Gait Analysis Management and Diagnosis in a Prototype Virtual Reality Environment

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Abstract. The constraints of the present way of dealing with medical data from patients with walking difficulties regarding collection, storage, searching and visualisation constrains the health professionals' ability to acquire information in a simple, clear, and timely manner. Through observing the current way of dealing with medical data and getting health professionals' feedback it has been found out that in order to enhance the gait analysis process there is a need to develop an automated system that can extract, save and visualise the data from different sources, in order to enhance medical data visualisation, increase efficiency and thus improve quality of service and management.

The proposed work goes through multiple stages; firstly, solve the fragmentation of medical data (in particular, the output from the gait analysis process) by integrating all patient/participant's data in an Electronic Medical Record (EMR). Secondly, solve the distribution of patients' data and lack of quality management by controlling access to the system for authorised users with different privileges. Thirdly, solve the visualisation issue by displaying all required data in one interface presented in a Virtual Environment (VE). Overall this work is concerned with the development of a virtual reality environment prototype to enhance the gait analysis process by building interactive information-visualisation software that will assist medical practitioners to simplify the retrieval, visualisation and analysis of medical data.

This paper presents the stages involved in the development process of a new system of managing medical data for gait analysis which offers simulation capacity in a VR environment. Moreover, this work investigates various methods of displaying medical data in a single application with a view to managing and sharing multimedia data and to employing a VR to enhance user interaction with medical data. Findings of a promising preliminary evaluation through user trials are also presented. Concluding, the paper discusses future plans to incorporate Human Computer Interaction (HCI) attributes with a view to providing the health professional with customizable information and

adfa, p. 1, 2011.

enhancing the interface functionalities. Furthermore, as the system is web-based there is scope for expansion of the application to other areas of medical assessments involving complicated datasets.

1 Introduction

Gait analysis is an assessment tool for individuals with conditions affecting their ability to walk, and is used for the formulation of medical diagnosis and future treatment improvements as well as for research purposes [1]. Some gait analysis assessments depend not only on the standard physical examination, but require a complete description of the complex pathology of an abnormal human gait pattern. Several techniques have been developed for gait analysis, with different types of information datasets offered. Gait analysis applications used currently by health professionals produce multiple sets of data that often need to be investigated simultaneously; there is currently no available system to support the multitasking process simulated in 3 Dimension (3D), and thus medical data is fragmented along multiple repositories with no integrated view or filtering criteria for required information, and with limitation of data view in 2 Dimension (2D).

The aforementioned limitations of the current system hinders the concurrent diagnosis route, thus it was considered essential to transfer the medical data from a randomly distributed system to an organised system that combines all the relevant data used for gait analysis under one application package. This paper presents the methodology used to integrate the various types of diagnostic medical data by developing interactive information-visualisation web based software that provides an authenticated access to clinical information over the internet in a Virtual Reality (VR) environment with an integrated view for all the various types of medical data. In turn, this enhances interaction with gait analysis data by simulation in 3D, enables report generation based on predetermined criteria for quality control and enhances data retrieval by filtering criteria.

Three dimensional representation either in a virtual environment or a typical computer screen offers a number of advantages over the current paper/digital media based method; VR enhances the interaction and

understanding as well as allowing collaboration to occur by giving the user the ability to explore structures from several viewpoints [2,3]. Storing different and scattered gait analysis data sets in an Electronic Medical Record (EMR) system offers multiple advantages such as cost benefit, confidential data storing, flexible and quick data retrieval, enhanced medical data visualisation and easier data sharing and access from remote sites [4]. The proposed approach acts for health professionals as a diagnostic and research aid for improving their 3D mental mapping, increasing productivity, facilitating medical decision-making and ultimately contributes to a better quality of service and time management process as presented in previous studies [2,5].

