Public Health and Informatics
J. Mantas et al. (Eds.)

doi:10.3233/SHTI210164

Data Vizualization Dashboards in Robotic Rehabilitation

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Abstract. Robotic rehabilitation can offer effective solutions, facilitating physiotherapist work, and helping patients regain their strength. Visualizing results of rehabilitative training could give a better insight into the factors that contribute to progress and measure the exact progress by every session. This paper aims to present a set of prototype dashboards to analyze and visualize data from robotic rehabilitation in order to help the patients measure their exerted force progress throughout the training period. The created visualization dashboards which proved helpful and essential to present achieved measurements, the progress of the patient, and the maximum force in a timeline presentation. The proposed prototypes could give a personalized overview to each patient, fed with the corresponding datasets.

Keywords. Data visualization, Robotic rehabilitation, Dashboard

1. Introduction

Data, a term widely used in our everyday life, is essentially a set of raw information, that can drive improvement and ease decision-making when processed. Data processing though is not necessarily enough to make data accessible and easily understandable. One of the main ways to give a good insight to data is by visualizing them. A good data visualization should be complex enough to include all important information, yet simple enough to pass that information to the user clearly and sufficiently manner. Robotic rehabilitation (RR) produces big amounts of data, that can give a thorough overview of the status and progress of the patient throughout his psychokinetic treatments.

RR strongly relies on the principles of resistance training. Resistance training is the form of physical activity aiming to improve muscular power by exercising it against external resistance. Progressive resistance training is considered one of the best ways to achieve a healthy muscle hypertrophy, i.e. a steady and continuous muscle growth [1]. Progressively bigger stimuli will cause the necessary muscle fiber damage that is needed to reach the goal of stronger and independent movement [2]. Physiologists and physiotherapists carefully choose how much resistance should be added at which stage of the rehabilitation training, supervise to ensure correct form and make changes to fit the patient ‘s needs on a continuous basis. Robotic arm rehabilitation is a relatively new field in the science of physiology. Rehabilitation training requires patient’s engagement. It is found that the more focused the more successful his/her training can be towards the

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goal of enhancing the muscle force [3]. The visualizations tools using the Robotariner case aim to enhance the patient's engagement in time, delivering better and faster results.

This study aims to present how raw data from RR of a patient's upper limb can be visualized so that the patient's progress can be monitored, and influential factors can be tracked. The next section presents a literature review on how medical data visualization has been used in the past and what findings occurred and a practical part, with creation of dashboards using data from rehabilitation training. Then, methodology which we use for development our dashboard is introduced briefly.

2. Related Works

The practitioner's physical presence is beneficial for the patient's mentality over robotic rehabilitation, but patients have proved to familiarize themselves easily with the robot and trust its functions [4]. When it comes to robotic data visualization aimed to help the patient monitor his/her progress, it can offer a bigger engagement in the process of the rehabilitation training and build the patient's trust to the efficacy of the robotic processes that control the movement. The visualization of data from RR can contribute to further patient engagement in the process and possibly lead to faster progress. Physiotherapists create individual goals for each patient, examples of which can be specific numerical force values or completions of an independent movement, such as drinking a beverage without help. Offering the possibility of visualizing the goal for the patient can increase the mind-muscle connection [5], helping the patient focus more on the process and therefore exerting more power in the training. Goal setting increases the motivation and determination of people in multiple aspects of their life [6,7]. Visualization makes the goal clear and directly effects the person' s psychology and can trigger more self-motivation and self-guidance throughout the training.

Data visualization in rehabilitation cases can prove beneficial for encouraging the patient to continue trying towards a force amelioration while enforcing the mind-muscle connection and a good indicator for the practitioners to gain a more in-depth insight into the most indicative progress factors. RR dashboards lie in the field of health-related dashboards, whose use has been researched widely in the past. In sixteen years of literature review regarding the effects and benefits of health data dashboards [8], a team of researchers studied a many visualizations framework, including different presentation and performance indicators, aimed to heterogenous types of users. Researchers found evidence that adding dashboards in day-to-day clinical life helps health practitioners stick to necessary routines and improve patient care as information availability increased. However, it was unclear which exact visualizations characteristics were more useful. This study motivates further analysis and research on the impact of dashboard use for RR cases and is complementary to the studies presented below. In 2016, Ploderer et al. [9] created a wearable, sensor-equipped prototype, which captures measurements from arm motion, paired with dashboards using them for visualizing and monitoring patient's progress. The dashboards follow a user-centric design approach and make use of timelines to display mostly average daily values. Multiple tabs are included to focus on different aspects, while there is a "spreadsheet"-looking tab for specific values referencing. Therapists found the dashboards beneficial in physiotherapeutic sessions and gave positive feedback on the use of timeline format. Patients proved to engage more in the rehabilitation process by reviewing self-progress via the dashboards, as they worked as a motivation. Using that case, researchers decided to extend the project by creating ArmSleeve [10], another wearable technology monitored by interactive dashboards for displaying how the arm undergoing RR functioned and how measurements were triggered, so that their rehabilitation plan could be changed accordingly, and previous study's findings can be further evaluated. Both therapists and patients benefited from the use of dashboards, which visualized how progress was made via the wearable technology.

