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REMOTE PARKINSON'S DISEASE MONITORING SYSTEM: FROM SMARTPHONE TO CLOUD PLATFORM

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СИСТЕМА ВІДДАЛЕНОГО МОНІТОРИНГУ ХВОРОБИ ПАРКІНСОНА: ВІД СМАРТФОНА ДО ХМАРНОЇ ПЛАТФОРМИ

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Parkinson's disease (PD) is a slowly progressive disorder that affects movement, muscle control, and balance. The earlier treatment can prevent the disease from developing and to prolongate the diseases prodromal phase. In this context, home monitoring services are potentially powerful tools for remote diagnosis and can improve healthcare services. Tremor is the most common symptom of a PD disorder and it has several advantages for continuous PD symptoms monitoring. The developing of solution based on smartphone sensors that allow remote monitoring of the monitored user is present. The connection between the smartphone application and cloud platform for smartphone sensors data transmission for early tremor symptoms detection is developed. It includesdeveloping of configuration of smartphone application for sensor data transmission and developing of configuration of a cloud platform for tremor symptoms monitoring. The active tests were developed to capture a motor disorder, that indicates PD symptom such as tremor. Initial trials of the developing demonstrated that the monitoring system has the ability to real-time data acquisition and transmission using smartphone sensors and cloud storage. The connection settings developed for the system proved to be efficient when sensor data transmitted from the smartphone to cloud storage. The period of time required to transfer data to the cloud equal to the period of time less than one second..

***Keywords**: health monitoring system, smartphone application, Parkinson's disease, data tramsmission*

1. Introduction

Parkinson's disease (PD) is a slowly progressive disorder that affects movement, muscle control, and balance.

In recent years, it has become clear that some symptoms of PD occur decades before the development of motor symptoms and clinical diagnosis, and that monitoring these symptoms may provide earlier PD detection. This may enable earlier treatment to prevent the disease from developing and to prolongate the diseases prodromal phase [1].

Using data from wearable devices, such as smartphone sensors, for movement measurements, the earlier detection of motor symptoms will become possible [2].

Parkinson's disease is characterized by four motor disorders: muscle rigidity, hypokinesia, tremors, and postural instability. The authors [3] present a method to quantify PD motor symptoms using an accelerometer, and researchers have extensively tested the validity of such technologies for examining specific motor tasks in controlled experimental settings [4, 5]. The findings suggest that technologies have high sensitivity and specificity for differentiating PD-specific mobility patterns from those of healthy controls and for classifying PD severity and progression within PD patients [6, 7].

Tremor is the most common symptom of a movement disorder [8] and it has followed advantages for continuous PD monitoring. Tremor is

- the most common symptom of movement disorder;
- appears at the early stage of diseases;
- the most obvious symptom;
- easy to detect.

Longer monitoring of tremors can make a diagnosis of Parkinson's disease more reliable. Outside the clinic, patient monitoring is used to monitor tremors. However, inconsistencies between these reports and objective tremor assessments are most often found. Long-term recordings at home can be useful for obtaining an objective assessment of tremor and identifying changes in tremor presentation that cannot be observed in the clinic. However, the inconvenience of long-term records lies in a large amount of data generated. Analysis and processing of these data will take a very long time [9].

In this context, home monitoring services are potentially powerful tools for remote diagnosis and can improve healthcare services.

A large variety of biomedical sensors is used to obtain a variety of human physiological signals [10]. The processing and analysis of these signals to monitor human health can be performed using a user's mobile device or server in cloud storage.

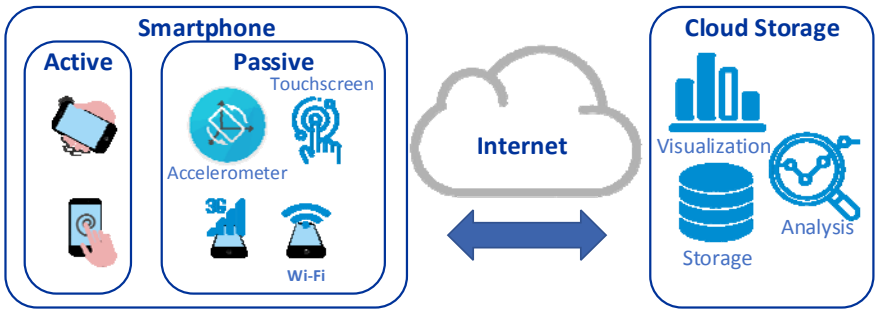

Fig. 1. Architecture of PD monitoring system

Smartphone sensors and web-based cloud platform enable remote monitoring, evaluation and daily monitoring of person with PD and earlier detection of PD symptoms.

