Framework of visual analytics for medical rehabilitation

Framework d’analytique visuelle pour la réhabilitation médicale

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Abstract – The accumulation of tremendous amount of medical data in healthcare centers has created a great potential for applications of visual analytics. In this study, a framework for collecting, managing, analyzing and visualizing medical data for rehabilitation therapy is proposed. The developed visual analytics system receives data inputs from different sources; it performs the homogenization of data structures, the creation of datasets and allows the visualizations using bar graphs and pie charts based on univariate and bivariate analysis. This system was deployed in a server using Ubuntu 16.04 operating system, equipped with Hadoop 2.9.0, WildFly 9.0.1 and MySQL. Finally, the result of initial testing is promising for medical decision-making.

1 Introduction

The application of visual analytics in healthcare has been shown to save substantial amount of working time [1], significantly reduce expenditure [2], as well as, offering a personalized service [3]. Medical rehabilitation is one of the fields that can benefit considerably from visual analytics. The rehabilitation process can be a really long and demanding process, which requires motivation and perseverance [4], [5]. Immediate feedback is one of the main prerequisite of a motivating rehabilitation system [6], [7]. Visual analytics can provide that instant feedback to the patients to enhance their adherence to the rehabilitative programs. In addition, it can be incorporated to help therapists monitor the progress of their patients, as well as, supervising and directing the course of their therapy [8], [9].

Visual analytics can be used for both physical and cognitive rehabilitations. For example, the rehabilitation of neuro-motor disorders caused by a brain injury such as stroke can be a very difficult and lengthy process for the patients. As part of the rehabilitation practice, constant feedback is required for both patient in terms of motivation and therapist to better assess and supervise the situation [6], [7]. An example of cognitive rehabilitation is dyslexia remediation. Learning to read can be a hard and laborious task, especially when the child is underachieving and feeling the pressure of lagging behind, which leads to demotivation for engaging in reading activities, which in turn can further widen the gap between achieving and underachieving readers [10]–[12]. Similarly, integrating visual analytic systems into the reading interventions can produce the extra motivation in children to follow the program and for the therapist to monitor the progress of the therapy programme.

Visual analytics is not merely about monitoring the current state of a patient. Its full potential comes in the form of supporting the medical decision-making. It can propose new rehabilitation directions based on the actual state of the patient. In addition, it can analyse other patients with similar states and based on their data, predict what will be the best course of action for the actual patient [3].

Home-based rehabilitation can be defined as the provision of rehabilitation services to a patient at home, by a therapist located at a remote site, which reduces the transportation constraints and the associated costs [13], [14]. Some of the main benefits of the home-based rehabilitation are: no geographical constraint, monitoring and intervention by the therapist, real-time patient’s data capture and allowing one therapist to monitor multiple patients [14]–[16].

Related Works

S. Mahmud et al. [17] proposed a framework for analyzing and visualizing the health-shocks predictions. They utilized a large-scale digital health dataset collected from 1000 households, to create a predictive model based on fuzzy rule summarization technique. Their framework was developed using cloud computing services and geographical information systems, and was able to capture, store, index, and visualize the analysed data.

W. Lin et al [18] proposed a framework of a self-caring service fed by big medical data. This cloud-based service is called “*Home-Diagnosis*”, which was implemented at a prototype level; it offers the users the possibility of selecting their symptoms classified by body parts. Once the symptoms were selected, the system computed a disease-symptom lattice and presented the results to the users to help them judge their disease.

2 Approach and Architecture

In this research, a visual analytics framework is proposed and developed to collect, manage, analyse and visualize healthcare data. More precisely, it includes five modules: a relational database, big data ecosystem, data analysis, dashboard and operational block. Each of these modules are briefly described in the following section.

Relational database: It is the database that aims at saving the following items:

-Details of users' profiles (name, username, password, etc.)
-The coordinates of sources added by the users. For example, for a single database there will be the records of its name, address, type, port, as well as, its architecture of tables and columns.
-Datasets created by the users
-Results of analysis accomplished by the system

Big data ecosystem: Being equipped with a NOSQL database, this part constitutes the active data support that exists in the sources added by the users. In this case, the data can be very large. The ecosystem must ensure the smooth operations of reading and writing on the existing data.

Data analysis: This module works only when there is at least one data source connected to the system and at least one dataset is created. This module performs a univariate analysis (single variable analysis) for each column that exists in the NOSQL database, as well as, a bivariate analysis.

