Neurorehabilitation Control Application: Development Using Ionic Framework

Lyudmila V. Babich, Dmitriy A. Svalov, Aleksey L. Smirnov and Mikhail V. Babich

Abstract — **This article discusses development of the cross-platform mobile application for medical devices control purposes using the Ionic framework. The SYMPATHOCOR-01 was used as an example of controlled medical device. The developed application helps to reduce the burden on physicians, performing actions automatically. The application allows to manage the patient's treatment process, automatically fills the patient's treatment history, stores patient data in an embedded database. Using Ionic framework with a cross-platform approach, it is possible to significantly reduce the financial costs of application development and make application compatible with 98% of mobile devices users.**

Keywords **— SYMPATHOCOR-01, Ionic Framework, ExpressJS, TypeScript.**

I. Introduction

MOBILE devices are very popular among consumers. Recent estimates show that by the year 2021 11.6 billion mobile devices will be released [1]. According to The Statistics Portal in 2018, more than 34% of the world's population use a smartphone, and by 2021 it is expected that the percentage of users will increase to 40% [2].

The rapid development in information and communication technologies, in particular mobile devices, leads to the creation of new mobile medical services and applications. Physicians use smartphones for drugs information searching using specialized web-sites [3], [4]. Also, smartphones are used as parts of a medical systems for data visualization, resending and processing [5]. Thus, smartphones can help to manage disease treatment process.

One of the important groups of diseases are neurological disorders. Unipolar depressive disorders (UDD) are among the top 20 causes of the disease burden. It is forecasted, that UDD will be one of the top three cases of Disability-Adjusted Life Year in 2030 [6]. According to WHO, neurological disorders are among leading causes of death and 12% of the total number of deaths caused by neurological disorders worldwide [7].

One of the most common devices that are used in the rehabilitation process in neurology is the neurostimulation SYMPATHOCOR-01 device. The SYMPATHOCOR-01 device has the following current pulses characteristics: pulse duration, modulation frequency and pulse amplitude.

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The device performs noninvasive electronic stimulation of the neck region using two multi-element electrodes and consists of 12 partial electrodes. Each partial electrode can generate monopolar current pulses. The pulses group into packets. Each packet has specific generation frequency. Each pulse in packet has programmable duration and amplitude.

There is an implementation of the SYMPATHOCOR-01 device that allows to remotely set the characteristics of current pulses using wireless Bluetooth low energy (BLE) technology. The scheme of treatment process using SYMPATHOCOR-01 device is shown on Fig. 1.

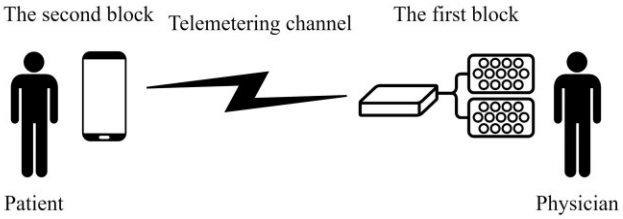

Fig. 1. The scheme of treatment process using SYMPATHOCOR-01 device

The first block generates a current pulse with specified characteristics using multi-element electrodes. The second block is implemented as a smartphone application using the Android SDK.

Current implementation has drawbacks. First drawback is a limited number of potential users, since the application can be run only on Android mobile devices. Second drawback is lack of automatization. Using current implementation physician should organize patient treatment, and should manually monitor patient treatment process.

The solution to the first problem is to develop an application for different mobile operating systems (OS). However, it is very time consuming since it requires iOS and Android programmers. Making any changes to program logic is also time consuming, since it is necessary to change two applications at once on different OS. Problem solution is to develop the cross-platform mobile application that can run on different mobile operating systems.

To solve the second problem, it is necessary to store large amounts of data in the application. This data will include the history of the procedures passed by the patient and all the procedures scheduled to him.

It was decided to develop the cross-platform mobile application that will help to automate the management of treatment history and will increase the coverage of

