A Gait Analysis Software as a Service

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***Abstract*—This paper presents the implementation of a human gait analysis Software as a Service (SaaS). This approach has as advantage, the software availability at the web. After the software is implanted at a webserver, users may access it from a recent web browser with HTML5 support. The goal of software is to minimize code development efforts of researchers from gait analysis, as well as to be useful tool for health professionals interested in the human gait analysis. The software allows import positional data from a third party motion captures system, that uses surface markers and video cameras, to plot markers spatial progression, angles, angular velocities and angular accelerations. Furthermore, it is possible to see and to interact with a 3D animation from markers. The software source code is available as free software, often receive new features and a new community is being created to maintain it.**

***Index Terms*—Gait analysis, software as a service, SaaS.**

I. Introduction

WITH the advent of software web, is possible to create services that are placed at webservers and access it from anywhere. Furthermore, modern web browsers have become a truly platform, which allows create rich interfaces that include graphical presentation and 3D animations without the need of plugins installations. These two technologies, web browsers and webservers, may be used to build what is known as Software as a Service (SaaS). The SaaS advantages for customers and software developers are [1]: customers do not need to install the application; data associated with the service should be kept centralized, so it is protected; data may be collectively accessed by a group of users; big datasets and data that is frequently updated, are kept centralized and remote access to them are offered; only a single copy of the server software runs in a controlled hardware and operating system environment, which avoids compatibility problems, in addition, new versions of the software can be tested with a small fraction of the real customers without disturbing most customers.

Although there was advances on the gait analysis by the middle of century XX, clinic gait analysis became broadly available only with the modern computer advent [2]. Actually, there are a lot of software packages for this purpose [3]. But until now there are no software provider committed to deliver a gait analysis SaaS. in other words, health professionals or gait analysis researchers who need to use software, must install it at specific hardware and operating system. Furthermore, they have to be responsible by data backup and if there are new software versions, it must be installed again. Whether they need to share data, then must copy and send it to the destiny. In addition, others security concerns must be addressed as well. These problems may be minimized or even eliminated with a SaaS.

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In order to implement a software is essential to accomplish the requirements elicitation and a certain domain of the field should be understood, in this case gait analysis. Nowadays, the theme is quite documented [4]–[11]. Moreover, there are experienced health professionals in the development with knowledge on gait analysis. Then, this paper presents the first implementation version of a gait analysis SaaS [12]. This software version may import data from a third party motion capture system, in this case data collected from video cameras using surface markers. Also the software may name markers, define angles, and plot markers progression at space, angles, angular velocities and angular accelerations. So, the software presents a 3D animation from imported data and allows user interact with it.

II. Materials and Methods

Two researches environments were used to undertake the project. One was the Human Performance Lab (*Laboratrio de Performance Humana* - LPH) in University of Brasilia (*Universidade de Brasilia* - UnB) at Ceilandia, and the other was the Health Informatics Lab (*Laboratorio de Informatica em Saude* - LIS) in UnB at Gama. Data acquisition was made in LPH and software development tasks at LIS.

The next subsections presents the process for data acquisition, the development process and the general view of the software architecture.

A. Data Acquisition

The data are acquired by sixteen Qualisys Oqus cameras that use the Qualisys Track Manager Software (QTM). The data are relative to surface markers along a patient's body.

For this paper a healthy patient, male, with age between 20 and 30 years old was selected. Fig. 1 summarizes the data acquisition process. First, the markers positions are defined by the gait analysis specialist. For this paper, only the left trochanter, left knee and left tibia positions were considered. So the surface markers must be set at defined positions on patient's body. The next step is acquire data from the cameras and QTM software. In this step, the patient performs a comfortable gait cycle in front of the cameras. Then, five gait samples were acquired. The last step is convert the acquired data to MATLAB format that use the QTM software. Furthermore, it is important due to the standard chosen for the gait analysis software.