Evaluation and feedback on the proposed work was initially informed by a survey of 30 health professionals as to the effectiveness, usefulness, and users' satisfaction of the proposed application. The questionnaire targeted areas in the users perception of the application relating to issues such as applicability of VR in general, users' overall satisfaction with the proposed system, medical data storage in a single repository, interaction with medical data, authenticated users' access to the system, motion capture in 3D, wireless manipulation of the data, better decision making and improved quality, and time management. Preliminary evaluation for the system indicated that the proposed system enhances the gait analysis diagnostic process and improves time management.

This paper is organised as follows: Section 2 reviews the related work and the background of this work. Section 3 demonstrates the research synthesis, system evaluation is presented in Section 4 and finally Section 5 concludes the paper, with a succinct summary of the project and a future tentative plan of work.

2 Background

Gait analysis is applied to assess human gait with the required data that can distinguish between normal and pathological gait, estimate the problem and determine the therapy needed. Gait studies are developed using various techniques depending on the required information, methodology, cost and applicability (research purposes, direct treatment) [7, 8]. To facilitate both ease and accuracy of the gait

analysis process medical data needs to be managed with regard to storage and visualisation regardless of the assessment tool used, or the purpose of the analysis [there are medical data produced from the analysis process with various media types]. EMR supports the coordinated and authenticated access over the internet to the specific medical information presented to the requester using appropriate HCI which enhances the medical decision-making [9, 10, and 11]. There are various techniques used to enhance medical visualisation above managing medical data in an integrated view; allowing the viewer to switch from 2D to 3D in a VR environment will be of great benefit for both the health professional and in other cases for the patient as VR systems proved their efficiency when used for rehabilitation and telerehabilitation [12, 13, and 14]. Furthermore, providing interactive navigation through 3D models using HCI will facilitate more efficient understanding of the complex models thus enhancing medical education [15, 16].

3 Proposed System

This section will present the current way that health professionals use to view, store, extract, and manage medical data produced as an output from gait analysis process. Afterward, the proposed system to enhance the gait analysis process is presented; it shows the solution provided regarding each issue in the current way i.e. storage, visualisation, time management, quality control, and interactivity.

3.1 Current way of gait analysis process

The proposed system overcomes most of the disadvantages that occur in the current way of dealing with medical data produced from the gait analysis process. Figure 1 show the current way of the gait analysis process described as follows:

- Health professionals contact participants or patients for data collection through phoning or direct contact. In both ways health professionals will describe for the patients/participants the process of data collection and give them the required details about the location and time. Once the patient arrives the HP takes the

patient/participant's information (text file), filling in and signing required forms (hard copy).
This process is time consuming for both the health professional and the participant/patient and it is repetitive; the same description has to be provided for each patient/ participant, in addition, it is not clear as much as providing examples to be viewed by a participant with no background (animation, video, images ...). When the patient/participant arrives there is no defined way to store the information provided leaving each HP to store it in different way.

- Data collection: the data collection process sometimes varies from one case to another, depending on the information required and the software used for collecting data (currently, in Glasgow Caledonian University (GCU) health professionals are employing a 3D Motion camera system (Qualysis - 16 cameras OPUS 3/5) to measure the kinematics and a Kistler Force Plate (Kistler - 9286B) to measure the kinetics of gait. These systems are synchronised using the Qualysis Track Manager software (version 2.5) during data collection). The output from this process is functional 3D models (.C3D files).
The output file is also left for each HP to save it without connecting it with the patient/participant's information entered previously and the view of the file is hindered by the 2D view.