3. Methodology

The methodology for this study can be described as both qualitative and quantitative. The qualitative aspect consists of literature review, providing a baseline for implementing the experimental part, which corresponds to the quantitative aspect and is based on the data acquired from the rehabilitation using the RoboTrainer. The methodology is divided in the following iterative phases:

- Research understanding and literature background search
- Data preparation and data processing
- Selection of techniques and developing data visualization dashboard
- Evaluation of results

The patient has completed his training sessions at the time of this study; thus the visualizations are based on historical data and can be used as prototypes that, fed with new data, can automatically be updated to fit the needs of new patients.

Data processing is practiced on 96 data files. Each file corresponds to a training session and is automatically created by the RoboTrainer. The initial datasets include a timestamp, angle formed between the patient's upper and forearm and force exerted. Based on those, the "phase" that each data points corresponds to is added in every file. The phases are tricep, bicep, and hold. This study focuses on the progress on the force that is exerted at the hold in the end of the triceps extension. Subsequently, a single file containing the number of training, date, average force per training, maximum force and result of moving average window for both average and maximum values, as well as progress to a goal is created. This file is used as a base reference for the creation of the dashboards. Two separate dashboards were created, each with different set of visualizations. All y-axis of the visualizations corresponds to force measured in Newtons.

The first dashboard, presented in Figure 1, highlights the proximity of each training's average and maximum value to goal values in a timeline format. The second dashboard, presented in Figure 2, presents the results of applying the moving average and moving maximum algorithm on the maximum force of each training, along with the trend line followed, in a timeline format, as well as the dates of occurrence of the top 5 values of the average and maximum force values. The dataset was filtered out in such a way that only the end of the patient's triceps extension movement is studied. The tension coming from the elbow flexors as the arm's angle grows, and the force that the person has to exert to counteract it are proportionate [11] which means that the effort needed from the patient to perform the movement rises as the flexors get stretched. Making sure that the range of angle values corresponds to the specific movement, the results presented in the dashboards can be indicative of progress. The produced visualizations are evaluated based on previous research findings, taking into consideration the nature of available data, in order to ensure that they indeed can highlight the exerted force progress in a clear and understandable way.

Figure 1. Dashboard 1: Progress to goal.

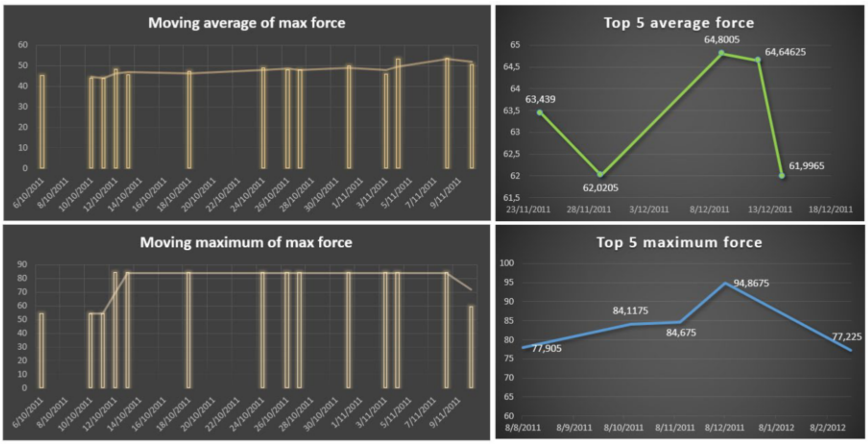

Figure 2. Dashboard 2: Moving average, moving maximum and top 5 values.

4. Discussion and Conclusion

In this study, we presented visualization approaches that can provide the patient insight of into how progress was achieved were created. We created an interactive visualization dashboard to monitor the progress of patients as well as a decision-making tool that helps physiotherapist to decide and monitor patients' training progress in long-term. This dashboard will then be used to track patients' training and also to investigate the impact of implementation of such a system in rehabilitation of patients. The first dashboard highlights the proximity that the average and the maximum force of every training have to a chosen goal. This dashboard's goal is to motivate the patient reach or exceed the goal. Inspecting the data, it is was observed that the maximum force was not achieved in the last training, but past the middle of the trainings period, for both average and maximum force. As such, the highest values were chosen as the goal. This goal can be modified by the physiotherapist in future cases where the dashboard is used.

The second dashboard includes two-line charts created applying the sliding window method, with the running average and running maximum filters and two-line graphs to demonstrate the five highest force values and when exactly they occurred. The purpose of this dashboard is to help visualizing the pattern of when and how progress is made. Regarding the size of the window chosen for the two algorithms, it was 10 trainings. Taking the size of the dataset into consideration, the chosen window managed to emphasize trends, while pinpointing the dates that the highest force values happened. The rest two visualizations present the five highest average and maximum force measurements throughout the entirety of trainings. The aim is to provide an easily accessible way of presenting the exact values of these measurements and the dates they were achieved.

Overall, techniques and methods that have been proved successful were used for creating visualizations such that they are meaningful and possibly motivating for the user. Focusing on the force that was exerted during a triceps extension hold, dashboards regarding the force progress throughout the training were created, in a clear and inclusive way. Visualization in robot rehabilitation has a plethora of interesting areas, such as live data transmission, thus visualization too, to further engage and excite the user. In our future work, we will focus on incorporating factors, such as the patient's mood and tiredness as a function of the exerted force, to provide a deeper insight on the factors that influence progress and contribute to the understanding of the muscle functions, as well as developing better robots and software.

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