INVESTIGATION OF MULTIMODAL INTERACTION AND 3D SIMULATION ENVIRONMENT FOR PROTOTYPE HEALTHCARE SYSTEM

Abstract

Purpose – Current healthcare applications produce a complex and inaccessible set of data that often needs to be investigated simultaneously. As such the conflicting software applications and mental effort being demanded from the user result in time-consuming analysis and diagnosis. The aim of this work is to provide a prototype, interactive system for management of multiple data sets, currently used for gait analysis capturing, reconstruction and diagnosis. In summary, this work is concerned with the development of interactive information-visualisation software that assists medical practitioners in simplifying and enhancing the retrieval, visualisation and analysis of medical data with the intention of improving the overall system leading to an improved service for the user and patient experience.

Design/ methodology/ approach – The design of the proposed system aims to combine all the related existing software currently used for gait analysis and diagnosis under one, user-friendly package. The latter will have the capacity to offer also real-time, three dimensional (3D) representations of all the derived data (CT, MRI, motion capture) in an interactive Virtual Reality (VR) environment.

Findings – It is intended that the proposed prototype solutions will enhance interactive systems for management of multiple data sets, currently used for gait analysis capturing, reconstruction and diagnosis. The derived data encapsulate a plethora of multimedia information aiming to enhance medical visualisation.

Originality/ value – The proposed system offers simulation capacity and a Virtual-Reality visualisation experience, which enhances the gait analysis diagnostic process. The 3D data can be manipulated in real-time through a novel Human-Computer Interface (HCI) which uses multimodal interaction through the use of Graphical User Interfaces (GUI) and gesture recognition. The system aims towards a cost effective, clearly presented and timely accessible system that follows a threefold approach; It entails managing the extensive amount of the daily produced medical data, combining the scattered information related to one patient in one interface with a filtering criteria to the required information, and visualising in 3D the data from different sources, in order to improve 3D mental mapping, increase productivity and consequently ameliorate quality of service and management.

Keywords*: Medical Data, Management, Visualisation, 3D Simulation, MMR, Virtual Reality, Podiatry*

1 INTRODUCTION

Improved management of healthcare data through employment of ameliorated interactivity tools/applications aims to enhance quality of patient healthcare and healthcare research, (Omachonu and Einspruch, 2010). Substituting an arduous system for storing a plethora of complex medical data sets by an Electronic Medical Record (EMR) system offers multiple advantages such as safe and confidential data storing, flexible and quick data retrieval and data sharing to name but a few (Wang *et al.*, 2003), whilst providing a managed system for user specific access to EMRs relating specifically to their patients.

Moreover, it presents an avenue for better data collection and presentation, by allowing users via a specialised purpose designed interface to view the different media types with additional options to filter the data upon predetermined criteria thus making the navigation easier. In addition, the 3D mode of data visualisation and interaction is designed to further support the decision making process as evidently presented on previous studies (Sakellariou *et al.,* 2011; Charissis *et al.,* 2008; Moschos *et al.* 2011).

This novel interface is being developed with view to improve user-experience, with particular focus to provide an all-inclusive 2D and 3D data representation of various musculoskeletal pathologies. Background research identified the issues of the currently available methods and thus informs the project objectives. The system requirements for a novel approach were determined, prior to the system design and development through focus-groups' evaluation and feedback as described below.

For evaluation purposes two groups of health professionals within the School of Health and Life Sciences in Glasgow Caledonian University (GCU), currently involved in the manipulation of large data sets relating to patient care have been approached; Twenty five users have been recruited from the 'Active Living' and twenty five users from the 'Musculoskeletal and Neurological Rehabilitation' research groups. Users have been members of staff or post graduate researchers in these groups.

This paper is organised as follows: Section 2 reviews the related work and the background of this work. Section 3 illustrates the current methods of gait analysis visualisation. The need for the MMR and 3D visualisation is presented in section 4. Section 5 demonstrates the research synthesis and finally Section 6 concludes the paper, with a succinct summary of the project and a future tentative plan of work.

2 BACKGROUND

Quality improvement in health care is affected by the delivery of accurate information in a timely manner, the latter depending on data storage and presentation techniques utilised. Many advantages are associated with patient health records; In addition to documenting patient's data, the record also enhances patient's data visualisation which is important for research, analysis and quality improvement purposes. It also increases storage capabilities and easier access from remote sites; Suggestions for a portable EMR systems have also been proposed, as there is an increasing incidence of accidents and illnesses during business trips, travel, or overseas studies (Chen and Shih, 2012). Their study proposes integrating and streaming media technology into the EMR system to facilitate referrals, contact laboratories, and facilitate disease notification among hospitals. Their proposed interface is a web based portable EMR interchanging system that uses streaming media techniques to expedite exchanging medical image information amongst hospitals.