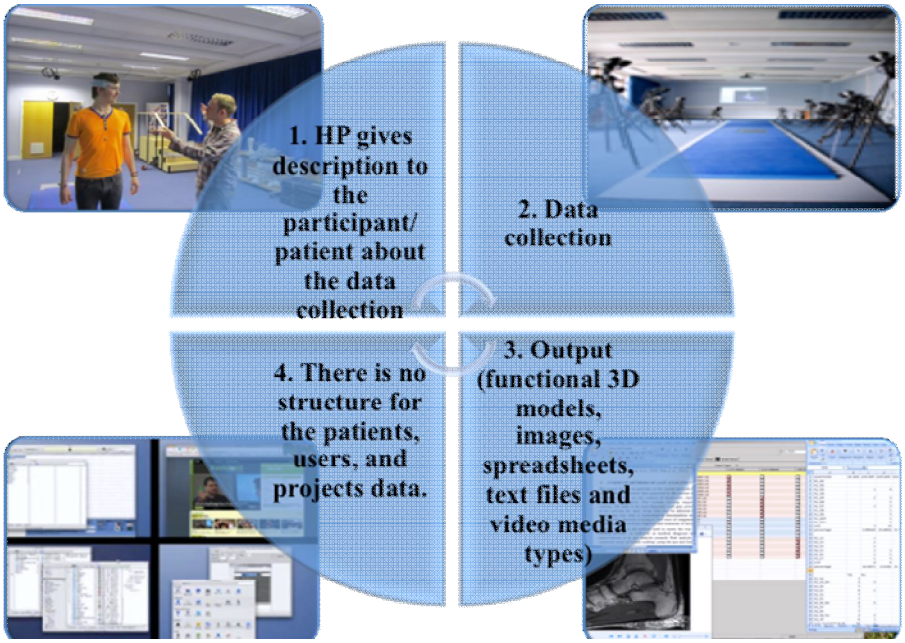

Fig. 1. Shows the Current way of Gait Analysis Process

- Data collected in track manager is exported in C3D format to be imported into Visual 3D (C-Motion – version 4.75) to do the analysis, and the output is also in C3D format (.C3D files).
  More output files are added to the previous ones without management.

- A patient/participant's information is saved on a document in addition to the output files from the software used (Scattered Files: Text files, Spreadsheets, Images, Videos, Functional 3D models). Each health professional has his own way of saving his/her patients' information. There is no search or filtering criteria to view data in single interface.

3.2 Proposed gait analysis management and diagnosis system

- Health professionals contact participants or patients for data collection through email, phone or direct contact. Health professionals will not spend time on giving a description for all the patients/participants about the process of data collection and give them the required details about the location. If the participants/

patients have an internet access the required information is provided on the website: directions, maps and parking, what will happen during the visit, multimedia demonstrations of techniques (to reassure patients), looking for information (pages which provides information on 'who we are', 'what we do', 'how we are funded', and summaries of current and active research).
That will save time and give detail information and answers questions for the patients/participant before arriving.

- On the patient/ participant's arrival if it is the first visit, the patient/ participant's information will be added only once, and in each new visit the visit details will be added to the existing information.
  The user logs in to the account to add new patient (for first visit) or adds new visit (for current patient). There is static information entered once and dynamic ones are entered on each visit to the EMR.
- The patients and projects data is added to each user's (health professional) account. The same process is repeated by each user. Search and query are provided to save time looking for a particular piece of information.
  For statistical analysis or producing reports filtering criteria is provided on the database and the results are shown according to the chosen view (view all patients' results, view each patient's files...).