Dashboard: This module visualizes the final analysis results to the users. For reaching the dashboard, the users must create at least one dataset and they have to choose the dataset to be analysed and visualized. For numerical variables, the visualization will be a linear graph and a table containing the results of calculations of statistical quantities. For categorical variables, the display are in bar graphs and pie charts, which present the percentages of the values for each variable.

Operational Block: From this module, users can connect the Framework with data sources. For this objective, the users must first create a profile, then authenticate, so that they are redirected to the home interface where they can add one or more data sources.

3 SPECIFICATIONS

Functional and non-functional requirements that were targeted to be implemented into the proposed visual analytics framework are listed below.

Functional requirements:
-Extraction of data from their sources regardless of their types and structures
-Homogenization of the structures of the added data into a single structure
-Enabling users to add new datasets from the added data
-Performing data analysis and predictive calculations

Non-functional requirements:
-Security: Connection establishment requirements, CRUD levels (Create, Read, Update and Delete), password requirements (length of the configurable password, special characters, expiration), disconnection after idle activity, etc.
-Performance: Response time, loading, refresh times, computing speed, data importing and exporting, data query and reports.
-Integrity: The capture of input-output errors and management of corrupt/incomplete data.
-Ergonomics & UI: Density of elements on screens, layout and flow, colors, accessibility, languages, spelling, formats, etc.

4 IMPLEMENTATION

This visual analytics system was built using a Macintosh laptop (4GB RAM, Corei7 processor). It was developed using Eclipse Luna JAVA EE (version 7), JDK 1.8 and XAMP. It was ultimately deployed in a server with Ubuntu 16.04 operating system, equipped with Hadoop 2.9.0, WildFly 9.0.1, MySQL and Apache HBase.

Initial testing: At the end of the development process, two simple initial testing scenarios were designed to accomplish a preliminary evaluation. These tests are described below.

On a single local machine: the system was deployed in a local machine (Macintosh Laptop, 4GB RAM, Corei7 Processor). A specific test, it was observed that obtaining the analysis of results from a dataset containing 10 columns and 1000 entries was estimated to take around three seconds (including data transfer time).

On multiple machines (Clients / Server): In addition to the local deployment, the system was deployed in a server, enabling multi-users to utilize the system. The same test was performed and the analysis of results from a dataset containing 10 columns and 1000 entries taken on average around five seconds (including data transfer time). This was two seconds slower than the local deployment. The visual analytics allowed the user to perceive the trends represented by the collected data.

5 CONCLUSION AND PERSPECTIVES

In this study, a visual analytics framework is developed to facilitate and enhance the medical rehabilitation processes. The ultimate goal of this system is to increase the motivation of patients for adhering to their rehabilitation program by providing them with feedbacks about their activities, as well as, to help therapists monitor and supervise the rehabilitation process. Different types of data can be fed into this system, it offers the user the ability to create personalized datasets, it analyses the data for both numerical and categorical variables using univariate and bivariate analysis, and finally, it visualises the data in forms of bar graphs, pie charts and tables.

For future studies, a more in-depth evaluation is necessary to optimize the proposed framework, in terms of the speed of processing and quality of the information displayed by the visual analytics. In addition, other analytical models could be incorporated into the framework for providing a deeper insight into the medical data.

[1] J. G. Stadler, K. Donlon, J. D. Siewert, T. Franken, and N. E. Lewis, “Improving the Efficiency and Ease of Healthcare Analysis Through Use of Data Visualization Dashboards,” Big Data, vol. 4, no. 2, pp. 129–135, 2016.

[2] B. Kayyali, D. Knott, and S. Van Kuiken, “The big-data revolution in US health care : Accelerating value and innovation,” Mc Kinsey Co., vol. 2, no. 8, pp. 1–13, 2013.

[3] J. Hu, A. Perer, and F. Wang, “Data Driven Analytics for Personalized Healthcare,” in Healthcare Information Management Systems, 2016, pp. 529–554.

[4] H. Jamshidifarsani, S. Garbaya, T. Lim, P. Blazevic, and J. M. Ritchie, “Technology-based reading intervention programs for elementary grades: An analytical review,” Comput. Educ., vol. 128, pp. 427–451, 2019.

[5] P. Tamayo-Serrano, S. Garbaya, and P. Blazevic, “Gamified in-home rehabilitation for stroke survivors: analytical review,” Int. J. Serious Games, vol. 5, no. 1, 2018.

