# Telemetry System for Diagnosis of Asthma and Chronical Obstructive Pulmonary Disease (COPD)

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**Abstract.** For people who live in rural or remote areas, or have a limited possibility of movement, disease is diagnosed late in the course, which unfortunately often results in death. In order to increase awareness among people and to reduce mortality rates, telemetry systems play a very important role. This paper presents the telemetry system for diagnosis of Asthma and COPD (COPD - Chronic obstructive pulmonary disease, a type of obstructive lung disease characterized by long-term poor airflow). Developed telemetry system is implemented using Android, Java, MATLAB and PHP technologies. Classification of respiratory diseases is implemented in our previous papers. During the six months' period telemetry system was tested on 541 subjects, where 324 were classified as asthmatics or COPD while 217 were classified as healthy subjects. Implemented system uses a spirometer connected via Bluetooth with a mobile phone application for sending data to the server where is installed Expert System for classification of Asthma and COPD. After the classification process Expert System is sending a diagnosis to the patient via e-mail.

**Keywords:** Telemetry · Expert System · Disease · Classification · Asthma · COPD

## 1 Introduction

The constant development of information - communication technologies (ICT) [1] results in increased use of these technologies in everyday medical practice and change the way of patient care. The combination of intelligent computer systems and mobile applications allow more involvement of patients in the care of their own health through interactive exchange of information with trained medical staff. In Europe in the last


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15 years (2000–2015) the number of Internet users increased for 454.2%, and statistics show that approximately 70.5% of the population in Europe has Internet access [2]. Cisco predicts that by the end of 2016 there will be 10 billion mobile devices worldwide in use [3]. Surveys carried out in European hospitals in the period 2012–2013 year [4] and general practitioners (2013) [5] showed that 9% of hospitals offer patients the possibility of using Internet applications in monitoring their health status. Studies in the United States in 2012, showed that 39% of the surveyed doctors use Internet and Web applications to communicate with patients, an increase of 8% as compared to [6]. In study published by Hardinge et al. [7] patients identified no difficulties in using the proposed Internet application and were able to use all implemented functions.

According to the World Health Organization (WHO), there are around 600 million patients with COPD and 344 million patients with asthma today in the world, which is double than diabetics and it is predicted to 2020, that COPD will become the world's third biggest cause of mortality [8], and thus the main growing public health problem. In recent years, several applications have been proposed to improve and ease the diagnosis of these diseases. Badnjevic et al. in their papers developed Expert System for diagnosis of respiratory diseases such as asthma and COPD based on combination of fuzzy rules and artificial neural network [9]. In papers [10, 11] they presented a system for diagnosis of asthma based just on fuzzy rules or developed artificial neural network, where they showed an importance of usage of Expert systems in healthcare institutions. In all mentioned papers they used spirometry (SPIR)[1] and/or Impulse Oscillometry (IOS) as input measuring parameters. Expert System results are convenient to read and analyze as they are presented in simple forms of texts and figures [12, 13]. The benefits of telemedicine have been shown in other papers [15], which has found that the application of the same procedure to each spirometry examination data and its central processing ensures that all the necessary procedures and checks are carried out with full compliance to the standards of the medical profession [16].

## 2 Methodology – Telemetry System

The developed telemetry system consists of mobile application and Expert System. Telemetry application will interact with the patient through user interface in several steps. In first step, SPIR test is conducted. Then, measured parameters are stored in mobile phone in .pdf format. In step 3, symptoms of disease for patients are indicated in mobile application. After that, measurement results and symptoms indication are transferred to server. Input vector for Expert System is formed in step 5. After that classification is performed and in final step test results are sent to user's mobile phone. Detailed system architecture and data flow is presented in Fig. 1. Developed telemetry system is implemented using a combination of technologies which include Android, Java, Matlab and PHP. Android and Java are used for implementing a simple mobile application that allows the user to upload the results of a conducted measurements.

[1] SPIR - Spirometry (meaning the measuring of breath) is the most common of the pulmonary function tests (PFTs), measuring lung function, specifically the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled.

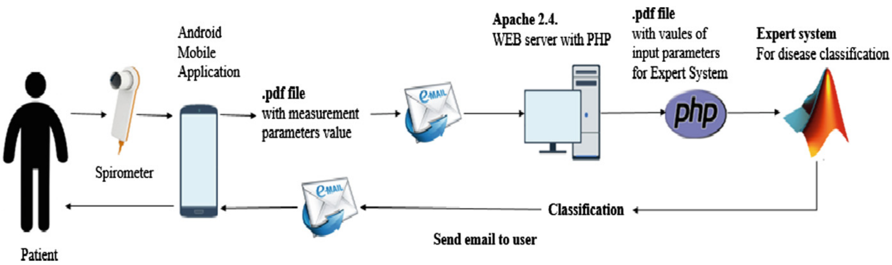


**Fig. 1.** Architecture of implemented telemetry system.

Expert System for classification of respiratory disease is implemented in Matlab. PHP programming language is used to parse the uploaded .pdf files and to call Matlab functions in the background. The input data of developed telemetry system are spirometry (SPIR) test results and symptoms of disease. For obtaining measurement result spirometers with communication module (Bluetooth communication module is used in this paper) must be used in order to get measurement results on used mobile phone. To obtain usable measurement results, examination protocol must be followed. To ensure that measured data are in accordance to Expert System input parameters format, error check is implemented, in the sense that the document with measurement results contains all necessary data for classification. If the check is successful, the file is wrapped in an HTTP POST request and sent to address of the server. Expert System is located on server. In this study, Apache 2.4 Server is used. Once, the input data are given to Expert System classification based on measurement results and symptoms is conducted and the results of classification performed by Expert System are sent to user by email.