Another benefit to the patient record is that it allows for personalised views of information relevant to the requirements of diverse health professionals and the needs of a variable patient base. Furthermore, having a user interface to present an electronic multimedia record can increase clinician productivity, facilitate medical decision-making, and improve quality of care (Dayhoff *et al.*, 2001).

Medical data is a focal point for any patient-focused quality improvement program (Rogers and Joyner, 1997). The effective use of the medical data is crucial for patient care enhancement either while treating the patient or for research purposes. As the electronic medical record systems enhance readability, availability, and data quality, evidently provide better accuracy and improved data retrieval, which allows validity checks for data quality monitoring, research, and decision support, (Roukema *et al.*,2006; Brusse *et al.,* 2005).

Improving health care has to address both involved parties, namely clinicians and patients. Easier access to the patients' information can also engage the patient in the process, which will shift the personal health records to become patient centred, (Krist and Woolf, 2011). Moreover, organising patients' data and visualisation by using virtual reality techniques, enhances diagnosis capabilities by data management, reduction and analysis, (Shaw *et al.*, 2001). Additionally, studies show that when patients are provided with suitable tools that encourage involvement and active management of their illnesses, better results can be observed in both health status and clinical outcomes (Stroetmann and Pieper, 2003). This is particularly important for patients with chronic conditions (diabetes, heart or renal disease) as they have to monitor complex sets of medical observations and trends and act on these appropriately. Providing these patients with a highly interactive graphical user interface that allows them to navigate through their historical data resulted in a more accurate, complete and useful application, (Andry *et al.*, 2009). Furthermore, in the study of human motion, using multimedia will render the process of analysis easier (Kirtley *et al.,* 2001). Multimedia techniques offer possibilities such as real-time applications and digital video recordings, thus allowing the movement to be studied concurrently with its biomechanical analysis. The latter also offers a more intuitive representation of muscle activity.

Optimisation, dissemination and presentation in 2D and 3D of medical data via a web application present a significant challenge not only from an implementation point view but also from a user perspective, due to various levels of computer literacy (Sakellariou *et al.* 2011). While it is important to keep the application interface simple, easy to use and interesting to the users, it is important to provide as much relevant medical information as possible (Clarke *et al.*, 2006). The PREPaRe system (Personal Repository for Electronic Patient Records) is one of the examples of these systems that provide a notion to generate easy to understand graphical data from different types of multidimensional medical data. It is an internet-based information system that is able to store, combine, process and visualise all types of medical data that are part of a Personal Electronic Medical Record (PEMR), (Tschirley *et al.*, 2002). Another example of a web-based system that can be accessed through internet/intranet described by Lim *et al.*, (2006) is the GP-Soft, which is a patient management system, designed to improve the records management for clinic, nursing home and hospital situations. In a more advanced way, aiming at delivering the multimedia medical record especially in emergency situations, Reponen *et al.,* (2005) demonstrated their system which connects an Electronic Patient Record (EPR) and picture archiving and communication systems to wireless terminals which deliver information to the point of care, using special types of mobile phones, smart phones and Personal Digital Assistants (PDA) with phone functions.

In addition to gathering medical data in an EPR patient care quality is also improved by 3D simulation systems which give much better understanding of the anatomy and functionality of the complex joints in the human body than static images in text books do (Weingartner *et al.*,). Studies point out that surgical skills learned using computational simulators directly enhance operating room performance by decreasing procedure time and reducing the frequency of medical errors compared to traditional training (Seymour *et al.,* 2002; Stava, 2005; Gallagher *et al.*, 2005). Furthermore, employing 3D virtual presentations improves the quality of the operation as surgeons are able to check the progress of the operation in real-time through intuitive 3D based interface which have the potential to prevent surgeons from penetrating into high risk areas (Charissis *et al.,* 2010; Tran *et al.*, 2011).

3 CURRENT METHODS OF GAIT ANALYSIS VISUALISATION

This project focuses in particular on the current methods for storing and visualising complex and varied multimedia source data generated in the process of clinical gait analysis. Gait is defined by Kirtley (2006) *as any method of locomotion characterised by periods of loading and unloading of the limbs. This includes running, hopping, skipping, swimming, cycling and walking. The latter is the most frequently used gait, providing independence and used for many of the activities for daily living*. Gait may be affected if a person is injured or suffers from disease that may lead to biomechanical abnormalities such as unusual or uncontrollable walk patterns while the body is trying to find ways of compensating for the problem. An analysis must be undertaken to facilitate diagnosis and treatment of the patient.

