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ORIGINAL

SOFTWARE ARCHITECTURE FOR CUSTOMIZED PHYSICAL EXERCISE PRESCRIPTION

ARQUITECTURA SOFTWARE PARA LA PRESCRIPCIÓN DE EJERCICIO FÍSICO PERSONALIZADO

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ABSTRACT

Currently there is a lot of available applications to do physical exercise. This article describes the software architecture for an application that allows customized exercise prescription. This architecture includes two functionalities, the functionality that allows specialists to prescribe physical exercises and the functionality for users who must follow this prescription. Interactions between specialists and users are allowed by means of sending events. Specialists (doctors, physiotherapists and physical educators) can indicate appropriate exercises in each case. This application will allow users with demand for personalized attention to improve their fitness and quality of life. Users can perform physical exercise autonomously, without having to travel and in a flexible schedule.

KEYWORDS: health information systems, mobile computing, physical exercise, prescription, software system.

RESUMEN

En la actualidad existe una gran cantidad de aplicaciones para la realización de ejercicio físico. En este artículo se presenta una arquitectura software para una aplicación que permite la prescripción de ejercicios físicos personalizados. Esta arquitectura incluye dos funcionalidades, la funcionalidad para el especialista que prescribe el ejercicio y la funcionalidad para el usuario que debe seguir esta prescripción. La interacción entre el especialista y el usuario se realiza mediante el envío de eventos. Especialistas (médicos/fisioterapeutas/educadores físicos) pueden indicar los ejercicios adecuados en cada caso. Esta aplicación permitirá a los usuarios con demanda de atención personalizada mejorar la condición física y la calidad de vida. Los usuarios podrán realizar el ejercicio físico de forma autónoma, sin tener que realizar desplazamientos y en un horario flexible.

PALABRAS CLAVE: eSalud, Programación de Dispositivos Móviles, Ejercicio Físico, Prescripción de ejercicio, Sistema Software.

INTRODUCTION

A large and growing body of literature has researched about health and the influence of physical activity in improving the quality of life of people. Public and private institutions are developing programs of exercises related to health, addressed to different groups. In recent years, most of these programs are targeted at elderly people and population groups with some specific need (i.e., diabetes, hypertension, obesity, fibromyalgia, cancer, depression) [1][2]. Generally speaking, people demand healthy physical activity. There is a need for physical exercise to feel better and to be able to perform activities of daily living with less effort and energy expenditure. At the same time, it is a serious problem to disregard an adequate exercise prescription and the advice of persons who are not specialized in this area [3]. When we use "physical activity" as a therapeutic and preventive tool, then we must speak of a physical exercise prescription that is defined [4] as the "process by which a person is recommended a physical activity regime in a systematic and individualized way, to obtain the greatest benefits with the lowest risks". The effectiveness of physical exercise programs is perfectly proven in the treatment and prevention of numerous situations.

The regular practice of physical activity is one of the fundamental pillars of a healthy lifestyle and a true protection and promotion of health. Regular physical activity ensures, to people of all ages, obvious benefits to their physical, social and mental health as well as their general well-being [5]. The aim of the exercise will vary according to the group and its characteristics, however the term health, implies an improvement in the functional capacity of the subject (aerobic endurance, muscular strength and flexibility) and aspects psycho-social (i.e. self-esteem, anxiety, relationships, body image) [6].

On the one hand, the expansion and growth of information and communication technologies in all areas of our life (professional, leisure, personal care, ...) has made it possible to familiarize the entire population and to be something more or less everyday in the life of most people. On the other hand, the price reduction of computer and telecommunication devices (computers, mobiles, tablets, printers, ...) has been a fundamental fact in the access to these technologies by the population in general [7].

There are a lot of mobile exercise applications (such as Runtastic, Endomondo) that are designed for healthy people, who want to make a training plan, however, these applications are not adapted for groups with special characteristics that need to perform physical exercise, either as prevention or improvement of certain problems related to the locomotor system (i.e., osteoarthritis, muscular pains), cardiovascular (hypertension) or metabolic (i.e., diabetes, cholesterol, obesity). Moreover, there are tools for exercise prescription [8] containing databases with many exercises that allow the specialist to prescribe exercise to users. The

prescribed exercises are usually printed or emailed to the user. However, it is an improvement to perform these exercises using mobile devices. So, users will be able to perform the physical exercise independently, without having to make trips and in a flexible schedule. This would allow users with a demand for personalized attention to improve their physical condition and quality of life.