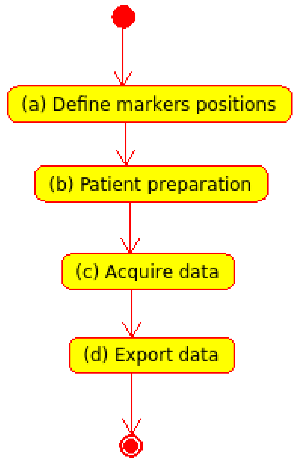

Fig. 1. Data acquisition process. (a) Positions of markers to be fixed in patient body are defined; (b) Markers are fixed at defined positions; (c) Patient executes some comfortable gait cycles in front of cameras. QTM software is used; (d) Data acquired are converted to MATLAB format using QTM software.

The process for data acquisition was approved by Ethics Committee from Faculty of Health *Faculdade de Saude* / UnB process number N11911/12.

B. Development Process

A scrum [13]–[15] inspired process for development was implanted. The scrum is a agile method [16] that has as mainly characteristics to be iterative, incremental and change friendly. These characteristics are essentials to deal with software requirements volatility and, hence, with software changes.

The process flow is presented in Fig. 2. These process consist of iterations called sprints. The sprints have a 2 weeks average duration. Therefore, a product backlog is created and managed by the product owner. Also the product backlog is open to receive additions from any project stakeholders, at any time, but only the product owner may prioritize it, that are based in expected values for final users. Each item at the product backlog is a user story [17].

Before a new iteration begins, there are a two phases meeting between the development team members. In the first phase, the last increment is presented and impediments occurred in the last iteration are revealed. In the second phase, the development team selects items from the product backlog. These items will be implemented in the sprint and are called the sprint backlog. Finally , is delivered an increment that consist in a piece of working software.

C. Software Architecture General View

The Fig. 3 shows the software architecture layered high level view. The web applications layer is responsible by application user interactions (Section II-C1). The layer REST web API is responsible by business logic, (Section II-C2). The document base layer is responsible by data application persistence (Section II-C3).

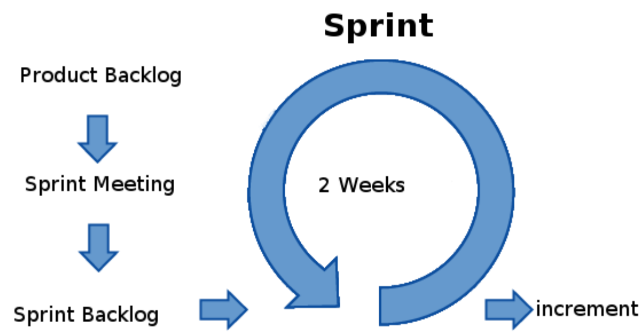

Fig. 2. Development process overview. Every two weeks a new increment, working software, is delivered. Adapted from [14].

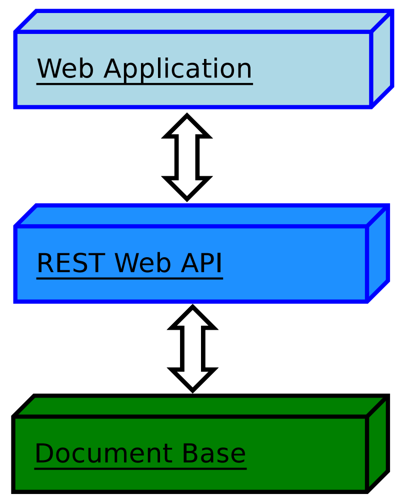

Fig. 3. The high level view of the software architecture layered.

1) Web Application Layer: This layer was designed to run in web browsers with HTML5 support. It was developed with Javascript, CSS and HTML languages. Moreover, the web development framework AngularJS was adopted [18], [19]. A great AngularJS adoption advantage is the directive creation possibility. Directives are developed components which may be embedded in a HTML template. Also, it was chosen to use the Angular-Material directive library. This library is based in the Material Design specification from Google, which describes about graphical design patterns and user interaction, it is based in the material metaphor [20]. The Angular-Material use, so it is possible to build a user experience that are acceptable by health professionals.

The ThreeJS library was chosen to run graphical 3D animations [21]. This is a high level library for computer graphics, which takes advantage from WebGL implementation in modern web browsers. The WebGL specification [22] uses the computer Graphical Processor Unit (GPU) natively, that allows to build applications which needs good performance to generate animations and graphics.