Gait analysis is the method used to assess the way movement manifested directly whilst treating patients, or indirectly in medical diagnosis and development of future treatment improvements as in gait analysis research. Gait analysis, is defined by Whittle (2007) *as the systematic study of human walking, using the eye and brain of experienced observers, augmented* *by instrumentation for measuring body movements, body mechanics and the activity of the muscles.*

Gait analysis is predominantly carried out by health professionals, which employ different methods for the analysis process, ranging from using no equipment at all to the need for more complicated equipment. For the advanced methods, 2D and 3D measurements can be performed using complex equipment and software.

Regardless of the analysis type and the variation in media types used to depict the different analysis we can safely identify the following common media types: functional 3D models, images, spreadsheets, text files and video media types. In order to present any type of analysis, all or some of these media types have to be opened/accessed simultaneously by the health professional in separate screens and to then interchange between them in order to describe the process. The problems faced by health professionals are summarised schematically in Figure 1. Consequently, this is an attention-demanding and time-consuming process which forces the medical practitioners to search, identify data and switch constantly through different software screens even if there are only three screens required to describe and diagnose each case.

Figure 1: Problem description, shows the obstacles that the health professionals face while dealing with medical data

The aforementioned issue hinders the concurrent diagnosis route as there is no available system to support this multitasking process simulated in 3D. As such the proposed system is required to store patients' data in a single repository, visualise all needed information in one interface without the need to switch between different applications, give an option to obtain specific information by search or query of patients' data, enhance interaction with gait analysis data by simulation in 3D, and generate reports depending on predetermined criteria for quality control.

4 THE NEED FOR A MULTIMEDIA MEDICAL RECORD AND 3D VISUALISATION

The first step to enhance medical data saving is to transfer the process from paper based to computer based i.e. EMR. The medical record accommodates medical data concerning the process of diagnosis and care of a patient; it has the medical history of each patient and is useful for the health professionals as both a support and a communication-documentation instrument.

For better management of patient care, the EMR must be as complete as possible; all media output forms should be considered part of the record. This constitutes the Multimedia Medical Record (MMR).

All data types should be in the patient record as shown in Figure 2: normal text (patients' information, case-notes or findings, and visit details), pictures from imaging diagnostics, video (recordings taken during treatment), sound recordings, three-dimensional models, uploaded required files and documents in their original formats.

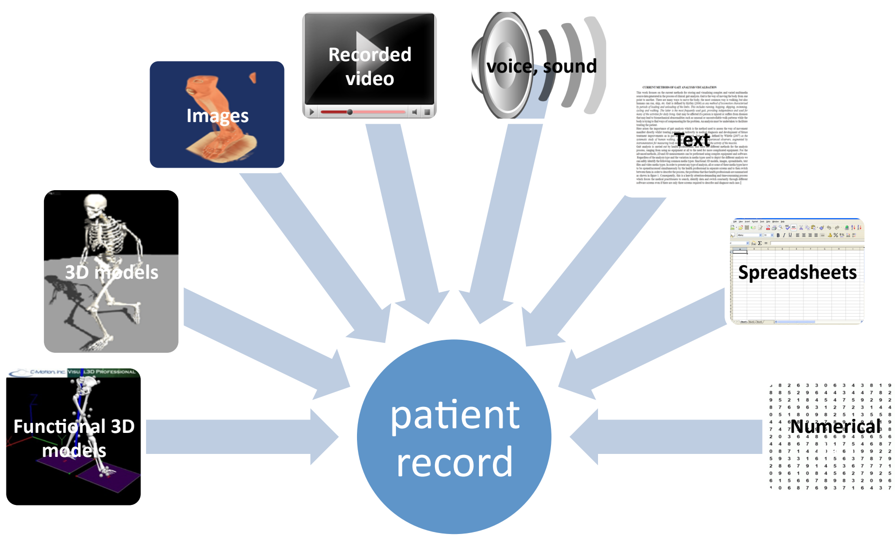

Figure 2: An Example of the typical data in the Multimedia Medical Record, *all media types that compose the medical record are shown, the medical record can consist of (normal text, pictures, videos, sound recordings, three-dimensional models, uploaded required files and documents in their original formats)*

In order to get the complete view and control of the patient's data, adding 3D motion capture visualisation provides highly precise data of human movement which can be used for empirical analysis and virtual human animation (Heloir *et al.*, 2010). As such, it is essential to transfer patient's data from a randomly distributed system to an organised and centrally managed system. This will facilitate for further data archiving, storage and viewing. This holistic approach aims to significantly improve the time management as it is expected to reduce by 50%, the time needed from health professionals for these actions and provide them with additional tools and time for better decision making and improved quality control, Figure 4 depicts the resolved issues to enhance visualisation.