The paper presents developing of solution based on smartphone sensors that allow remote monitoring of the monitored user. The system can detect and quantify the motor symptom of PD such as tremor.

The proposed solution consists of a smartphone application, a cloud platform that receives and processes daily motion information of a monitored user, gathered from a data of smartphone sensors.

The system aims to provide a tool for the objective and efficient monitor the status of a monitored user in Parkinson's disease context.

The goal of the research is developing connection between mobile application and cloud platform for smartphone sensors data transmission for early tremor symptoms detection. The objectives are:

- developing of configuration of smartphone application for sensor data transmission;
- developing of configuration of a cloud platform for tremor symptoms monitoring.

2. System Architecture

The proposed system allows the monitoring of PD symptoms remotely by using an application installed on the users' own smartphone. The most significant benefit using of smartphone-based approach is high accessibility. Smartphone-based approach helps to enable automated acquisition, transmission, processing and analyzing of the monitored user data. The core of the smartphone application is the testes to monitor and assess PD symptoms, which consists of active tests, that are initiated and self-administered by the participants at various times during the day. The accelerometer and touchscreen used in these tests. The tests are designed to measure symptom of motor function, such as tremor. The system can detect and quantify the motor symptom of PD such as tremor. The system is used Back4App platform to data collection, the processing will be done in the cloud while allowed users can view and manage all the information related to the monitored user using a web browser.

The system architecture include smartphone, communication channel, cloud storage.

2.1. Cloud platform for tremor symptoms monitoring

The Back4App platform is offered as cloud storage [11]. The platform provides the features discussed below.

Live Query function enables to subscribe to a specific query, store and synchronize app data in real-time.

JSON Import / Export function help import and export JSON files using Parse Dashboard.

The function of Manage Parse Server Versions allows ensuring full compatibility between app and server versions.

Parse Command Line Tool can be used to perform various actions on your Parse app. It can be used to create new Parse apps, deploy Cloud Code to an app, view all releases, and more.

Back4App platform allows monitoring of several users.

In order to use the system, users need only have a smartphone or tablet and Internet access to upload their data to the server. Any device that logged in with a user account can then access data from the server through Wi-Fi or a mobile data network. The system includes an Internet server that is responsible for storing and processing secure data readings.

Thus, the platform allows to reliably track user data without significantly filling up the phone memory and using the smartphone's energy resources. The collected data is stored locally in the memory of the smartphone, and then transmitted to the cloud via the device, initiating an authenticated HTTP push request.

2.2. Smartphone applications requirements

Constant breakthroughs in medical sensor technology and mobile devices fields, combined with growing wireless communication capabilities, have made possible the emergence of new health monitoring paradigms. A smartphone has many additional abilities like a Wi-Fi, Bluetooth, infrared, large memory and an operating system. These technologies make smartphones a personal device that is not always on but is always somewhere on us providing an always-available computing environment with many applications that can be used for continuous health state monitoring.

The mobile application of the personal health monitoring system is used to obtain data on the presence or absence of tremor symptoms. Data acquisition occurs when conducting two tests using the built-in mobile phone sensors described above. The tremor test is performed using an accelerometer and a capacitive touchscreen.

Also, the developed smartphone application is used for preliminary processing of the obtained data. It consists of assigning timestamps to test data. The mobile application store obtained data and processed it in the internal memory of the phone (in the absence of an

Internet connection). It is transmitted data to the cloud using a wireless Wi-Fi or a mobile 2G network.

The experiment run on the conditions, includes follow parameters (but not limited of). The minimum system requirements of the mobile application have been determined. The smartphone app module should run on Android 4.4 and higher. Minimal requirements to characteristics of smartphone and Internet connection are presented in Table.

Table

Smartphone Characteristics

Characteristics	Requirements
Display	5.5 ″
RAM	2 Gb
Internal storage	16 Gb
Wi-Fi connection	~20 Mb/s
2G connection	~473,6 Kb/s

3. Case study

3.1. Active test for tremor symptoms monitoring.

In the current release, the personal mobile sensing system includes two tests for evaluating motor symptoms of Parkinson's disease. They are tremor tests using an accelerometer and tremor test using a touchscreen.