The rest of the paper presents the objectives of the work, the architecture of the proposed system, detailing the different components of the architecture, the prototype and conclusions of the work.

AIMS

The aim of this work is to help to prescribe personalized exercise for elderly people or people with specific needs, which can be guided by a multidisciplinary team of doctors, psychologists and sport and exercise science professionals. A software reference architecture for the required application is proposed. The analysis and design will be performed, as well as the implementation and testing of a prototype of the application that allows the prescription of personalized physical exercises to each person. With this application, the specialized staff will have available a more comfortable way to tell your patients the appropriate and recommended exercises to improve their physical condition and thus their quality of life. It will also help users to carry out these exercises, always under the recommendations of the specialist, without the need for travel or subject to schedules imposed, due to the use of a mobile application.

MATERIAL AND METHODS

To carry out the objectives outlined in the previous section, a software architecture of the application for customized exercise prescription is proposed. The functionality of the application for customized exercise prescription can be seen from the point of view of the specialist prescribing exercise or from the point of view of the user performing these exercises to improve its fitness.

The specialist may prescribe exercise to application users in a customized way. To achieve this, the system must have the necessary information about users and exercises that the specialist can prescribe as well as training routines composed of a set of exercises to be performed by the user. The system will allow registering new users and new exercises, as well as assigning exercises to the workout routines and assigning routines to a user.

From the point of view of the user, he can display physical exercises assigned by the specialist to perform them. To do this, the user will have available a mobile application that will allow him to authenticate himself in the system if he is already registered or otherwise to register, and to access to all the assigned training

routines, visualizing the exercises that he must carry out and being able to consult their descriptions.

To provide the application with these functionalities, the proposed architecture is divided into four different subsystems:

- **Database management subsystem:** responsible for managing user data, exercises and routines required for the prescription of exercises.

- **Event subsystem:** allows storing and retrieving events in an event queue, decoupling the event producers and consumers (users and specialists respectively).

- **Prescription subsystem:** application that allows the specialized staff to prescribe the exercises to each user that uses the tool. The database management subsystem is used to access to data and the event subsystem to access to events produced by users.

- **User subsystem:** Application used by the end user to perform the prescribed exercises. The database management subsystem is used to access to data and the event subsystem to send events produced by users.

Figure 1 shows this architecture with the four subsystems and the interaction with the specialist and the user.

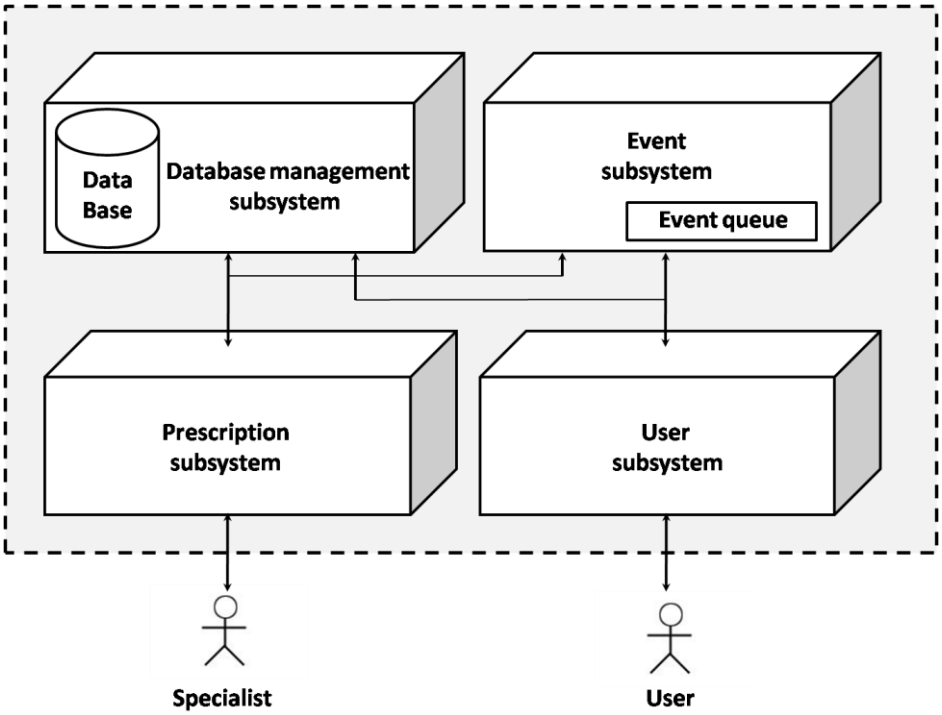

Figure 1. System Architecture

The following sections detail the different subsystems and the prototype developed.