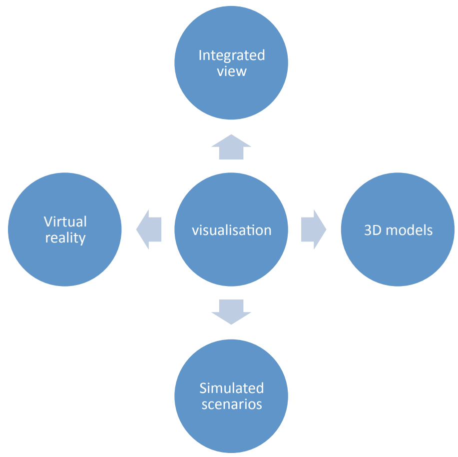

Figure 4: Visualisation to gain the complete view and control of the patient's data, the medical data visualisation is enhanced by providing the integrated view of the patients data in 3D

5 RESEARCH SYNTHESIS - SOLUTION STEPS

Building on the data capturing requirements outlined in section 3, and the opportunities highlighted in section 4 presented by the use of multimedia technologies and related approaches, the work on synthesising possible solutions and steps towards creating appropriate enhancements is contained within this section. This work currently investigates the multimedia output from the medical software used for gait analysis and assists in the display and understanding of the data. Different types of media (Graphs, Images, Videos, Text files, Spreadsheets, etc) and the methods used to display these in a single application to manage, share and visualise multimedia data.) have been considered. A simplified design structure of the web application is shown in Figure 5.

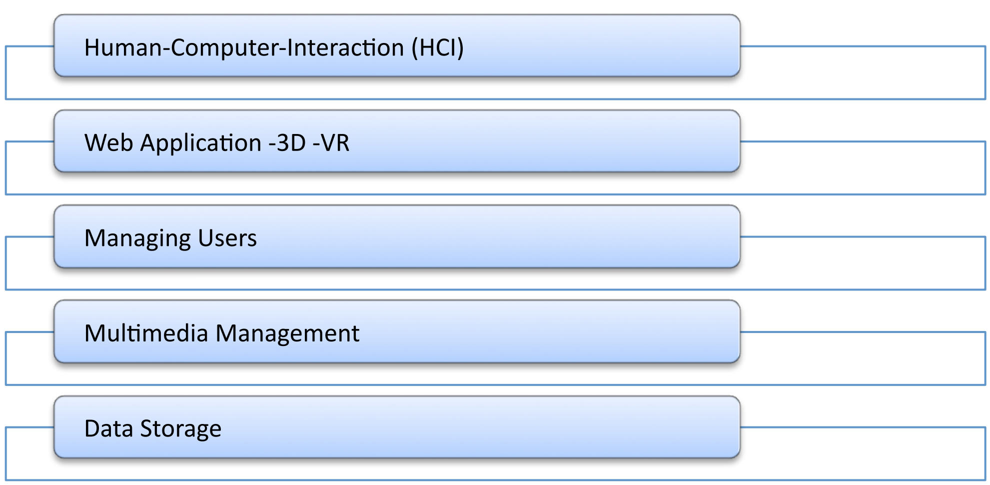

Figure 5: The Simplified design structure for the web application

To maximise the benefit from the provided system, time and place constraints have to be reduced significantly. Based on the aforementioned, it was deemed necessary to extend the software in a web-based application, which allows the users (Health professionals) to access their database when needed. Figure 5 shows the structure of the web based system: Human Computer Interaction (HCI) standards were taken in consideration while designing the system screens, colours and navigation. The usability of the system enables different users to access different areas of the software maintaining patients' confidentiality. The 3D representation compliments the system either in a typical computer screen or in Virtual Reality environment (Riener and Harders 2012). Note that for simplification purposes the 3D, and Virtual Reality definitions would be used indistinctively throughout the manuscript and referring to the same type of artificially generated environment.

5.1 Development of 3D Simulation Environment

In medical field the difficulties of using directly patient information derived by radiological input such as CTs, MRIs, or motion capture for identifying the gait analysis and even cadaveric material (i.e. mainly for training purposes) is well recognised. Yet the aforementioned depiction and diagnosis' tools have remained the preferred method as they allow in-detail investigation and physical interaction with the data.

In recent times, due to technological advances it became evident that fresh opportunities to compliment these methods are available with the employment of 3D models presented in an Virtual-Reality operating environment (Peng Wu et al., 2012; Sakellariou et al, 2009b). These new presentation and investigation methods would preferably be supplementary to traditional diagnostic triage and data analysis initially, but nonetheless offer a remarkably flexible and powerful instrument towards faster and more accurate diagnosis. As such this newly acquired technological "instrument" would also avert some of the difficulties that medical practitioners have in obtaining information previously impossible to access and visualise (i.e. selective transparencies in musculoskeletal information so as to investigate previously un-noticeable pathologies). As such advanced Human-Computer Interaction (HCI) will be appropriate so as to enable the medical users to maximise the system's capacity and improve the quality and time of their assessments.