This is the simplest test performed with the smartphone at arm's end. The software for tremor testing via accelerometer performs the following functions: data acquisition from the smartphone accelerometer; time-series data preprocessing; sampling; data transformation for processing and analysis; transferring to the cloud storage; normalizing the values of the accelerometer data array to gravity "g."

The software for tremor testing via the touchscreen assumes the following operations: user login; data acquisition from the results of spiral test execution; data processing; data transferring to the cloud storage.

The target object on the screen is a spiral line. User actions during the spiral test using a touchscreen are as follows. At the first stage, it is necessary to go over the spiral on the screen. The person should perform flowing motion by their index finger and avoid sharp movements as much as possible. On the second stage, the spiral line becomes flashing. The task is the same, to run the finger along the spiral line.

3.2. Developing setting of a smartphone application for data transmission

Developing settings of a smartphone application for data transmission.

Consider the developing of settings of a configuration for a smartphone application for data transmission. At this stage, Android Studio [12] is used. In order to demonstrate the developing of settings of a configuration for data transmission, the accelerometer tremor test is used. The developing consist of several steps.

The first step is followes. The new layouts for smartphone application are created as follow. Using path "app → res → layout" create the following files: activity_accelerometer; activity_login; content_accelerometer; content_login.

The next step is checking to create files using path "layout → New → Layout resource file". The "toolbar" was created in follow files: "activity_accelerometer" and "activity_login". The next step is applied path "palette" → "container" → "AppBarLayout". And the next step, the creating "include" in follow files: "activity_accelerometer" and "activity_login" with links to "content_accelerometer" and "content_login" respectively. The next one is applied path "palette" → container → <include>. Choose "content_accelerometer", use window "component tree", and do follow constraintLayout→ convert view→ relativeLayout→ apply. The elements from "palette" placed on the screen and insert text from brackets on the bottom respectively in the ID field of attributes.

```
TableLayout
TableRow
        textView  (txtXLabel)
TableRow
        Button (read_btn)
TableRow
        LinearLayout (Layout_Graph_Container)
```

The "content_login" was be chosen, the button (element "button") is placed, and the "btn_login" is written to ID field. In menu file "menu_menu" the element "item" with ID "action_logout" must be created. The developing code [13] was copied to res → values → strings.

3.3. Data transmission to cloud platform using smartphone application

The free cloud storage platform [11] is used. The new app was build and key of "Application ID" and "Client key" are copied. To access the device, the Internet and the ability to data synchronize, determined the permissions using follow path "app → manifest → AndroidManifest.xml"[14]. The following line was added to "AndroidManifest.xml".

```
<?xml version="1.0" encoding="utf-8"?>
<manifest
xmlns:android="http://schemas.android.com/apk/res/android"
    package="com.example.myapplication">
.....
    <uses-permission android:name="android.permission.INTERNET" />
    <uses-permission android:name="android.permission.ACCESS_NETWORK_STATE" />
    <uses-permission android:name="android.permission.GET_ACCOUNTS" />
    <uses-permission android:name="android.permission.READ_PROFILE" />
    <uses-permission android:name="android.permission.READ_CONTACTS" />
    <uses-permission android:name="android.permission.VIBRATE" />
.....
```

The next step is the "Java com.example.appname" using and the "new → Java Class" choosing, and following files are created: AccelAnalysis; AccelData; Login; MainActivity; ParseApp; ParseFunctions; Statistics.

The configuration settings [15] are used.

For connecting the smartphone application to cloud storage, the "Application ID" and "Client key" were added to the ParseApp file.

For correct connecting of the smartphone application to cloud storage and data visualization, the libraries [16] must be copied follow path "app → libs".

The following code was written to file build.gradle(Project: appname).

```
allprojects {
    repositories {
            ...
            maven { url "https://jitpack.io" }
    }
}
```

The following code was written to the end of file build.gradle(Module:app).

```
dependencies {
    implementation 'com.github.parse-community.Parse-SDK-Android:parse:1.18.5'
    }
```

4. Testing and evaluation

In order to demonstrate the connection reliability of the monitoring system, the active tests provided on 2 healthy individuals with no previously diagnosed motor conditions. As a comparison, the tests were also run an additional 2 times with simulated Parkinson's disorder, such as tremor. The data was transmitted from smartphone application using Wi-Fi network to cloud storage. The time delay of data transmission is up to 1 seconds. The dashboard on Back4Upp platform used for real-time data visualization. Viewing the real-time data using a web browser is shown in Fig. 2.