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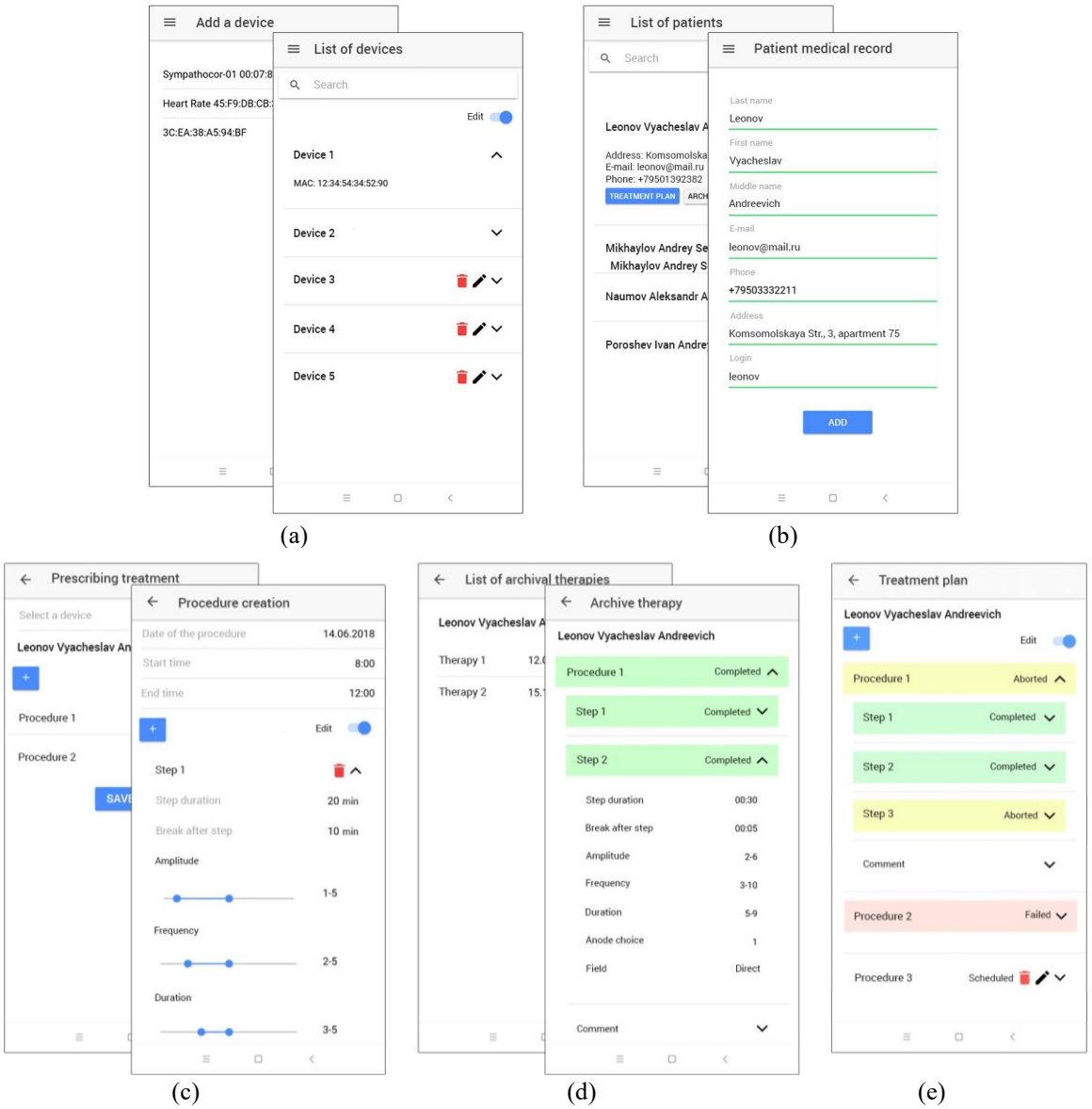

Fig. 2. Application Screens

potential users of the application. It was decided to use Ionic Framework for the application development.

II. Materials and Methods

The Ionic Framework is based on Angular and Apache Cordova frameworks; it allows developing the cross-platform mobile applications using web technologies. This framework was chosen for development because, unlike other frameworks, it has its own UI components that copy the appearance and behavior of standard native UI elements of the Android and iOS mobile OS [8]. Also, the advantage of this framework is that it allows assembling a mobile application installation file without using third-party tools.

The Apache Cordova is used as a native application deployment tool. It is possible to extend the standard functionality of Apache Cordova using plugins. Plugins are needed to work with native smartphone functionality, such as Bluetooth Low Energy (BLE) [9].

The Ionic Framework application is executed using the UIWebView shell for iOS or WebView for Android. With this shells, the application has the ability to display HTML and to execute JavaScript.

Also, the Ionic Framework supports a component approach. This approach allows to organize and to reuse repetitive parts of the application interface. A combinations of components allows one to create application screens without duplicating the code.

III. Application Description

The developed mobile application is cross-platform and can be launched on Android and iOS. The use of the SYMPATHOCOR-01 device by the patient is possible only if the therapy for a specific patient was scheduled. Therapies are stored in the treatment plan. A therapy is a set of procedures, each has treatment schedule and consists of steps with a variable duration in time. The SYMPATHOCOR-01 device current pulses characteristics are set at each step.

The application controls the completion of the procedure, creates treatment plan, performs predefined steps, has the ability to automatically switch anodes in sequence, automatically fills the patient's treatment history and provides quick access to it using the embedded database.

The application has 6 groups of screens and a common

menu screen. Screens transitions are presented in the structural diagram on Fig. 3.

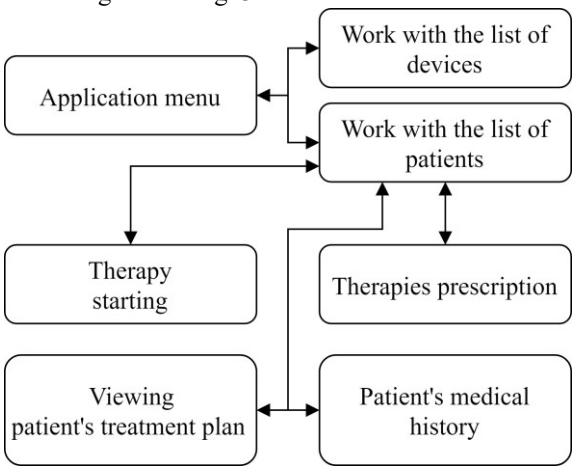

Fig. 3. Structural diagram of the application screens

The screens shown on Fig. 2 (a) allow the physician to edit list of registered in the system devices by adding, changing, and deleting list items. The screens shown in Fig. 2 (b) allow the physician to edit the patients list in a similar way.