An analysis of the above observations deemed necessary the development of a simple and adaptable system that could offer this plethora of information in a more intuitive way, imitating real-life in a digital environment. The traditional diagnosis process and radiological examination offers the closest realism and insight to a patient's anatomical characteristics and pathologies. The traditional methods, however, differ from Virtual Reality representations radically as they cannot present three-dimensional data embedded in motion capture data that could be manipulated freely by the user in real-time. Equally these factors can present a misinterpreted understanding, diagrammatic information offered by the traditional methods, which does not fully capture the complexity of motion and the direct effects to the musculoskeletal structure. In addition the existing gait analysis information is typically accompanied by anatomical texts, photographic atlas' publication and didactic PowerPoint presentations, which could not convey effectively the three-dimensional complexity of the human body and related pathologies. Furthermore specific regions of the human body have to be investigated out of context due to inherent anatomical inaccessibility. These sections can only be investigated by medical practitioners through two-dimensional images in text-books and projected presentations. In some cases 3D representation through existing CTs is feasible yet unusable if motion capture data need to be embedded and tested in real-time.

In contrast the virtual environment is unable possibly to imitate fully the degree of physical interaction and realism provided by a real human body. Conversely a virtual environment equipped with a flexible human-computer interface can enable the user to interact with the 3D human model in infinite ways. In particular, complicated anatomical issues can be visualised intuitively by a VR interface, which does not have any physical constrains (Charissis et al, 2008; Peng Wu et al., 2012). Hence it is possible for the user to interact freely with a volumetric 3D model, selecting their own number of infinite viewpoints, a factor suggested as being central in spatial anatomical understanding (Turney et al, 2007).

Our preliminary trials evaluating interface designs for VR systems have indicated that the particular type of digital interaction (Real-time 3D) may improve significantly user's spatial awareness resulting in faster knowledge accumulation of anatomical and pathological information. Employing this past experience, in this project we entertain the possibility of expanding the HCI attributes to provide the medical practitioner with customisable information regarding the section of interest and importing vital CT and MRI information alongside to motion capture data.

5.2 3D Human-Computer Interface

In order to investigate the suitability of the proposed interface in a medical environment, we employed generic manipulation icons (Ward et al, 2008) and designed a new series of symbolic representations, specific to gait analysis. Interestingly, this combined interface could offer numerous ways to interact with any 3D model in the synthetic environment.

The interface allows manipulation of the model in three dimensions with the use of mouse, joystick, gesture recognition or a haptic glove. In this case, we employed a wireless mouse and gesture recognition with the use of a Kinect device. The interface was mainly responsible for the rotation, enlargement/minimising and dismantling of the model in primary sections, as Figure 6 illustrates below.