## A. Expert System

Expert System for classification of respiratory disease consists of Artificial Neural Network (ANN) and Fuzzy rules. The possible outputs of classification are: Normal condition, Asthma, COPD and Additional testing needed on the Pulmonary Clinic. Architecture of Expert System is presented in Fig. 2 [9]. The input data for the implemented fuzzy rules are values obtained by conducting spirometry (SPIR) test.

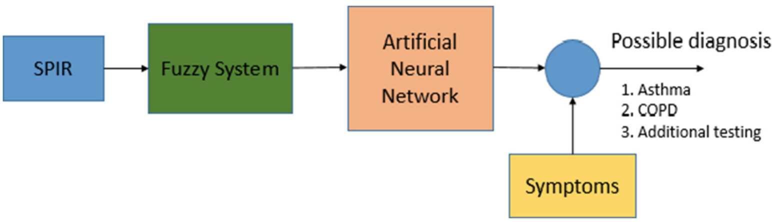


**Fig. 2.** Architecture of Expert System.

Based on these data, fuzzy system has the ability to make a preliminary classification of the disease, if it is a simple case. Otherwise, outputs of fuzzy systems represent input vector of ANN. The Expert System was designed based on the recommendations of Global Initiative for Asthma (GINA) and Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines and based on expert experience and instructions, gathered from a number of experts in the field of respiratory medicine and pulmonary functions tests. Expert System was previously validated on more than 1000 patients [9–14].

**B. Mobile application**

The mobile application is developed for the Android operating system and it was implemented in Java using Android Studio 2.0 integrated development environment. The structure is relatively simple, which opens it to development for different mobile operating systems in the future. An activity diagram representing the application flow is shown in Fig. 3.

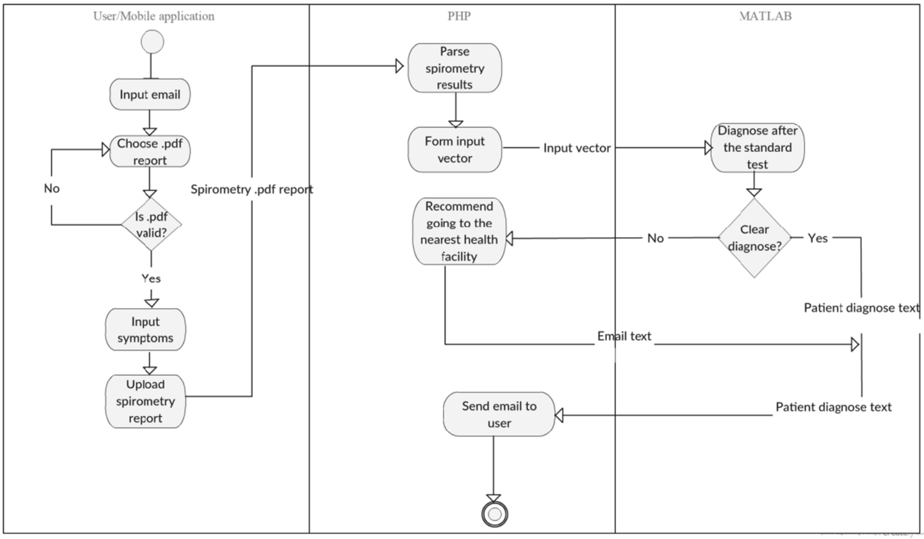


**Fig. 3.** Application activity diagram

After conducting SPIR test, user stores the measured data in .pdf format on used mobile phone. Measurement data are transferred from spirometer to mobile phone using Bluetooth communication. User has the ability to insert symptoms of disease in order to ensure better classification using Expert System. Data is validated before sending to the server. When the file is transferred to server, a PHP script activates which handles the file, first using UNIX pdf to text utility with a preserve layout flag, which writes the data to a text file. The script then loads the content of the file as a string, then using regular expressions, parses the measurements and forms an input vector for the Expert System. The Expert System gives an assessment, as is shown in Fig. 1. Since PHP cannot interact directly with Matlab, the results are written to console output and read by PHP. These results, along with the symptoms and patient data form a report which is written to an email and sent to the user. The user receives a confirmation email that his report was successfully uploaded.

## 3 Results

During the design of the application, usability in accordance with ISO 9126 software quality model was followed. The developed application has relatively straightforward design, icons and information assistance. The time needed for installation and setup is minimum. The main function is sending an email with measurement data and symptoms indication from patient in order to establish quick diagnosis of possible respiratory disease in real time in remote areas. The entire process that takes part on the server side, takes on average ten seconds. When compared to the time needed to obtain the necessary documents to visit a doctor, the application allows the user to quickly identify his condition, or directs him to a physician to conduct more tests. To validate the integrated software suite, reports of 541 patients who have previously visited departments for lungs diseases have been used. There were 25 patients with diagnosed COPD, 72 patients with asthma and 217 patients treated as a healthy control group.

## 4 Conclusion

One of the greatest challenges in rural healthcare system is assuring that professional medical presence is available when and where it is needed. This is difficult for remote rural healthcare institutions because they are often intractable for those medical professionals or those institutions cannot afford or retain these specialty providers. In today's healthcare systems telemedicine is reflected through synchronized data exchange and the advantage of telemedicine/biotelemetry is that recordings of signals of patients are done under the standard conditions, so that stress does not create artifacts that distort the typical form of the signal and subsequent diagnosis on the basis of the recorded signal is more accurate since they are used more realistic signals.

The developed telemetry system described in this paper enables patients living in remote areas, or patients with limited ability of movement to establish a diagnosis based on results of spirometry obtained from a simple to use spirometer. This enables better self-management for patients since they are able to track their health condition and if needed get adequate professional care.

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