[6] N. Barrett, I. Swain, C. Gatzidis, and C. Mecheraoui, “The use and effect of video game design theory in the creation of game-based systems for upper limb stroke rehabilitation,” J. Rehabil. Assist. Technol. Eng., vol. 3, pp. 1–16, 2016.

[7] M. F. Levin, P. L. Weiss, and E. A. Keshner, “Emergence of Virtual Reality as a Tool for Upper Limb Rehabilitation: Incorporation of Motor Control and Motor Learning Principles,” Phys. Ther., vol. 95, no. 3, pp. 415–425, 2015.

[8] M. H. Chen, L. L. Huang, and C. H. Wang, “Developing a Digital Game for Stroke Patients’ Upper Extremity Rehabilitation – Design, Usability and Effectiveness Assessment,” Procedia Manuf., vol. 3, no. AHFE, pp. 6–12, 2015.

[9] N. Shah, A. Basteris, and F. Amirabdollahian, “Design Parameters in Multimodal Games for Rehabilitation.” Games Health J., vol. 3, no. 1, pp. 13–20, Feb. 2014.

[10] B. Hart and T. R. Risley, Meaningful differences in the everyday experience of young American children. Paul H Brookes Publishing, 1995.

[11] A. Biemiller and N. Slonim, “Estimating root word vocabulary growth in normative and advantaged populations: Evidence for a common sequence of vocabulary acquisition,” J. Educ. Psychol., vol. 93, no. 3, pp. 498–520, 2001.

[12] W. Nagy, “Why vocabulary instruction needs to be long-term and comprehensive,” in Teaching and learning vocabulary: Bringing research to practice, 2005, pp. 27–44.

[13] G. Burdea, “Virtual Rehabilitation - Benefits and Challenges,” Methods Inf. Med., vol. 42, no. 5, pp. 519–523, 2003.

[14] B. Lange, S. M. Flynn, and A. A. Rizzo, “Game-based telerehabilitation,” Eur J Phys Rehabil Med, vol. 45, no. 1, pp. 143–151, 2009.

[15] J. E. Deutsch, J. A. Lewis, and G. Burdea, “Technical and patient performance using a virtual reality-integrated Telerehabilitation system: Preliminary finding,” IEEE Trans. Neural Syst. Rehabil. Eng., vol. 15, no. 1, pp. 30–35, 2007.

[16] M. McCue, A. Fairman, and M. Pramuka, “Enhancing Quality of Life through Telerehabilitation,” Phys. Med. Rehabil. Clin. N. Am., vol. 21, no. 1, pp. 195–205, 2010.

[17] S. Mahmud, R. Iqbal, and F. Doctor, “Cloud enabled data analytics and visualization framework for health-shocks prediction,” Futur. Gener. Comput. Syst., vol. 65, pp. 169–181, 2016.

[18] W. Lin, W. Dou, Z. Zhou, and C. Liu, “A cloud-based framework for Home-diagnosis service over big medical data,” J. Syst. Softw., vol. 102, pp. 192–206, 2015.

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ANNEX:

