Development of an approach and software tools to distance the rehabilitation process for adaptation to home use

Y A Orlova¹, A S Dmitriev¹, A R Donsckaia¹, V V Noskin¹ and N D Sibirny¹

¹ Volgograd State Technical University, Lenina Avenue 28, Volgograd, 400005, Russia
E-mail: yulia.orlova@gmail.com

Abstract. The article analyzes the existing approaches and software solutions for carrying out exercises to restore the patient's hand mobility in a remote format, shows the process of developing the admin panel module for the existing solution "Devirta.Accuracy". This article proposes an approach to solving the problem of distancing the process of restoring hand mobility using the application "Devirta.Accuracy" and presents the implementation of the program.

1. Introduction
Restoring limb mobility after a stroke is an important and difficult task facing doctors. The doctor should assess the degree of damage to the patient's hands, select an individual set of exercises for the recovery process. In addition, the doctor also needs to monitor the dynamics of the patient's results in order to correct the course of rehabilitation at the right time [1]. The traditional process of interaction between a doctor and a patient during the rehabilitation period can be simplified for both parties by introducing specialized hardware and software into this process.

Today, the problem of restoring the mobility of the hands of stroke patients is one of the urgent tasks for doctors. According to statistics, the incidence of stroke ranges from 460 to 560 cases per 100,000 population. 31% of stroke patients require outside help to care for themselves, and 20% cannot walk on their own. Only about 20% of patients can return to their previous work. The possibility of implementing software and hardware solutions to simplify the process of interaction between the patient and the doctor during the recovery of the patient's upper limbs is an urgent task.

For example, from November 2014 to November 2015 at the Chinese Research Center for Rehabilitation, with the possibility of using the Leap Motion sensor to restore the mobility of the hands of patients after a stroke. [2, 3, 4] Studies have shown positive rates for both the experimental and control groups. The metric for analysis in the study was the WMFT test, which showed significant improvements in both experimental and control patients after 4 weeks of using the developed simulator with a Leap Motion sensor.

In addition, the centralized collection and convenient display of the dynamics of the patient's exercise results, even when using a simulator with a Leap Motion sensor, is an urgent task due to the lack of such services.

During the rehabilitation process, both the doctor and the patient face various problems. Firstly, the patient's need to visit the clinic often enough to learn new exercises and check the patient's condition by the doctor. Secondly, is the doctor's need to devote a sufficiently large amount of time to the
patient's appointment in order to analyze the dynamics of the patient's exercise results, adjust the course, teach new exercises, etc. Thirdly, there is no centralized collection of information about the patient's exercises at home, in the clinic. Fourth, the lack of control over the correctness of the exercise by the patient at home. All these problems can be reduced to one thing - the problem of remote interaction between the doctor and the patient during the course of the course to restore the mobility of the patient's arms after a stroke.

The main task under this project: the implementation of the remote process of interaction between the attending physician and the patient for a treatment course to restore the mobility of the patient's hands.

2. Analogs

At the moment, there is no full-fledged solution that would allow the rehabilitation process of patients with hand mobility impairment in a remote format using precise equipment, support of the Russian language and an explanation of the exercise, and the ability to visualize the results of patients and manage their courses by a doctor through a personal account with any operating system. Comparison of all the analogs listed below is presented in Table 1.

| Comparison criterion | "Devirta.Accuracy" before the development of the service | habilect | Evolvrehab hands |
|----------------------|--------------------------------------------------------|---------|-----------------|
| Data sync            | -                                                      | +       | +               |
| Leap Motion for more precision | +                                                | -       | +               |
| Russian language support | +                                                     | +       | -               |
| Web interface for managing patients and their courses | -                                      | (only PC version for windows OS) | (only PC version for windows OS) |
| The ability to get a demo version of the product | +                                                      | +       | -               |
| Number of exercises  | 8                                                      | 150     | 8               |

3. Approach

The input to the developed service through the API provided by the server module from the application for the implementation of "Devirta.Accuracy" is supplied with information characterizing the results of the exercise by the patient. On the authorization page of the doctor's personal account, the phone number of the attending physician and his password for authorization are entered in the appropriate fields. On the patient registration page, information about the added patient is entered. When adding a rehabilitation course on the corresponding page, the exercises, the diagnosis and the injured arm are selected from the proposed lists, as well as the time period of the course.