Fig. 4 shows the interaction between main components in web application layer. It can be observed that this is only a logic representation. When a user interacts with the application in the web browser, it produces events detected

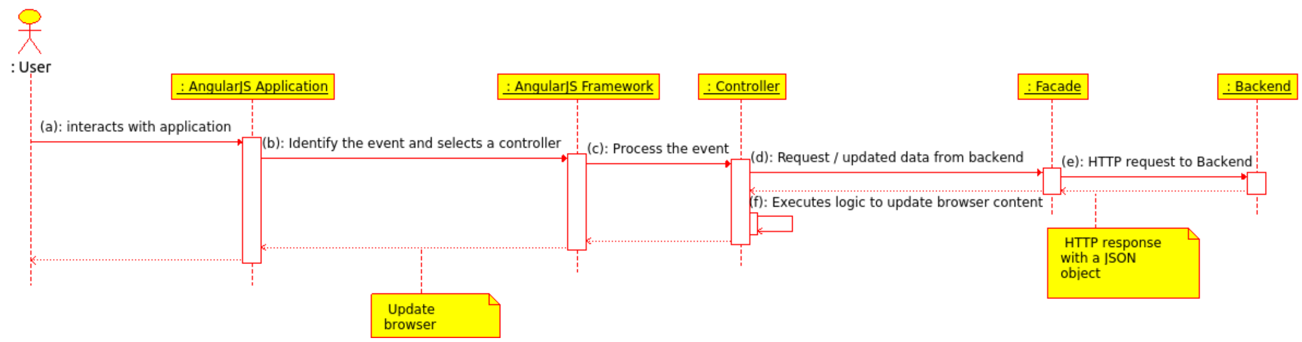

Fig. 4. Main web application layer components interactions. All these components, except the component backend, run inside the web browses. The component backend correspond to the infrastructure and components of REST web API layer. (a) A user interacts with the application, for example, a click button on screen; (b) The AngularJS framework detects the event, selects a controller component and dispatch the event for it; (c) The selected controller process the event; (d) If it is necessary to execute some action, as request more data, the controller requests to a facade component to requests the backend; (e) The selected facade component prepares and send a HTTP request to the backend, which returns a JSON object; (f) The controller updates the model, variables used by the framework to show data at screen, and signals to the AngularJS framework to update the screen.

