800,
      "main": "Clear",
      "description": "clear sky",
      "icon": "01d"
    }
  ],
  "base": "stations",
  "main": {
    "temp": 282.55,
    "feels_like": 281.86,
    "temp_min": 280.37,
    "temp_max": 284.26,
    "pressure": 1023,
    "humidity": 100
```

Fig. 11. Sample fragment of OpenWeatherMap answer in JSON

JSON (JavaScript Object Notation) is a format for saving and exchanging data. It is a text format. It is considered a machine-readable and human-readable format. The data received in the form as shown in Fig. 11 is converted into a POJO (Plain Old Java Object). POJO is a class containing fields, a default constructor, getters and setters. When the data is in POJO form, it can already be shown to the user via the graphical user interface as shown in Fig. 10. The system also uses multi-threading in many places. The use of external services is a good example of this because the data is downloaded by a separate thread, so if it may be temporarily unavailable it will not cause the application to crash.

IX. JAVA MAIL API APPLICATION IN THE SYSTEM

Another interesting technology used in the project is the Java Mail API. The mentioned library allows the application to easily send an e-mail and is used in three places in the system. The first use is to send the registration confirmation key to the e-mail address to the user provided by him. This solution gives us more confidence that the user has provided his real e-mail address because its authenticity is important for the further operation of the system. At this point, the second use of the Java Mail API in the system is visible. In a similar way to registration, the user can reset his password if he has forgotten it, so it is important that the e-mail address provided during registration is authentic. The only difference is the length of the password reset key, which is 8 digits and 4 digits for registration

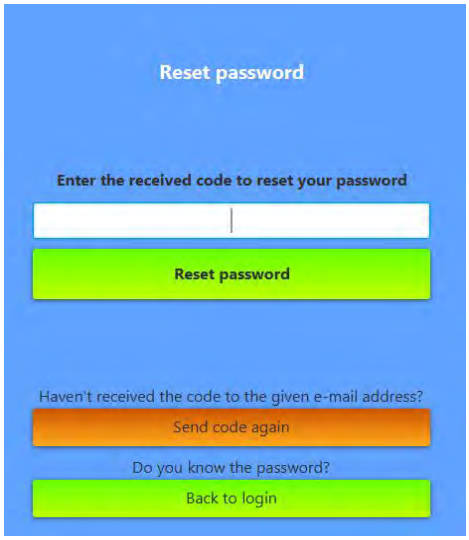

Fig. 12. Reset forgotten password fragment of the system

Java Mail API apart from distributing the keys to the user as shown in Fig. 12 has one more last use in the system. The application uses this library, therefore the user could notify other people or institutions about the asthma attack via e-mail. The system user can select in advance to whom the alarm message is to be sent and what content it should contain, therefore he is able to send it very quickly. The user can also choose in the settings whether he wants the alarm notification to be sent immediately after clicking or with a confirmation similar to the one shown in Fig. 5.

Apart from the described tasks of the library implemented in the system, it should be remembered that in order for messages to be distributed correctly, e-mail must also work properly. The system uses a Google account and Gmail to send messages, but there is no problem to use another mailbox. It is important to properly configure e-mail because in the case of Gmail the "Access of less secure applications" option must be enabled for the library to work correctly.

X. CONCLUSION

This article proved that it is possible to create a system that can help people with asthma in their daily life. Developed information system includes a lot of aspects aimed at better controlling or fully controlling the disease. The biggest challenge for the project is to maintain access to the data in the database and ensure its security. The information system is expandable because one could think of creating intelligent devices that provide data collected from the user by communicating with the system via the network. It is possible to transfer the system to other technologies, for example using a different database system, e.g., Oracle.

Another possibility is to create a web application in the form of a website, along with keeping the mobile version of the application. The system should also be produced for devices with the IOS operating system as it can be a large group of potential users.

This project was created with the intention of working with the patient, but it is possible that the data entered by patients could also be available to their doctors using a different version of the application intended for doctors, but still communicating with the same database.

Finally, the system could find great application in today's world as the number of people with asthma continues to grow and is already very large. In addition, the use of the system is currently not associated with any limitations or additional costs, such as the purchase of a dedicated device for cooperation with the system. The system presented in the article is patient-oriented, but in the future, it can be expanded so that doctors can directly view the data of their patients entered into the system. The proposed solution would require the creation of an application for doctors and establishing the rules on which data about patients are made available to them.

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Konrad Glinka was born in 1996 in Poland. He received the B.S. degree in informatics at the John Paul II Catholic University of Lublin. His research interests include medical informatics technologies and solutions for people with bronchial asthma. Currently he is writing desktop, mobile and web applications.

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