The output is a graph of the dynamics of changes in patient results on the patient results page, as well as complete information about the patient and all courses of the patient with the latest results for the exercises of the courses on the patient record page. The patient list page displays a list of patients who are attached to a physician authorized in the system. In the main menu of the “Devirta.Accuracy” application, the patient is shown a list of exercises available to him, which are set as active at the current moment in the course of rehabilitation.
Let’s consider the standard process of interaction between the patient and the doctor in the process of restoring the mobility of the patient's upper limbs. This process can be broken down into several stages, some of which together represent an iterative process. The process is shown in Figure 1.

![Figure 1. IDEF0 (as-is) diagram of a standard doctor-patient interaction process](image)

The first step in the interaction process is the physician's diagnosis of the patient. At this stage, the doctor examines the patient and, based on the results of the examination, diagnoses him.

The exercise selection phase usually occurs immediately after diagnosis, or after analysis of the results after part or all of the rehabilitation course. In the standard process, this stage is carried out in face-to-face format, since it is necessary for the next stage, which in the standard version is also conducted face-to-face. After the exercises are selected, there is a stage of recording and transferring the list of exercises assigned to it for execution. The doctor gives the patient recommendations on how, when and in what sequence the patient should carry out the rehabilitation program assigned to him. When transmitting recommendations, they are most often presented in text format, printed on a printer or handwritten by a doctor.

In the standard process, the stage of teaching the patient how to perform the exercises correctly is quite time-consuming and time-consuming on the part of the doctor, since it requires face-to-face interaction with the patient when demonstrating and checking the technique of performing various exercises. This approach has other disadvantages in addition to time costs. For example, a patient may not fully learn the rules for doing exercises and do them incorrectly at home, which can lead to a worsening of his condition.

When the patient performs the exercises at home, the doctor does not participate in this stage in any way. Evaluation of the correctness of the exercises at home and recording the results is carried out by the patient himself. The disadvantage of this approach is that the assessment of the results may not be objective enough for further analysis of the results by the attending physician. Also, at home, it is not always possible to measure parameters to assess the patient's results, for example, the maximum angle of inclination of the hand. During the exercise, the patient needs to record intermediate results. Therefore, the next step is to record the results and transmit them to the doctor.

The last step in this process is the physician's analysis of the exercise results obtained from the patient. This stage is quite important, since, based on its results, the doctor decides either to complete the rehabilitation course, or to continue and change it by changing the list of exercises or something else.
After analyzing all the stages of the standard process of interaction between a doctor and a patient, it can be concluded that this approach is not intended for remote interaction between a doctor and a patient, since the patient often needs to visit a doctor during the course of rehabilitation. Also, the doctor spends a lot of time teaching the patient how to perform the exercises, analyzing the results and personal meetings with the patient to adjust the course of rehabilitation. In addition, the doctor cannot find out the current state of the patient at any time and control the quality of the exercises performed by the patient at home.

Let's consider the process of interaction between a doctor and a patient using a modified program "Devirta.Acuracy" and the developed online doctor's office. Using the modified application and the online doctor's office, we can reduce the number of patient visits to the doctor. In addition, in this process, we relieve the doctor and the patient from routine work at some stages and provide the doctor with the opportunity to access the dynamics of the patient's results at any time. The process of interaction between a doctor and a patient using a modified application "Devirta.Acuracy" and an online doctor's office is shown in Figure 2.

![Figure 2](image-url)

Figure 2. IDEF0 (to-be) diagram of the process of interaction between a doctor and a patient using a modified application "Devirta.Acuracy" and an online doctor's office

The online doctor's office is a web service that makes it possible to synchronize patient data and manage patient courses by a doctor in a remote format. The modified version of the "Devirta.Acuracy" simulator includes the ability to authorize the patient and display only the list of exercises available for execution in the program interface. In addition, the modified version of the program also sends the results to the server upon completion of the exercise by the patient.

Let's consider the changes in the stage of saving the information about the course in comparison with the previous processes. In this case, thanks to the creation of a web service, all information about patients is stored centrally in a special database with which the web application of the online doctor's office works. This approach allows you to synchronize information about the patient, regardless of whether he is in the clinic at the doctor's office or at home.