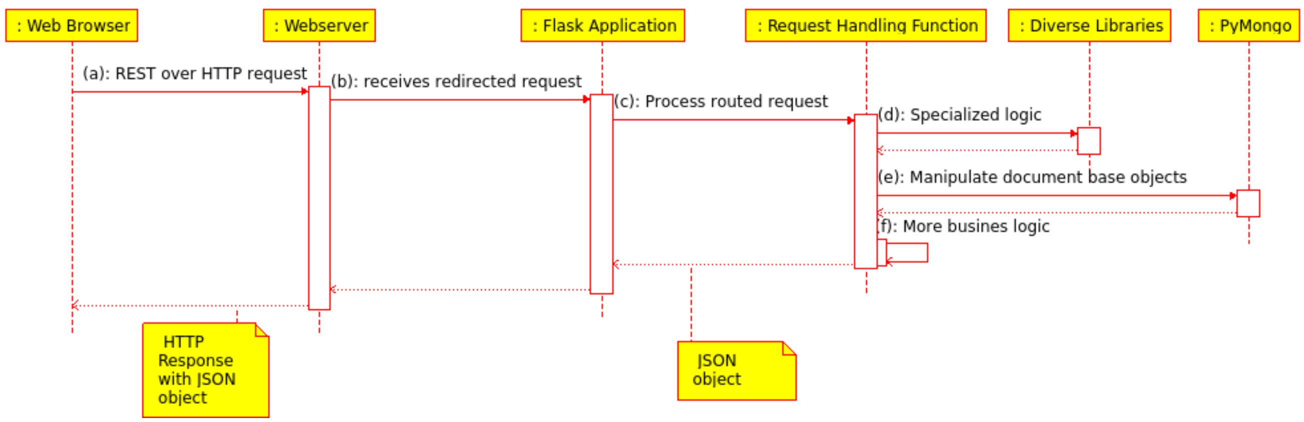

Fig. 5. Main REST web API layer components interactions. (a) From the user web browser, a HTTP request is sent to the webserver that runs the web API; (b) The webserver redirects the request to the Flask Application. (c) The flask application routes the request to the appropriate handling function; (d) If necessary the handling function access specialized libraries, like NumPy, Matplotlib or a library for business logic, for example, to calculate kinematics from gait data; (e) If data manipulation from document base layer is needed, calls to PyMongo can be made; (f) The function handling may implement business logic too, but it is only advise for simple things. The return data is encapsulated like a JSON object end sent to the webserver to complete the original request from the web browser.

by the AngularJS framework. The interaction may be a button click event, a mouse over event, a drag event or other. So, the framework selects a controller component to process the event. Controllers are components developed to the application, these are responsible to coordinate data access to the model and to update the view.

AngularJS applications use a famous design pattern called Model-View-Controller [23]. In practice, this means that controllers update the application state, so the AngularJS framework should update the screen to users. If new data or business logic execution are relevant, the controller request to a facade component that communicate with the backend. Facade is a design pattern which hides complex logic required to perform some action [23]. In this case is the communication over HTTP protocol to the backend. After the backend receives the request, it process and sends a HTTP response with a JSON object inside. JavaScript Object Notation (JSON) are a specification to represent and exchange data.

2) REST Web API Layer: This layer is responsible to execute business logic, for example, calculate angles, extract data from QTM software, among others. The layer was implemented using the architectural style Representational State Transfer (REST) [24]. The main advantage of this technology is the high decoupling with the web application layer. This decoupling promotes concepts separation between these layers, improving development process and application maintainability. To implement the REST style, was chosen the framework Flask [25]. Flask is implemented in Python language, it is known by minimalist philosophy that allows to create a simple project, which evolves into more complex models, according with requisites at moment.

Fig. 5 shows the interaction between main components in REST web API layer. This representation is only a logic view. After a user interacts with web application run at web browser and an action from the REST web API is needed, a HTTP request is sent to the webserver. This is a REST style request. The webserver receives the request and verify it. If, this request to the web API is yes, the request is dispatched to the web API implementation, that is written by the framework Flask. The framework Flask identifies the request and selects the appropriate handling function. This function is written in Python language. The request handling

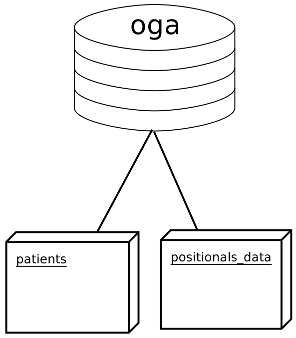

Fig. 6. Application document base. The data base name is ”oga”. This database has two collections: patients and positionals_data.

function may access many libraries, like NumPy for number crunching, Matplotlib for generate scientific graphics that are be sent to the user. Business logic application specific libraries may also be used, like libraries to calculate cinematic information; The PyMongo is an important library that may be used by the handling function as well. This component will access the document base manager MongoDB (Section II-C3), so is possible manipulate and persist the application data. The request handling also implements business logic, but is advised to implement complex logic in a specific library. When entire processing is done, a response is generated as a JSON object and sent back to the web application that runs at the user browser.

3) Document Base Layer: The data persistence and basic manipulation is done by the document base layer. This layer comprises a server running the document base manager MongoDB [26], [26]. This technology was chosen instead of a relational database management system, because the multidimensional data scope of the application is easily modeled with a document base. Also MongoDB is more easily scalable than a relational database management system. MongoDB does not use tables like relational databases, it uses the collection concept. A collection is a set of objects. Objects of a collection may have different structures or types, although this is a bad practice. A MongoDB database can have multiple collections. Objects are expressed using de BSON notation, which are very similar to JSON.

The Fig. 6 shows the application data base. It have two data collections: patients and positionals_data. The patients collections have basic data from the patient. The positionals_data collection has spatial and markers data imported from a QTM/MATLAB file.

