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BAMOS: A recording application for BAsso MOuse scale of locomotion in experimental models of spinal cord injury

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ABSTRACT

Transparency in science is increasingly a hot topic. Scientists are required to show not only results but also evidence of how they have achieved these results. In experimental studies of spinal cord injury, there are a number of standardized tests, such as the Basso-Beattie-Bresnahan locomotor rating scale for rats and Basso Mouse Scale for mice, which researchers use to study the pathophysiology of spinal cord injury and to evaluate the effects of experimental therapies. Although the standardized data from the Basso-Beattie-Bresnahan locomotor rating scale and the Basso Mouse Scale are particularly suited for storage and sharing in databases, systems of data acquisition and repositories are still lacking. To the best of our knowledge, both tests are usually conducted manually, with the data being recorded on a paper form, which may be documented with video recordings, before the data is transferred to a spreadsheet for analysis. The data thus obtained is used to compute global scores, which is the information that usually appears in publications, with a wealth of information being omitted. This information may be relevant to understand locomotion deficits or recovery, or even important aspects of the treatment effects. Therefore, this paper presents a mobile application to record and share Basso Mouse Scale tests, meeting the following criteria: i) user-friendly; ii) few hardware requirements (only a smartphone or tablet with a camera running under Android Operating System); and iii) based on open source software such as SQLite, XML, Java, Android Studio and Android SDK. The BAMOS app can be downloaded and installed from the Google Market repository and the app code is available at the GitHub repository. The BAMOS app demonstrates that mobile technology constitutes an opportunity to develop tools for aiding spinal cord injury scientists in recording and sharing experimental data.

1. Introduction

According to the World Health Organization [1], the term spinal cord injury (SCI) defines the "damage to the spinal cord resulting from trauma (e.g. a car crash) or from disease or degeneration (e.g. cancer)", which in many cases leads to permanent disability and loss of quality of life. Considered untreatable for centuries, the seminal work by David and Aguayo [2] demonstrating the regenerative capabilities of the spinal cord ushered in a research field that is in continuous growth. Unfortunately, none of the scientific and economic efforts accomplished to date has led to an efficient therapy. Several reasons underlie this failure, of which the most important is the complexity of the pathology. However, researchers, agencies, journals, and pharmaceutical companies acknowledge that lack of good practices and standards of transparency cause important reproducibility issues that also contribute to this failure, as occurs in other biomedical areas [2].

Recently, several consortia have joined efforts to promote coherent reporting guidelines for biological and biomedical investigations (MIBBI [4]). In 2014, the most renowned SCI researchers highlighted the importance of applying these standards in the field and built up the MIASCI (Minimal Information About Spinal Cord Injury) and its associated database [5]. According to these authors [3], the aims of these tools are: 1) to warrant access to sufficient information for other groups to replicate their results; 2) to inform research groups on good practices; and 3) to store experimental data and associated metadata from published SCI studies in an appropriate format. The present contribution is

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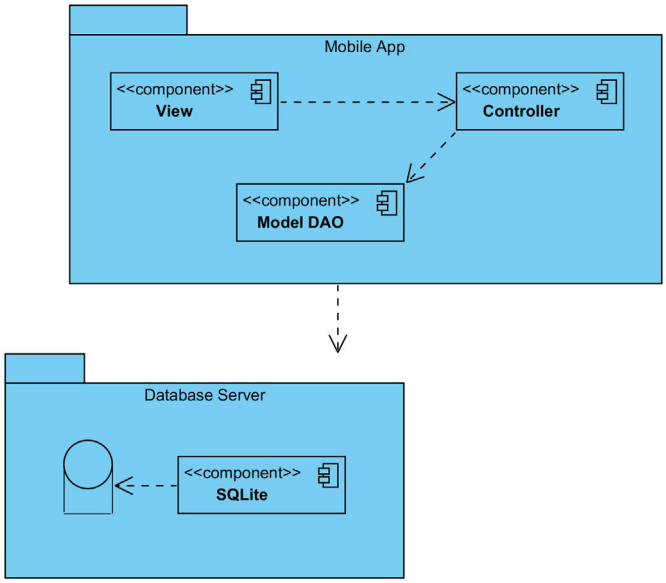

Fig. 1. Components of BAMOS tool.

part of a collaborative effort from informatics and SCI researchers, drawing on this conceptual framework. Our aim is to use mobile technology to develop tools for recording, storing and sharing data from SCI experiments. In this first study, we have developed a mobile/tablet application allowing researchers to record locomotion data from injured and uninjured mice.