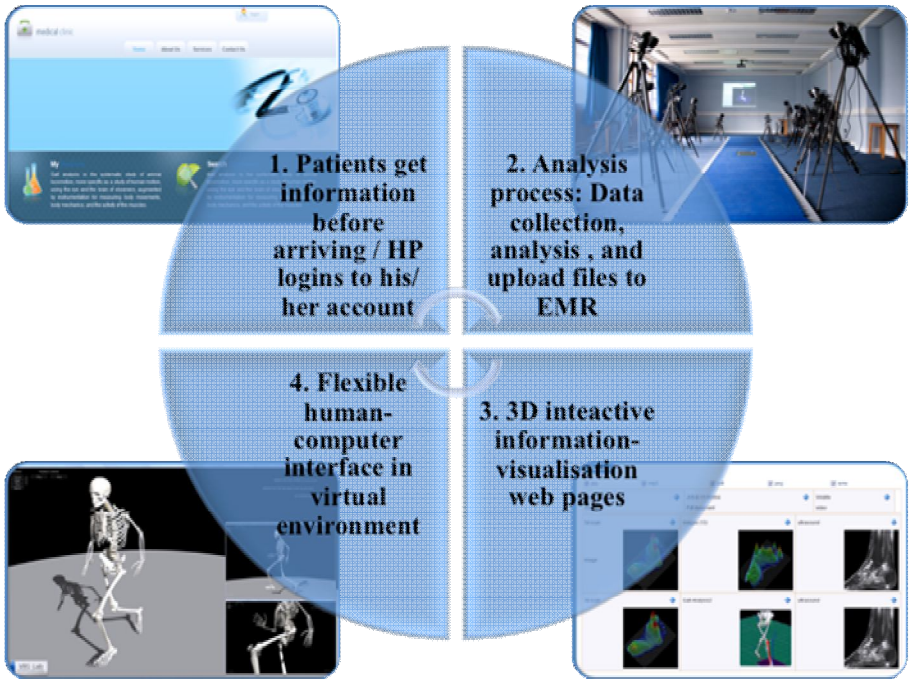

Fig. 2. Proposed Gait Analysis Management and Diagnosis in a Prototype Virtual Reality Environment

– Viewing medical data is not hindered by the 2D limitation as it provides a VE Real-Time 3D visualisation of patients gait analysis with the use of the proposed multimedia application in the Virtual Reality and Simulation Laboratory at GCU.
VRS LAB …

4 System Evaluation

A questionnaire was distributed to in-house health professionals for system evaluation after presenting a Real-Time 3D visualisation of patients gait analysis in the University's Virtual Reality and Simulation Laboratory (VRS Lab) to measure the HP's acceptance of the proposed work. The questionnaire was measuring multiple aspects, applicability of VR, users' satisfaction of the proposed system, data storage (EMR), interactive medical data, motion capture in 3D, wireless manipulation of data, enhancing the process of decision making and quality management, and the management of the system users.

Health professionals were first asked to supply background information, such as name, academic discipline, and academic level. They were then asked to rate their satisfaction by answering the three groups of questions as follows:

- The first group of questions measures the users' satisfaction about the proposed system and its ability to combine all the related existing software currently used for gait analysis and diagnosis under one, user- friendly package. Participants were asked to rate their percentage satisfaction. 76.6% of the participants state that the system under development satisfies 60-100% of their requirements.
- The second group of questions measures participants' satisfaction relating to the 3D representation of the derived data in an interactive VR environment; 76.2% of the participants state that the application is promising and satisfies most (60-100%) of their expected requirements.
- The third and final group of questions evaluates the participants experience about the system's navigation features and functionality, design and colour scheme, and organisation and layout of the screens; 96.4 % of the participants found that the navigation system was intuitive and helpful, 71.4 % of the participants were completely satisfied with the application's HCI, and 85.7% of the users estimated that the system would improve work flow by reducing time spent on information retrieval and archiving by a factor of 50%.

The analyses of the results derived by the survey were encouraging. Feedback shows that users are accepting the system and found that the VR environment and the HCI less distracting in contrast to viewing data in 2D and using different software packages and interfaces to look for a piece of information. In addition to the potential benefits desired from applying this system regarding reduced time spent on saving, searching, and extracting data, quality control reflected upon medical data, data analysis efficiency, and improved data visualisation.

5 Concluding Remarks

This paper describes the work carried out which examines the database and the visualisation of medical data by designing a system to manage patients' data storage in a medical record and presenting medical data in a single interface in 3D in a VR environment which simplifies the

process of storing, searching and enhancing visualising gait analysis data. Apparently, from the system evaluation and participants' experience, the system managed to some degree to gain participants' satisfaction and meet most of their requirements and expectations, by providing an easy and simple way of interaction with simple tools to extract medical data, and a natural way of delivering the virtual environment and immersing the user to the virtual environment. In summary, the medical practitioners who experienced the proposed system found the subject matter exciting and interesting in both presentation methods (i.e. traditional and VR), but felt that the traditional method was more tiresome than the VR visualisation and data description.

Users' feedback raised more requirements which are in the future plans for the work; to enhance interface functionalities and provide users with customisable information. As the system is web-based, additional groups of health professionals in different areas may be added to the system which makes the data sharing and cooperation easier.

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