III. Results

The developed software allows to register patients. After the patient is registered, the user may include gait samples to this patient. This sample is imported to the software from a MATLAB file generated by the QTM software. After the file is imported the screen described in Fig. 7 is shown. From this screen is possible to run a 3D animation including the markers acquired (Fig. 8). There is possible accelerate or slowdown the animation, to apply zoom in or zoom out, to controller pan and to see a specific frame in the animation. It is am important feature to see a frame because may be used to visualize the initial contact and terminal swing frames. So, it is possible to update these fields in the screen shown at Fig. 7(c). These data fields must be correctly filled otherwise the graphics will be incorrect.

The software has an option to name markers. After a marker is named, a graphic showing the marker's spatial progression will be plotted (Fig. 9). Another important feature is the angle registering tool (Fig. 10). After an angle is registered (Fig. 11), angular velocities (Fig. 12) and angular accelerations (Fig. 13) will be plotted.

Another advantage of AngularJS and Material-Angular is the seamless adaptation of their components to small screens. This characteristic turns possible with little effort to adapt the application to mobile phones. The Fig. 14 shows the application running in a mobile phone.

IV. Discussion

A software for gait analysis fully available at web is a innovation in the field. The bigger advantage is the easy access to the software, because after the application is implanted in an internet webserver, a user with a recent HTML5 browser can use the application, independent from the location.

Another theme that raises from this project is the creation of a centralized base, with data collected around world. Such endeavor would be priceless to gait analysis researchers. This would require a more profound care with information security.

The software is available as free software. The intention is to attract developers and health professionals to contribute and to use the software.

As future works, new data acquisition methods should be implemented, as plate force, electromyography (EMG) and inertial measurement unit (IMU). The inclusion of automatic detection events at gait cycle could be a plus, for example, detect the initial contact and terminal swing. Furthermore, a simulation module is being developed. It will support machine learning methods to regression and classification.

V. Conclusion

This paper presented a gait analysis SaaS. It source code is available as free software under the MIT license [27] at the web address ¡http://github.com/rob-nn/open_gait_analytics¿.

The software offers data importation from the third party software QTM from Qualisys. These data are about surface markers fixed in a patient body. The software allows name markers, plot a spatial progression from it. Also is possible to register angles and show graphics with angular velocities and angular accelerations. The markers may be viewed by 3D animation. All graphics are displayed according to the gait cycle phases.

The software will continue receive more features, and gradually will be available for more users. It is possible to other people implant or use the software as they wish.

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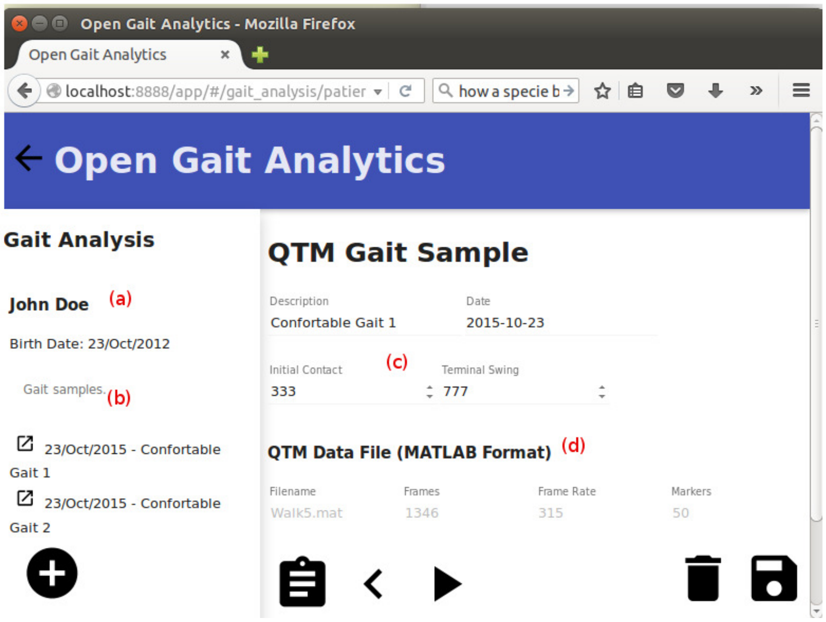

Fig. 7. Gait analysis screen. (a) Patient name; (b) Gait samples acquired from the patient and imported to the software; (c) Initial contact and terminal swing frames must be informed by the user, which may use the animation feature to know the correct frames; (d) QTM imported file summary.