Loss of locomotor abilities (paraplegia and tetraplegia) is probably the most noteworthy among the functional deficits of spinal cord injury. The analysis of locomotion is a common practice in SCI experiments aiming to understand the mechanisms underlying functional deficits and recovery, or to evaluate the efficacy of experimental therapies [6]. Many different tests have been employed over the years to analyse animal locomotion, but the BBB locomotor rating scale [6] for rats and its adaptation to mice, the Basso Mouse Scale for locomotion (BMS scale [7]), are undoubtedly the most widely used in SCI studies. These scales are used to rate key locomotion parameters while animals are moving in an open field during a 4-min period. The values of each parameter are recorded and used to score the animals locomotor abilities. The simplicity, standardization, and good agreement with injury severity, together with the availability of annual training courses at The Ohio State University, have helped to spread the use of these tests. Following the procedures established by the authors, locomotor data is recorded on a paper form and can be documented with video recordings. Although the standardized and coded data from BBB and BMS experiments is particularly suited for storage and sharing in databases, to our knowledge neither the system of data acquisition nor the repository is still available. Furthermore, most published papers only refer to the final scores computed after the values of the whole set of locomotion parameters evaluated during the test, leaving out information that can be relevant to understand locomotion deficits or recovery, or even important aspects of the treatment effects.

Therefore, we aimed to develop a mobile application that evaluators can use to record both video and input BMS data while performing the experiments, which automatically computes the scores and subscores established by Basso and colleagues (2006), and which could be used to upload the obtained information to databases or analysis software. In addition, we decided the app should meet the following criteria: i) user-friendly, so it requires no training (besides BMS training); ii) few hardware requirements (just a smartphone or tablet with a camera running under Android Operating System); and iii) based on open source software, so anyone from the scientific community may implement further developments.

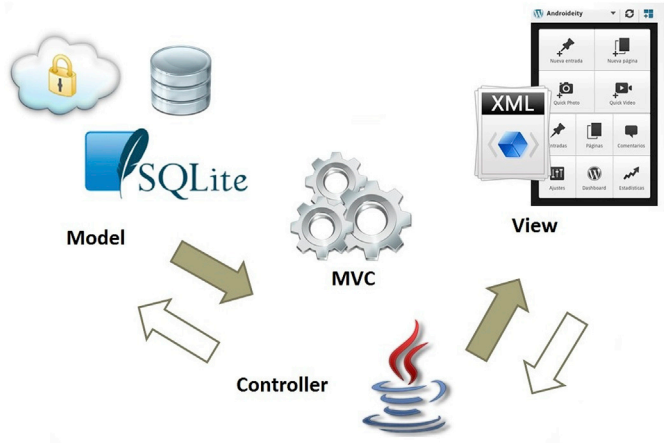

Fig. 2. Layers of MVC pattern for Android.

The next section presents BAMOS, a recording application for testing locomotion in mice models of spinal cord injury. We first describe the design and structure of the app, including information on the software used in its implementation, followed by a description of its use. Future developments and other comments are included in the discussion section. BAMOS can be downloaded from the Google Market repository and the app code is available at GitHub [8] repository. This program is free software: users can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 [9] of the License, or any later version.

2. Analysis and design of BAMOS tool

As previously stated, BAMOS is a software tool allowing researchers in spinal cord injury to record data and video from BMS tests easily, to automatically compute the associated scores and subscores, and to store (or export) the information obtained.

In accordance with the proposed criteria, this software tool has been developed following an Open Source Software philosophy, so that the scientific community can participate and contribute. The software engineering methodology followed for the analysis and design of BAMOS tool is based on SCRUM [10], an iterative and incremental agile software development framework for managing product development.

The application has two main components (Fig. 1). The first, the app, records BMS information (both video and parameter data), performs all calculation and sends a message to the researchers e-mail when the experiment finishes. This component has been implemented by using Model-view-controller (MVC) pattern adapted to mobile application development, especially to Android devices. This software architecture pattern separates data, user interface and business model into three interconnected layers, conforming the application:

- Model (DAO model), the layer that manages and interacts with the data, being responsible for carrying out the insert, update and delete operations in the database, which is implemented in SQLite [11]. This layer interacts with the second component, that is, the database.
- View, which defines the set of interfaces the user interacts with. These have been designed using the XML language [12].
- Controller, which is in charge of connecting the different layers.

We have used Java [13] -more specifically, Android SDK [14], to develop the model and controller layers. The IDE has been used for the development of the product is Android Studio [15].

The second component represents the database server where information about the researcher, the experiments, and the animals, together with BMS data are stored. The Entity-Relation diagram of Fig. 3 describes the relationships among the different tables included in the database and