DATABASE MANAGEMENT SUBSYSTEM

The database management subsystem is responsible for the maintenance (create, read, update and delete) of the necessary data so that specialists can prescribe exercises. The database stores user data, exercises and routines assigned to different users.

The used database schema is shown in Figure 2. The main tables in the database are the followings:

- **Users:** Stores the main user data, such as name, surnames, username, password required for authentication, and so on.
- **Routines:** Contains different routines defined by the specialist.
- **Exercises:** This table contains the physical exercises along with information on their description, purpose and duration.
- **Tools:** Stores information about the different tools that may be needed to perform the exercises.
- **Resources:** Stores the locations of resources to carry out the exercises, such as photos or videos.

- **Muscles:** Stores information about the muscles that will be worked in the different exercises.
- **ExerciseExplanations:** Contains a full description of how to perform each exercise.
- **ExerciseFeatures:** Stores the main features of each exercise, for what it is used and affected areas of the body.
- **ExerciseRecommendations:** Stores the recommendations of each exercise, who it is for and aspects to take into account when performing it.

On the other hand, there are tables used to relate a table to another table. These tables are:

- **UserRoutines:** Relates users to their routines assigned by the specialist.
- **ExerciseRoutines:** Relates exercises to routines. When the user chooses the routine he should perform the exercises in this routine.
- **ExerciseMuscles:** Contains the relationship between each exercise and different muscles involved in that exercise.
- **ExerciseResources:** Relates each exercise to available resources, such as photos or videos.
- **ExerciseTools:** Relates each exercise to the tools needed to carry out it.