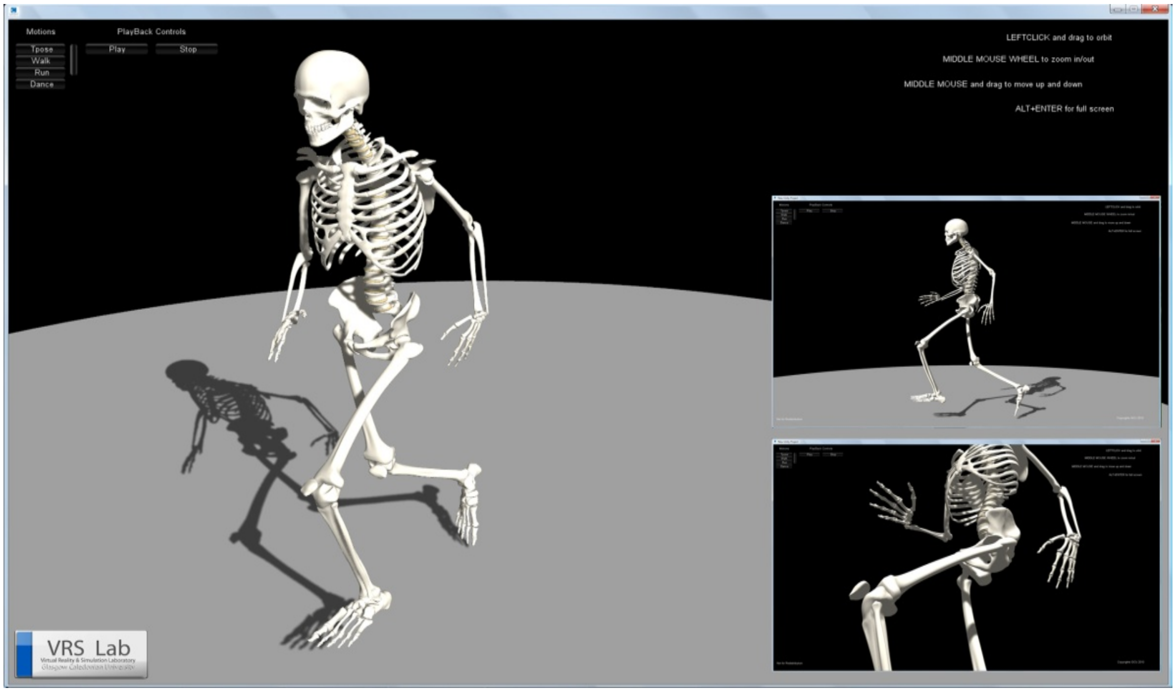

Figure 6: A Screenshot of a Real-Time 3D visualisation of patients gait analysis with the use of the proposed multimedia application in the Virtual Reality and Simulation Laboratory at Glasgow Caledonian University

Additionally it could be used to evaluate the motion coherence with the use of selective motion patterns delivered by the motion-capture gait analysis data. Figure 6 presents a screenshot of the proposed solution for gait analysis data visualisation, which enables the medical user to manipulate in 3D environment all the derived information previously available in a segmented and two-dimensional manner from a group of software applications that had to be simultaneously available. In the particular 3D environment the motion capture data are embedded on the patient's skeletal information and can be viewed from infinite points. Selective screen-captures or "window in window" techniques can offer simultaneously presentation of the gait analysis and embedded CT and MRI data.

An initial evaluation of the system was performed in Virtual Reality and Simulation Laboratory of Glasgow Caledonian University. The lab is equipped with state of the art HD, 3D monitors and large scale projection systems, powered by an array of custom PCs. The configuration used for the particular experiment is illustrated in Figure 7 below.

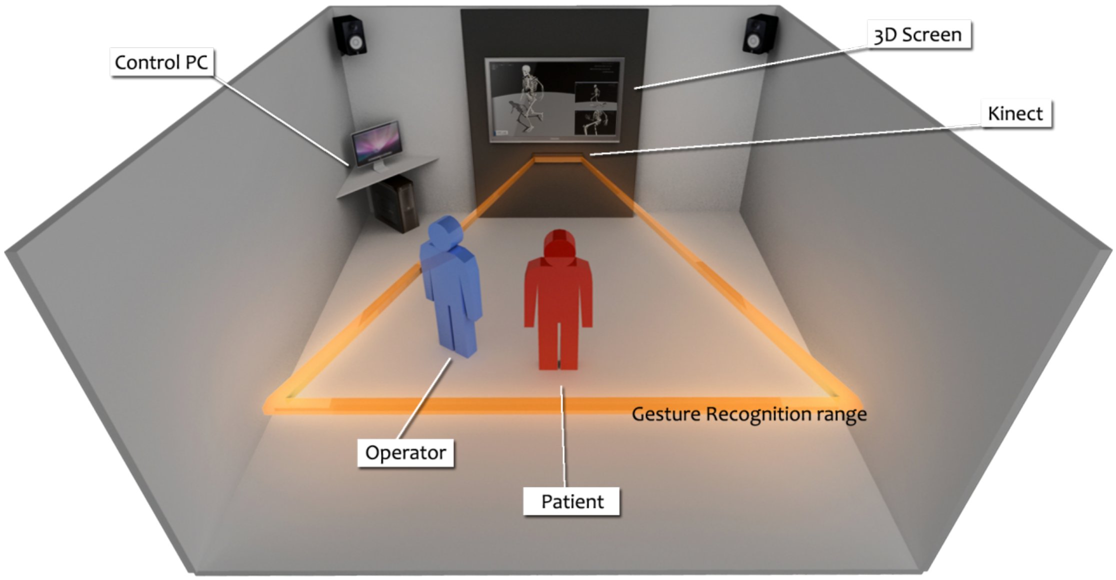

Figure 7: Virtual Reality and Simulation Laboratory configuration for gait analysis diagnosis and evaluation

The particular real-time 3D simulation was powered by an NVidia Quadro FX 4000 graphics card and projected to a 65inch 3D TV by Samsung. The rationale behind the selection of the specific monitor was mainly to test the system in typical high-street equipment available "off-the-shelf". Although this monitor is high-end, the software trial offered a proof of concept that could be functional in different sizes and manufacturers.