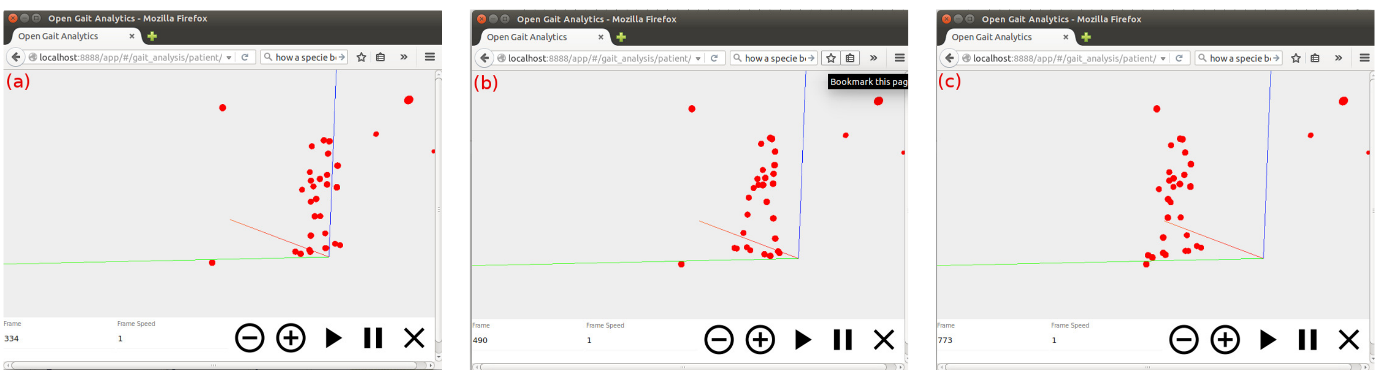

Fig. 8. Markers 3D animation. (a) Left inferior limb initial contact; (b) Left inferior limb terminal instance; (c) Left inferior limb terminal swing.

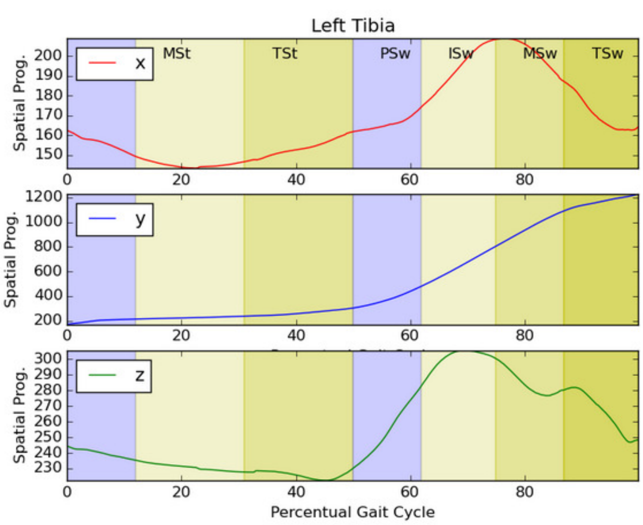

Fig. 9. Left tibial spatial progression.

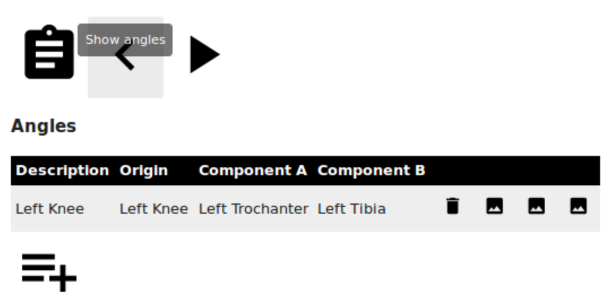

Fig. 10. Angle registering tool.