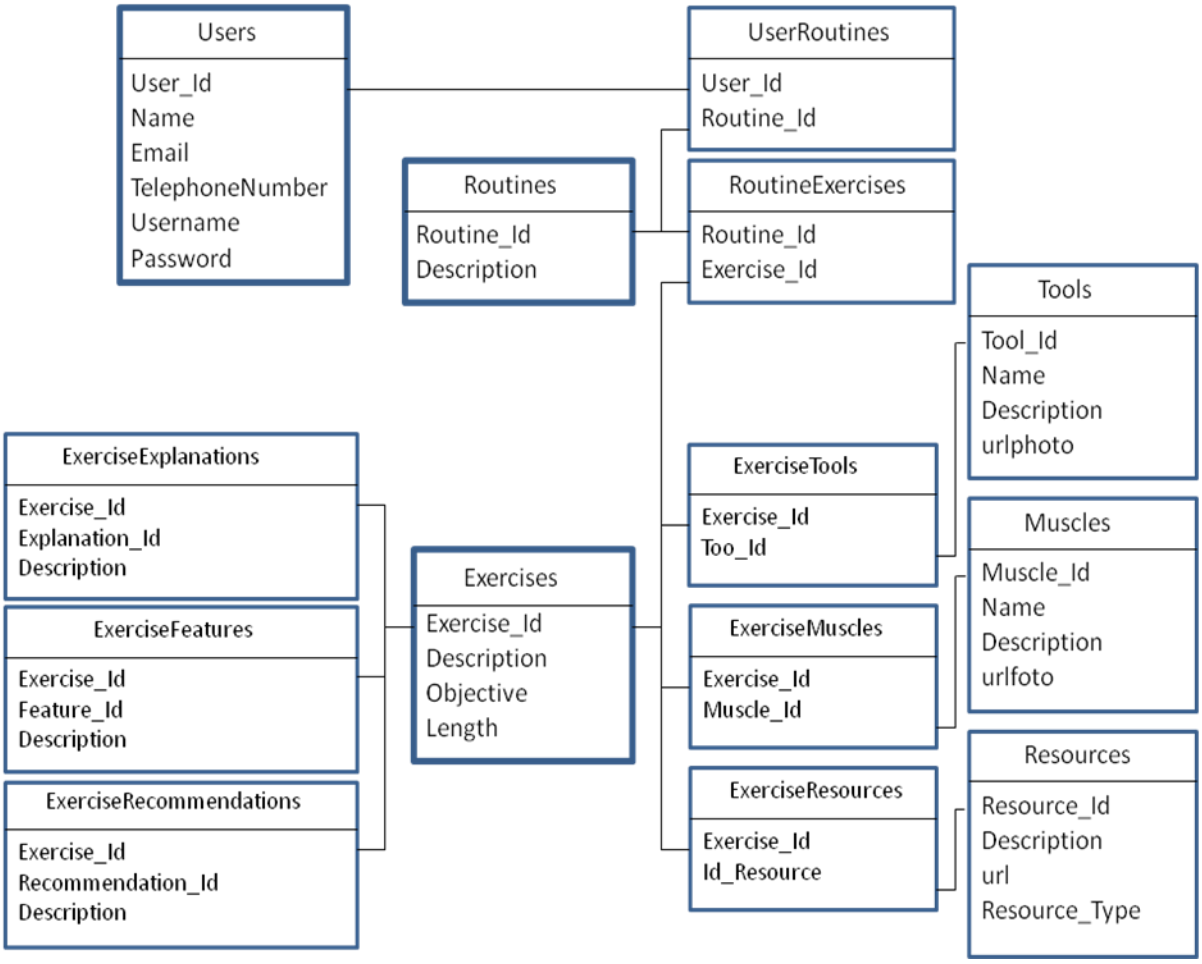

Figure 2. Database Schema for physical exercise prescription

This database management subsystem is used by both the prescription subsystem and the user subsystem.

PRESCRIPTION SUBSYSTEM

The prescription subsystem is the tool used by the specialist to perform a customized user management. This tool, called Training Manager, enables the specialist to assign exercise routines to the users. It is used via an intuitive graphical interface. The main functions of this subsystem are:

- Create, modify and delete users.
- Send an email in case of forgetting the password, with the new password assigned by the system.
- Create, modify and delete routines.
- Create, modify and delete exercises.
- Modify the routines assigned to each user, allowing to add new routines or to remove old routines.

- Modify the exercises contained in each routine, allowing to add new exercises or to remove old exercises.
- Change the photos and videos that will be displayed for each exercise in the user application.
- View events produced by users.

USER SUBSYSTEM

The user subsystem aims to allow a user to view on a smartphone physical exercises that the specialist has prescribed. In addition to this, it enables to send information about the routines that the user performs.

The application has different features for the user. The user can access the application once registered in the system or without registration. In the latter case, only a limited set of general routines will be accessible and the possibility of signing up for the system with the required user data. If a registered user accesses, then the application offers the following functionality:

- Change personal information.
- Request for new password via email in case of lost password.
- Access to user routines.
- Free access to all routines.
- Access to all exercises belonging to a routine.

Access to the exercises can be carried out in two different ways:

- Detailed access to each of the exercises.
- Quick access to the exercises, using a list with only the videos of the exercises of the routine to be performed.

Within the detailed access of each of the available individual exercises of a routine, the user can get:

- The description.
- The objectives.
- The length (number of series or repetitions).
- The properties, characteristics and recommendations.
- The tools (if they are needed to perform the exercise), such as elastic bands, weights, mats, etc.
- Data about the muscles involved in the exercise, with a description and a photo of each of them.

- For a better understanding of the exercise, photos of the exercise to be performed, such as a photo of the initial position of the exercise, another photo with the final position, as well as a photo with a detail of the exercise that the doctor or specialist has found it appropriate to highlight.
- Finally, an explanatory video, which simultaneously shows the exercise execution, as well as an explanation.

EVENT SUBSYSTEM

The event subsystem enables communication events occurring in the system by the user. For example, via the event queue the specialist is informed about routines carried out by the user. Also through this event queue the user can ask the specialist to contact him to inquire about the exercises. This allows the performance of exercises in a supervised way by the specialist.

In Figure 3 event communication between the user and the specialist is shown. The events are produced by the users and consumed by the specialists.