During the first trial by the allied health practitioners, (which participated in the developing team), it became obvious that another set of icons, should be incorporated in order to facilitate very specific medical requirements. In addition the symbolic representations were also depicted in alphanumeric format so as to improve the learning process of the system. As such the users had a familiarisation period where alphanumeric and iconic representations were both available.

5.3 System Evaluation

The requirements of the system are determined by the particular health professionals involved; multiple interactive methods were used such as interviewing, sampling and investigating data in the gait analysis laboratory, questionnaires, and observing health professionals while collecting data. Defining the required fields for the patients' and projects' data, users, and users' privileges started by interviewing the health professionals, taking their feedback, and filling out feedback templates after presenting the vision of the database.

A preliminary design for the system screens, database tables and system users were designed and previewed by the system's end users for initial feedback prior to commencing the development phase.

A questionnaire was distributed to two groups of health professionals to measure their expectations of having such a system after presenting Real-Time 3D visualisation of patients gait analysis with the use of the proposed multimedia application in the University Virtual Reality and Simulation Laboratory. The questionnaire was measuring three aspects, data presentation, data storage, and the management of the system users.

The Health professionals were first asked to supply background information, such as name, academic discipline, and academic level. They were then asked to rate their general expectations and define the requirements of the proposed system to manage the medical data and enhance its visualisation on a 5-point Likert scale:

1. Not expected
2. Not important
3. Preferred
4. Important
5. Essential

The questionnaire has twenty questions broadly divided into three main groups measuring the aforementioned aspects and then further divided into sub groups (five in total). The first three groups of the questions measure the users' requirements and expectations about data presentation, the fourth group measures the users' requirements regarding data storage, and the fifth group measures the users' requirements regarding managing the system users, as follows:

1. View medical data in a single interface (ability to view patients data in a single interface (2D, 3D), view projects data in a single interface (2D, 3D view medical data in 3D, motion capture in 3D visualisation, 2D & 3D interface switching, ...)
2. 3D simulation (virtual-reality visualisation, interactive visualisation, wireless manipulation of data, and gesture recognition and interaction with the data, ...)
3. Data search (provide query and search data and view researchers accounts for quality management)
4. Data storage (build an electronic medical record for the patient's data, store projects and users data, and the ability to send stored data to other users)
5. Manage system users (grant different authorities to the system users).

6 DATA ANALYSIS AND DISCUSSION

An initial analysis of the users' feedback was in favour of accepting the proposed system, highlighting the potential benefits on time and quality reflected upon research results, data analysis efficiency, reduced time and improved education process. The latter will be of particular use as an explanatory tool from the lecturers and the research students respectively.

The analysis of the questionnaire was conducted by using the Statistical Package for Social Science (SPSS) software which was used to calculate the 'frequencies' of the questions.

For the questions in the group 'Data storage', which has three questions, 16.7% of health professionals answered that the questions were 'between not important and preferred', 16.7% answered 'Important', 16.7% answered 'between important and essential', and 50.0% answered 'essential', as shown in Table 1.

The results show the importance of the proposed requirements as a solution to replace the current ways of storing the medical data. The 'percentage' of the questions in the five groups was also calculated.

Table 1: Percentage of the answers to questions in the group 'Data Storage'

Value	Scale	Percent	Cumulative Percent
2.67	Between 'Not important' and 'Preferred'	16.7	16.7
4	Important	16.7	33.3
4.33	between 'Important and 'Essential'	16.7	50.0
5	Essential	50.0	100.0

Overall for the five groups of questions the average of the answers were calculated for each group as shown in Table 2 and Figure 8, and the range for all groups was between (3.33) and (4.33), which suggests that health professionals see that having these requirements applied in the proposed systems is preferred, important, or essential.

Table 2: Summary for the average for the five groups of questions to measure the users' requirements importance and expectations

Group name	Average for the answers	Scale
Data presentation, view medical data in single interface	3.90	Between 'Preferred' and 'Important'
Data presentation, 3D simulation	3.33	Between 'Preferred' and 'Important'

Data presentation, data search	4.05	Between 'Important' and 'Essential'
Data storage	4.33	Between 'Important' and 'Essential'
Manage system users	3.95	Between 'Preferred' and 'Important'