From the patients list, it is also possible to work with a list of patient therapies. The screens shown on Fig. 2 (c) allow the physician to schedule the therapy or procedure for the specific patient. In the procedure, steps are created as set of certain characteristics of the device. Each step contains the following characteristics: the duration of the step, the duration of the rest, the ranges of amplitude, frequency and duration, the anode switching mode.

The screens providing viewing of therapies history for each patient are presented on Fig. 2 (d). Medical history is presented as list of completed procedures. The following statuses of a procedure are possible:

- «Scheduled» – the time of therapy has not yet come;
- «Completed» – successful completion of the procedure or step;
- «Aborted» – the procedure was started, but not completed for any reasons (for example, deterioration of the patient's state of health);
- «Failed» – the patient did not start the procedure.

Editing is possible only for therapies with the «Scheduled» status. Procedures that have been passed by the patient also have a feedback section. The section provides feedback from the physician to the patient. It contains data about the patient's functional data, as well as a brief description of the patient's condition during the procedure.

The screen for viewing and changing the treatment plan is shown on Fig. 2 (e). This screen shows that the procedures and steps have predefined statuses, that were previously mentioned.

The application architecture diagram is shown in Fig. 4.

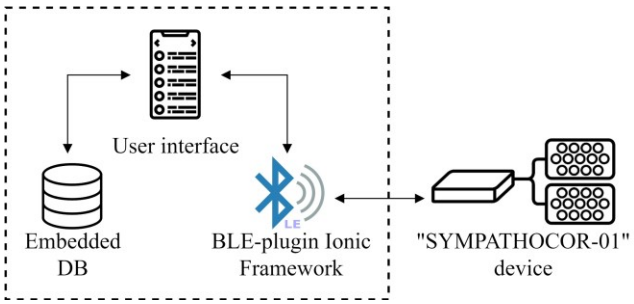

Fig. 4. Application architecture

The application architecture includes an embedded database and a BLE plugin. The database is necessary for storing data about patients associated with a physician, scheduled and passed therapies. The BLE plugin allows one to receive and transmit data to the SYMPATHOCOR-01 device via build-in Bluetooth module on a smartphone.

IV. Discussion

Comparison was made between the application developed using the Ionic Framework and the existing application based on the Android SDK.

Android Profiler was used as a profiling tool. It allows one to collect smartphone resources data used by the application. The test was performed on a Xiaomi Redmi 5 Plus smartphone. The comparison of applications characteristics is given in Table 1.

Table 1 - Comparative characteristics

Characteristic	***Value***	
	Ionic Framework	***Android SDK***
Memory footprint, MB	5.38	9.03
Min RAM usage, MB	113.11	9.87
Max RAM usage, MB	197.77	28.29
Min CPU usage, %	1.12	0.20
Max CPU usage, %	22.64	21.00
Supported mobile OS	iOS, Android	Android

As can be seen from the table, the developed application can be launched on Android and iOS. Android OS is used on 70.86% of mobile devices, iOS is used on 27.81% of mobile devices. Android OS and iOS cover more than 98% of mobile devices market. Since the BLE transceiver is used for data transfer, the smartphone OS should support this functionality. The OS must provide an application programming interface that applications can use to discover devices, receive and transmit information. Mobile OS Android supports BLE, since version 4.3, iOS - since version 7.

According to smartphones characteristics analysis, mobile devices with Android 4.3 and higher and mobile devices with iOS 7 and higher have from 16 to 128 GB of read only memory (ROM) and from 1 to 6 GB of random access memory (RAM) [11]. Based on the analysis, it can be concluded that the developed application takes no more than 0.03% of the ROM and 0.19% of the RAM. These results indicate that the developed application consumes an acceptable amount of smartphone resources.

As a result of testing, there were no delays in responses

user actions. The application worked smoothly on tested device.

Compared to the previous application, the developed application for the physician has an expanded functionality as viewing the history of the patient's treatment and scheduled therapies. This allows physician to perform treatment more efficiently.

V. Conclusion

This paper describes crossplatform application development for neurorehabilitation. This application could help to automate the management of medical records for a physician. At the moment, the application supports only SYMPATHOCOR-01 device and has not been released. In the future, it is possible to support other neuroelectrostimulation devices.

Cross-platform approach significantly reduces the financial costs of application development, accelerates development and facilitates application support. There is no need to develop separate applications for each of the mobile OS.

Further development of this work is remote neurorehabilitation system creation. This system will consist of mobile applications for a physician and a patient, which will interact via the centralized server over the Internet. Server will communicate with DB, which stores all patient and physician data.

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