5. Conclusion and future work

We have developed settings of configuration connection of a monitoring system for the continuous home assessment of PD symptoms, such as tremor, using smartphone embedded sensors. The configuration connection consists of settings for two components: a smartphone application and cloud storage. The active tests were developed to capture a motor disorder, that indicates PD symptom such as tremor. Initial trials of the developing demonstrated that the monitoring system has the ability to real-time data acquisition and transmission using smartphone sensors and cloud storage.

The connection settings developed for the system proved to be efficient when sensor data transmitted from the smartphone to cloud storage. The period of time required to transfer data to the cloud equal to the period of time less than one second.

In addition, future work will involve developing and implementation of a technique for tests data processing and analysis for PD symptoms detection.

References

1. Brundin, P. and Bloem, B.R., 2018. The Times They Are a-Changin': Parkinson's Disease 20 Years from Now. Journal of Parkinson's disease, 8(Suppl 1), p.S1.
2. Son, H., Park, W.S. and Kim, H., 2018. Mobility monitoring using smart technologies for Parkinson's disease in free-living environment. Collegian, 25(5), pp.549-560.
3. Pérez-López, C., Samà, A., Rodríguez-Martín, D., Moreno-Aróstegui, J.M., Cabestany, J., Bayes, A., Mestre, B., Alcaine, S., Quispe, P., Laighin, G.Ó. and Sweeney, D., 2016. Dopaminergic-induced dyskinesia assessment based on a single belt-worn accelerometer. Artificial intelligence in medicine, 67, pp.47-56.
4. Cerasa, A., 2016. Machine learning on Parkinson's disease? Let's translate into clinical practice. Journal of neuroscience methods, 266, pp.161-162.
5. Cook, D.J., Schmitter-Edgecombe, M. and Dawadi, P., 2015. Analyzing activity behavior and movement in a naturalistic environment using smart home techniques. IEEE journal of biomedical and health informatics, 19(6), pp.1882-1892.