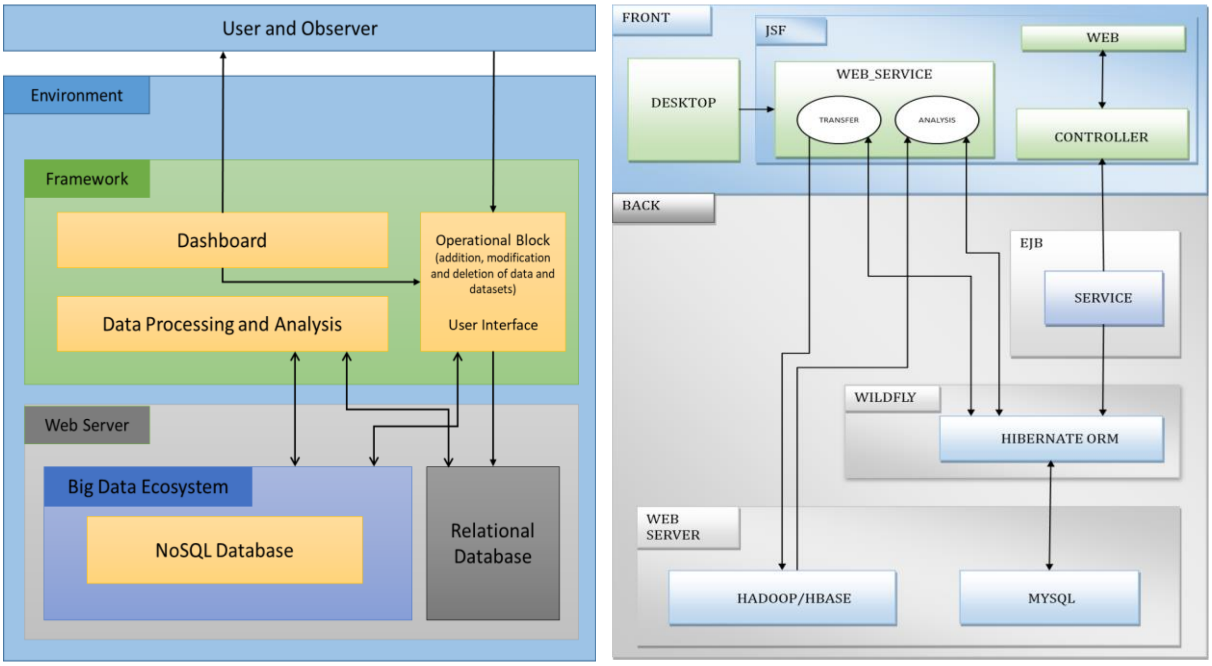

Figure 1: A) Architecture of the Framework. B) Implementation and Deployment

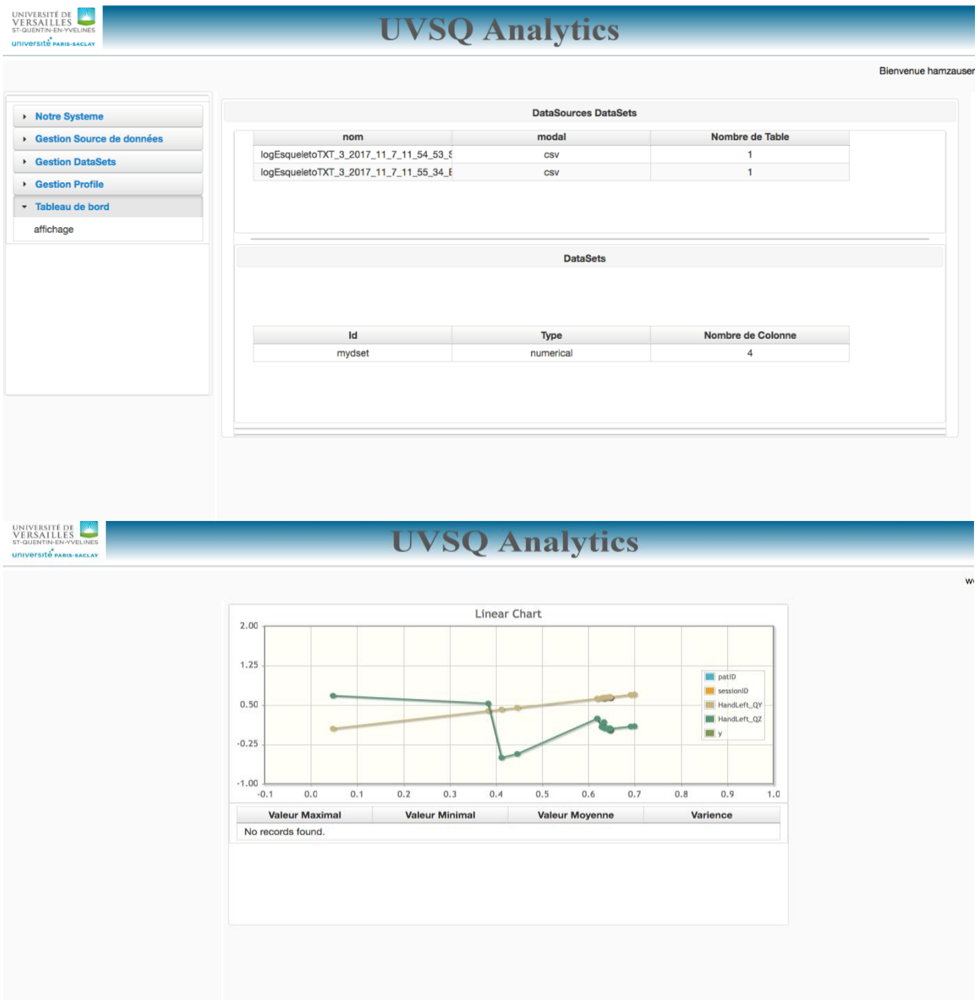

Figure 2: Up) Operational Block. Down) Example of visualization