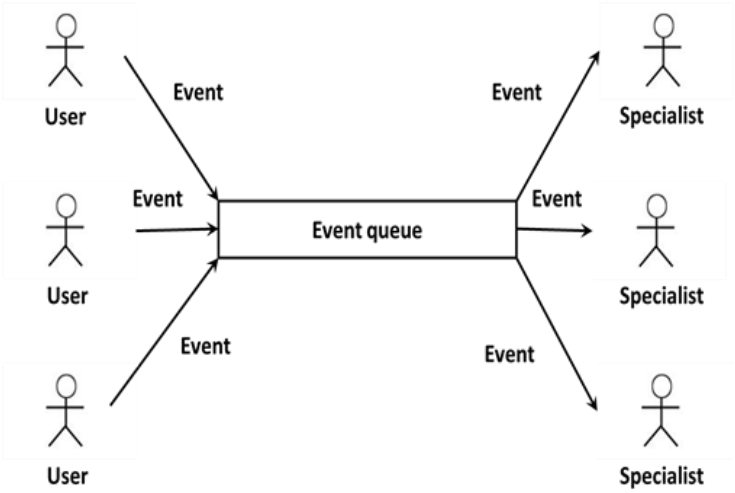

Figure 3. Event communication scheme

DEVELOPED PROTOTYPE

As part of this work, a prototype for prescribing exercise to users by the specialist has been developed. A desktop application to be used by the specialist for prescription and a mobile application to be used by the user have been developed, as well as the required software to access to the database and access to the message queue.

The architecture of the prototype including the technologies used in its construction is shown in Figure 4.

The technologies used in the prototype are the followings:

- **Java:** It is an object-oriented programming language, cross-platform, very popular for building distributed applications. It has been used to develop both, the application for the specialist and the mobile application for the user.
- **Android:** It is an operating system for mobile phones. It is based on the Linux operating system, an open source, free and cross-platform kernel. The operating system provides all necessary to develop applications that access phone features (such as GPS, calls, calendar, etc.) in a very simple manner in the Java programming language. For several years the Android operating system has the bigger smartphone market share.
- **MySQL:** It is a relational database management system, multithreading and multiuser. This database is used for storing necessary information for the exercise prescription system.
- **Apache:** It is an open source HTTP web server that implements the HTTP / 1.1 protocol (*Hypertext Transfer Protocol)*. Apache is widely accepted on the Internet. In the prototype, it is used to respond the request of specialists and users, both for data access and for communication of events.
- **PHP:** (PHP Hypertext Pre-processor) is an interpreted high-level programming language, designed for the development of dynamic content. PHP scripts are responsible for access to the database and communication of events.
- **JSON:** (JavaScript Object Notation) is a lightweight format used for exchanging data, being a subset of the notation for objects used in JavaScript. In the prototype, this format is used for the exchange of data between the server and the user or the specialist.
- **Kafka:** Apache Kafka is a publisher/subscriber distributed storage system, partitioned and replicated. These features, added to fast reading and writing makes it an excellent tool for communicating events generated at high speed and to be managed by one or more applications.

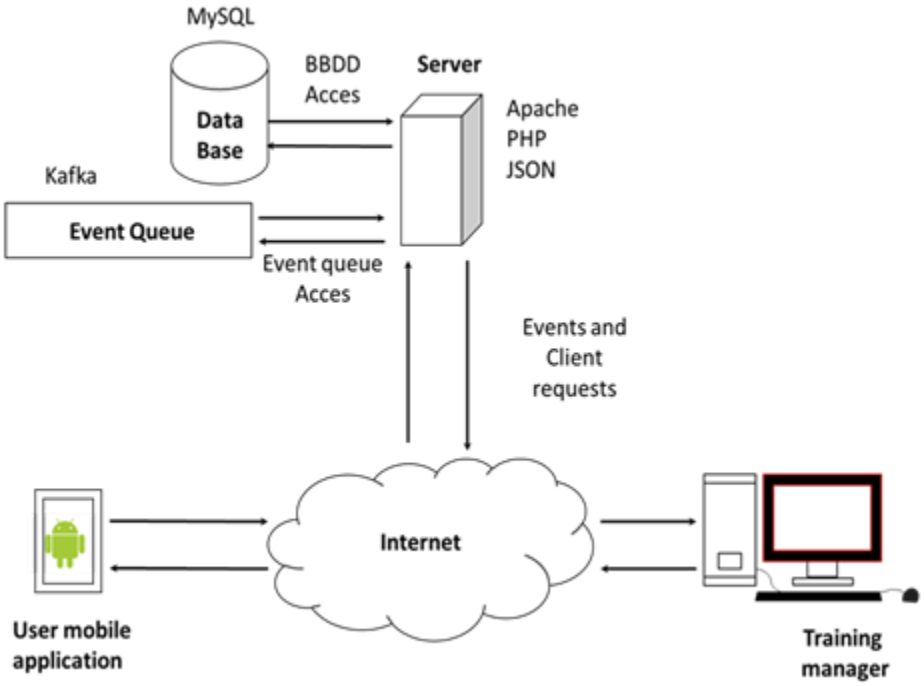

Figure 4. Architecture of the prototype

A user-friendly interface has been built for both the application of the specialist and the user mobile application. In Figure 5 the user interface of the application of the specialist can be seen. Here four different tabs, corresponding to User, routines, exercises and log can be distinguished. The first three tabs are used for user management, routines and exercises, respectively, which enable the creation, modification and deletion of these. The log tab allows the specialist to view events produced by users. In Figure 5 the log tab of the application is also shown.