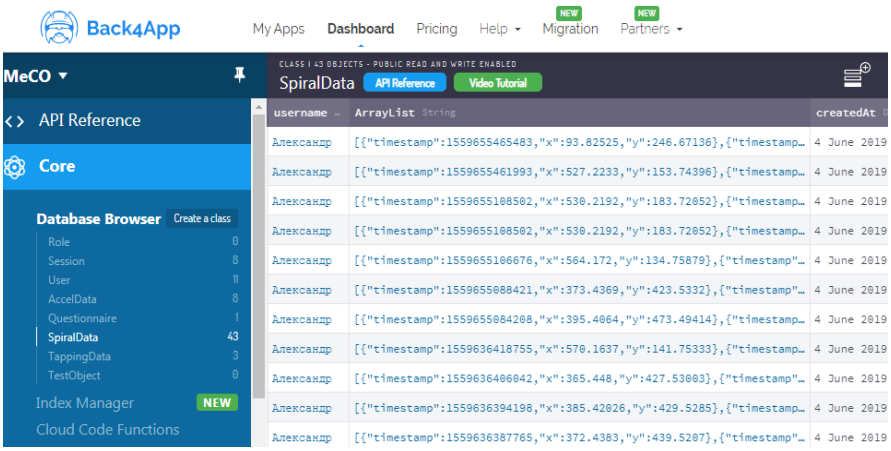

Fig. 2. Vital signs data from smartphone application

6. Horne, M.K., McGregor, S. and Bergquist, F., 2015. An objective fluctuation score for Parkinson's disease. PloS one, 10(4), p.e0124522.
7. Mancini, M., El-Gohary, M., Pearson, S., McNames, J., Schlueter, H., Nutt, J.G., King, L.A. and Horak, F.B., 2015. Continuous monitoring of turning in Parkinson's disease: rehabilitation potential. NeuroRehabilitation, 37(1), pp.3-10.
8. Jankovic, J., 2008. Parkinson's disease: clinical features and diagnosis. Journal of neurology, neurosurgery & psychiatry, 79(4), pp.368-376. DOI:10.1136/jnnp.2007.131045
9. Manzanera, O.M., Elting, J.W., van der Hoeven, J.H. and Maurits, N.M., 2016. Tremor detection using parametric and non-parametric spectral estimation methods: A comparison with clinical assessment. PloS one, 11(6), p.e0156822.
10. Schwab, P. and Karlen, W., 2019, July. PhoneMD: learning to diagnose parkinson's disease from smartphone data. In Proceedings of the AAAI Conference on Artificial Intelligence. Vol. 33, pp. 1118-1125.
11. Back4App [Electronic resource]. – Avaible at : https://www.back4app.com.
12. Android.com [Electronic resource]. – Avaible at : https://developer.android.com/studio/.
13. Github.com [Electronic resource]. – Avaible at : https://github.com/beloborodova-t/ALIOT-47/blob/master/pack/string.xml.txt.
14. Github.com [Electronic resource]. – Avaible at : https://github.com/beloborodova-t/ALIOT-47.
15. Github.com [Electronic resource]. – Avaible at : https://github.com/beloborodova-t/ALIOT-47/tree/master/pack.
16. Github.com [Electronic resource]. – Avaible at : https://github.com/beloborodova-t/ALIOT-47/tree/master/libs.

Бережний О.В., Білобородова Т.О., Скарга-Бандурова І.С. Система віддаленого моніторингу хвороби Паркінсона: від смартфона до хмарної платформи

Хвороба Паркінсона - це повільно прогресуюче захворювання, яке впливає на рухову активність, м'язовий контроль і баланс. Більш раннє лікування може запобігти розвитку хвороби і продовжити продромальную фазу захворювання. У цьому контексті домашній моніторинг є потенційно потужним інструментом для дистанційної діагностики та може поліпшити надання медичної допомоги. Тремор є найбільш поширеним симптомом хвороби Паркінсона і має кілька переваг для постійного моніторингу її симптомів. Представлена розробка рішення на основі сенсорів смартфонів, що дозволяють здійснювати віддалений моніторинг спостережуваного користувача. Розроблено підключення між додатком для смартфона і хмарної платформою для передачі даних з датчиків смартфона для раннього виявлення симптомів тремору. Воно включає розробку конфігурації програми для смартфона для передачі даних з датчиків і розробку конфігурації хмарної платформи для моніторингу симптомів тремору. Активні тести були розроблені для виявлення рухового розладу, який вказує на симптом хвороби Паркінсона, такий як тремор. Початкові випробування розробки продемонстрували, що система моніторингу має можливість в реальному часі збирати і передавати дані за допомогою датчиків смартфона в хмарне сховище. Параметри підключення, встановлені для системи, виявилися ефективними при передачі даних датчика зі смартфона в хмарне сховище. Період часу, необхідний для передачі даних в хмару, дорівнює періоду часу менше однієї секунди.

Ключові слова: *система моніторингу здоров'я, додаток для смартфонів, хвороба Паркінсона, передача даних.*

Бережной А.В., Белобородова Т.А., Скарга-Бандурова И.С. Система удаленного мониторинга болезни Паркинсона: от смартфона к облачной платформе

Болезнь Паркинсона - это медленно прогрессирующее заболевание, которое влияет на двигательную активность, мышечный контроль и баланс. Более раннее лечение может предотвратить развитие болезни и продлить продромальную фазу заболевания. В этом контексте домашний мониторинг является потенциально мощным инструментом для удаленной диагностики и может улучшить оказание медицинской помощи. Тремор является наиболее распространенным симптомом болезни Паркинсона и имеет несколько преимуществ для постоянного мониторинга ее симптомов. Представлена разработка решения на основе сенсоров смартфонов, позволяющих осуществлять удаленный мониторинг наблюдаемого пользователя. Разработано подключение между приложением для смартфона и облачной платформой для передачи данных с датчиков смартфона для раннего выявления симптомов тремора. Оно включает разработку конфигурации приложения для смартфона для передачи данных с датчиков и разработку конфигурации облачной платформы для мониторинга симптомов тремора. Активные тесты были разработаны для выявления двигательного расстройства, которое указывает на симптом болезни Паркинсона, такой как тремор. Начальные испытания разработки продемонстрировали, что система мониторинга имеет возможность в реальном времени собирать и передавать данные с помощью датчиков смартфона в облачное хранилище. Параметры подключения, разработанные для системы, оказались эффективными при передаче данных датчика со смартфона в облачное хранилище. Период времени, необходимый для передачи данных в облако, равен периоду времени менее одной секунды.

Ключевые слова: *система мониторинга здоровья, приложение для смартфонов, болезнь Паркинсона, передача данных.*

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