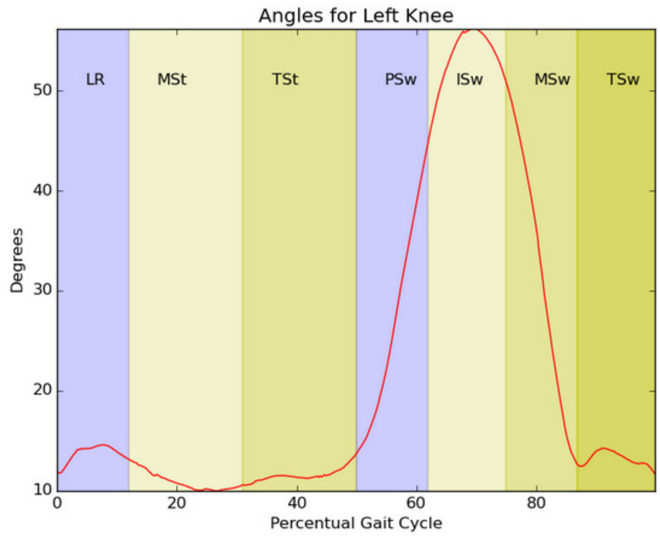

Fig. 11. Angles.

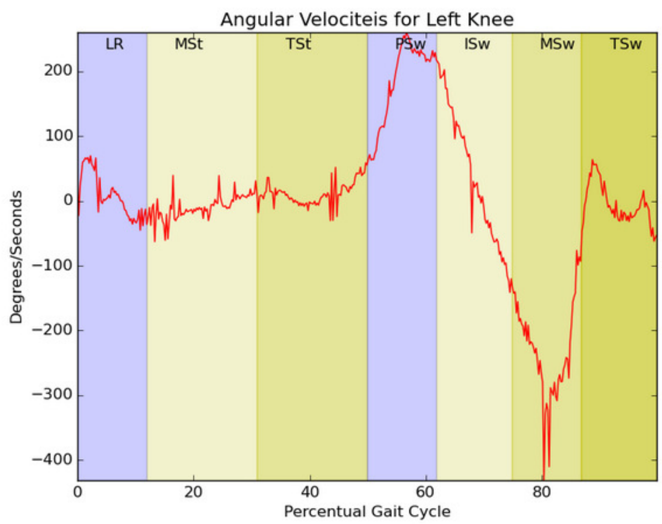

Fig. 12. Angular velocities.

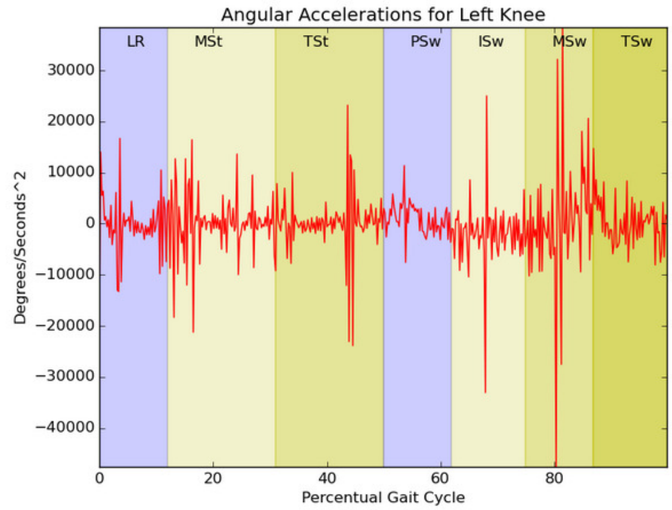

Fig. 13. Angular accelerations.

Fig. 14. Application running at a mobile phone.

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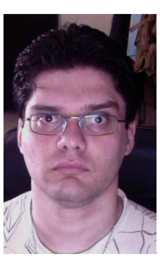

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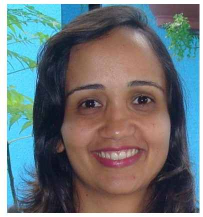

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