Therefore, changing the course of rehabilitation, the doctor only needs to change it in his personal account, and the patient will see the updated list of exercises in his application-simulator "Devirta.Acuracy".
The next step, which involves adding a system, is recording the patient's results and transferring them from the patient to the doctor. Thanks to the modification of the application, after the patient has completed the exercises, the results are automatically sent to the server of the web application and correlated with the current course of rehabilitation. This solution eliminates the need for the patient to record their results in any format and transmit them to the doctor, as this is done automatically by the application.

The changes also apply to the stage of analysis of the results by the doctor. Now, in the online office, the doctor can always see the current course of rehabilitation of the patient, its results of performing the exercises. In addition, the doctor can view the more detailed dynamics of changes in the patient's results during the course of rehabilitation on the corresponding page of the personal account. The data is also displayed both in a tabular and in the form of a graph, where the X-axis is the date and time of the exercise, and the Y-axis is the value of the result of the exercise. The graphic way of displaying allows you to more quickly and clearly assess the situation and adjust the course of recovery, if necessary. In addition, the doctor has the opportunity to study in more detail the individual time period of the patient's results using the filters on the results page.

Using this process, it can be noted that with the introduction of a doctor's personal office and modification of the "Devirta.Accuracy" simulator, it becomes possible to distance the process of interaction between the doctor and the patient during the period of restoration of upper limb mobility. The personal presence of the patient is now necessary only at the first examination, when the doctor makes a diagnosis to the patient and during other full examinations of the patient, to obtain information about the condition of the patient's hands, which cannot be obtained using the Leap Motion sensor. In addition, due to the use of the “Devirta.Accuracy” training program, it controls the correctness of the exercises and educates the patient. With this decision, doctors are freed from some routine stages and at the same time have the opportunity to get the current state of the patient at any time and quickly adjust the course. The disadvantage of this solution is the need for the patient to have inexpensive Leap Motion equipment and a personal computer with Internet access.

4. **Description of the service structure**

To implement the requirements for synchronizing data about patients, their diagnoses, courses and results, a client-server architecture of the service was chosen. The structure of the service being developed is shown in Figure 3.

![Figure 3. The structure of service modules](image_url)
In this service structure, the client part includes the web application of the doctor's personal office and the application for performing exercises "Devirta.Accuracy". The back end includes a RESTful server and database. The interaction between the client and server side takes place through the REST API. [5] Upon receiving a request from a client, the server executes a request to the database to create or receive information requested by the client and after performing operations on the data sends the status of the operation to the client to further inform the user about the changes [6, 7, 8, 9].

There are two service roles in the developed service:

- Doctor;
- A patient.

The doctor is able to register, attach, detach a patient, receive information from him, add and edit his diagnosis, and also receive the dynamics of the patient's results.

The patient is able to perform the following functions:

- authorization in the service;
- getting information about yourself;
- add the results of the exercise.

A diagram of the use cases for the doctor and the patient of the developed online doctor's office and the application for performing exercises "Devirta.Accuracy" is shown in Figure 4.

![Diagram of the use cases](image)

**Figure 4.** Diagram of the use cases of the developed online doctor's office and application for performing exercises by the patient "Devirta.Accuracy"

The process of using this service by the patient is as follows: after receiving the login and password for the doctor, the patient is authorized in the program and performs the exercises available to him, after which he can view the result of the current session. In the event of complications or any kind of ailments associated directly with the system used, the patient should contact a specialist to adjust the course of treatment. After the end of treatment or a successful recovery, access to exercise for the patient is limited.

Considering this process from the side of the doctor, it will become clear that his main role is that he both registers and adds all information about the patient and assigns him exercises, monitors the dynamics of the results of their implementation and, if necessary, corrects the course of restoration of motor skills.

The service is presented as a website intended for use by both the doctor and the patient. This decision was associated with the principle of creating maximum comfort for doctors and patients.
5. Conclusion
As a result of this work, an analysis of the approach to monitoring and managing the rehabilitation of fine motor skills of the upper limbs of the patients' hands was carried out. And also, a service providing a service for timely monitoring and adjusting the course of treatment for patients with various fine motor disorders was developed and implemented.

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