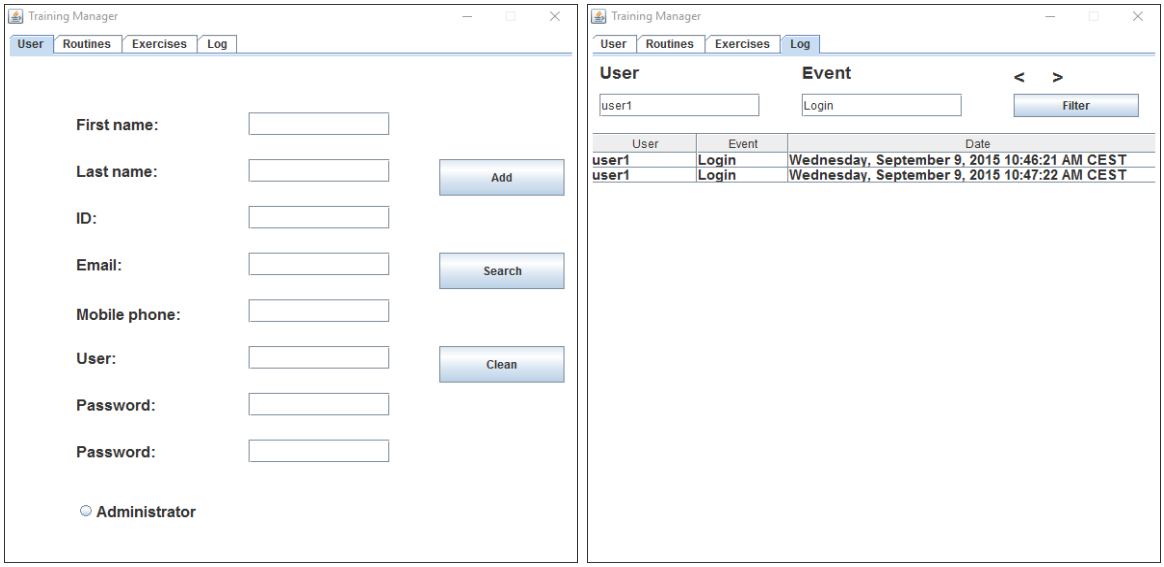

Figure 5. Application interface of the specialist

Some of the screens of the mobile application is shown in Figure 6. The screen that is presented to the user after using a login ID and password, the screen allowing the user to select a specific routine and the screen with information concerning an exercise are displayed.

Figure 6. Mobile application screens

RESULTS

The results obtained in this work are on the one hand a software architecture proposal for the improvement of the prescription of personalized physical exercise and on the other hand the development of a prototype based on the proposed architecture. With this architecture, specialized personnel have a more effective way of prescribing to their patients the exercises that allow them to improve their physical condition. They have the help of the mobile application in which the user can visualize exercises and recommendations of the specialist, without having to travel or at fixed times.

DISCUSSION AND CONCLUSIONS

Nowadays technologies are present in all aspects of our lives and improving the physical condition is an important aspect affecting the quality of life and health. This work describes the software architecture of an application that allows a specialist to prescribe customized exercise to a person, adapted to their physical

condition and their needs. A prototype that includes both prescription and user application is presented. With the help of this application, the specialized staff will be able to indicate the exercises to be performed by the users, who will have a mobile application to follow the prescribed exercises.

This work has focused on the architecture design and the development of the prototype therefore several improvements can be proposed, such as those mentioned following. The communication between the specialist and the user can be improved by means of a messaging system. The database of exercises should be expanded. It is possible to incorporate the use of external devices that allow the measurement of physical parameters of the user by means of sensors. Using a security system that allows us to authenticate the user device without having to identify the user each time the application is started would facilitate access. The user's mobile application could also be programmed for the iOS operating system, to reach users using this operating system. To expand the number of users who can access the application it could be deployed in the "cloud" to be scalable.

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