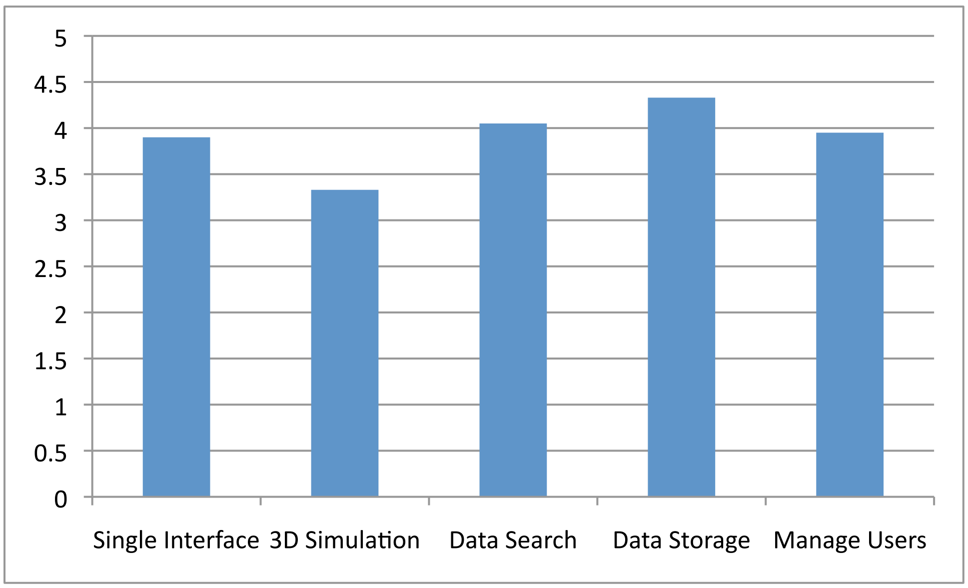

Figure 8: Average of the answers for the five groups of questions to measure the users' requirements importance and expectations - the range for all groups was between (3.33) and (4.33), preferred to essential

The analysis of the results derived by the QUIS (Questionnaire for User Interface) were encouraging as they were significantly in favour of the VR user group. The latter perceived an intuitive interaction as data set as present in Figure 8. Notably the questions candidly relating to the interface's ease of use highlighted the fact that the users found the VR environment and the HCI less annoying or frustrating in contrast to interpreting two dimensional images and multiple graphs simultaneously on different software packages and interfaces. This advocates they became accustomed easily to the environment, the interface via the wireless interaction devices (wireless mouse or Kinect). This was positive as the group had little previous experience of VR and suggests they were able to manipulate and readily adjust their viewing position and the medical information displayed in an intuitive and timely manner via the console.

Furthermore subjective feedback to the questions regarding disorientation within the environment suggested they found it neither confusing nor unpleasant. Evidently the system achieved to some degree a natural way of delivering the virtual environment and immersing the user to the virtual environment. This was further emphasised in the thematic analysis of open questions, users reporting a simplicity and ease of interaction confirming our initial aim for a user-friendly system. In a nutshell the medical practitioners found the subject matter stimulating and interesting in both presentation methods (i.e. traditional and VR), but felt that the traditional method was more wearisome and problematic than the VR augmented visualisation and data description.

7 CONCLUDING REMARKS

This paper describes the initial work carried out at Glasgow Caledonian University with the in house health professionals and research team within the school of Engineering and Built Environment, the work includes a formal system analysis, which assists in gait analysis data storing and visualisation to aid in resolving the following issues: medical data fragmentation along with multiple repositories, no single interface to view or search patients' data, no management tools to control the data, and the limitation of data view in 2D.

The proposed solution is designed to manage patients' data stored in a medical record and presented in a single interface in 3D which simplifies the process of storing, searching and enhancing visualising gait analysis data.

This work examines the database and the visualisation which addresses these problems. The initial objective is to integrate seamlessly the different types of media (Graphs, Imagery, Patient records, Text files, Spreadsheets etc.) in a multimedia medical record. In turn, this work investigates various methods to display the medical data in a single application to manage and share multimedia data. Concluding, this work employs virtual reality and data visualisation to enhance user interaction with data and data representation whilst controlling navigation.

The provision of the patient record in a digital format has many advantages: improvement of quality of care, fast and easy access to the records, easy navigation through the data due to having the option to query, and data presentation is better for educational and research purposes. Conversely, some of the disadvantages of applying these systems are: the financial burden involved in developing and maintaining such systems, a number of health professionals are unwilling to invest time in learning a new system, and privacy and security concerns are also an issue.

Based on the aforementioned results and observations the authors envisage developing the system and expanding it towards direct input of Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) data in 3D format. Prior investigation of embedded medical information as CT and MRI images in a 3D simulation environment offers a significant advantage towards faster diagnosis and training of complex medical cases (Sakellariou et al, 2009a). This future work will entail further involvement of industrial partners, which will support the specific format outputs. The future version of the software will be evaluated in comparison to the existing prototype and the prior, as well as traditional methods in order to identify the benefits and drawbacks of these additional tools. It is intended to evaluate the future integrated system utilising appropriate digital data with a group of health professionals and review the outcome before approaching a live testing scenario.

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