An Overview of the Surrey Virtual Reality System in the Rehabilitation of Gait for Children with Cerebral Palsy

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Abstract: - There is a need to consider a new framework for the development of virtual rehabilitation systems that are suitable for routine clinical use. With this in mind, a passive stereo, semi immersive system considered appropriate for gait rehabilitation in children with cerebral palsy (CP) is being developed at the University of Surrey - the Surrey Virtual Reality System (SVRS). In conjunction with a local rehabilitation centre, the research aims to investigate the practicality of the SVRS. The paper reviews the first steps on this programme of research at the University of Surrey.

Keywords: Gait Rehabilitation, the Surrey Virtual Reality system, practicality, cerebral palsy

1. Introduction

Cerebral Palsy (CP) refers to a set of motor disorders that are caused by damage to the brain before, during or almost immediately after birth [1, 2]. Approximately one in every 400 children born in the United Kingdom is affected [3]. The majority of children with CP are able to recover partial or full mobility if the management of CP arises early. Management focuses on using suitable combinations of interventions often through a multidisciplinary team. One aspect is gait (re)education or rehabilitation often provided under the guidance of physiotherapists. However, staffing and space allocation can limit the number of gait rehabilitation sessions that can be provided. In addition, some patients can find it difficult to maintain an appropriate level of motivation, particularly when sessions are undertaken in unrealistic environments or conditions.

Treadmill training is considered as a possible method to address some of these limitations. It has been used in gait rehabilitation to enable patients to repeat tasks and relearn basic patterns of walking, for example, adults suffering from symptoms post-stroke and other neurological impairments [4]. The potential of rehabilitation based on treadmill training for children with CP have been recognized [5-16] and the outcomes of the literature are encouraging; however, motivation on the part of the child remains an issue.

One approach to addressing the motivation issue could be the inclusion of a virtual reality (VR) environment such that training can become, for example, a structured 'game' that the child can become immersed in. VR is defined as an approach that allows users or physical objects to interact with a computer simulated three-dimensional (3D) environment [17]. The technology has been used in many medical applications. In the last few years, VR has been growing in a number of rehabilitation areas; for instance, benefit has been demonstrated in cognitive rehabilitation and motor learning [18, 19].

Clinical pilot studies have investigated the effectiveness of VR based lower extremity rehabilitation for patients post stroke [20-26]. Studies have showed improvements in walking parameters such as stride length [23, 27] and speed [20, 21, 24]. It has also been concluded that through use of simulated environments and interaction, VR can make rehabilitation safer leading to greater involvement of the patient [28]. For children with CP, considerable research and controversy has taken place over the past few years when reviewing the effects of VR on outcomes of rehabilitation programmes. For example, it has been shown that VR helps children with CP to increase self-confidence and motivation during upper extremity rehabilitation [29-32].

Recent literature shows the potential for the use of games during lower extremity rehabilitation. For example, five children with CP were encouraged to walk for longer in a treadmill training session while watching games without being immersed in them [33]. However, there is little evidence [33, 34] of the effectiveness of VR based lower extremity rehabilitation of children with CP.

The purpose of this paper is to confirm the direction of the research that has been identified by undertaking a review of existing programmes for children with CP, during VR based lower extremity rehabilitation. In turn this has facilitated the need to define the practicality of VR systems used for clinical rehabilitation. In this paper, the term 'practicality' refers to satisfaction, safety, comfortability, and compatibility to rehabilitation type, and has been adapted from the term 'usability' defined by Nielsen [35]. The paper also presents a summary of the main challenges that need to be addressed before the use of VR based lower extremity rehabilitation for children with CP can become routine.

2. Overview of Virtual Reality based Gait Rehabilitation of Children with CP

For children with CP, an intriguing and challenging area of study in VR based gait rehabilitation is the behaviour and the interaction of the children with the VR. A limited number of studies [29, 31, 33, 34, 36, 37] have recognised the potential benefits of VR based rehabilitation for children with CP. However, even though some of these studies have shown that VR therapy may lead to positive effects in real life activities [30], the recent review by Snider and colleagues [38] has shown that taken as a whole the current evidence for VR based rehabilitation of children with CP is poor. Most of these studies reviewed by Snider and colleagues investigated the effectiveness of VR with relatively small sample size. Furthermore, the majority of these studies had used VR systems that had not been designed with rehabilitation in mind. As an example, it has been suggested that the Nintendo Wii may have a place in rehabilitation, but concerns have been expressed that the current scenarios used (Wii games) may not always be appropriate for a given patient group [39]. Some VR systems however, have been designed particularly for use in physiotherapy programmes; but these are often expensive limiting widespread use in the clinical environment and therefore have not been investigated thoroughly [38].

3. Approach at Surrey

As a first step to addressing the issues outlined above, a strategy for the design of a VR system for lower extremity rehabilitation was proposed. This is illustrated in Figure 1. The process that we have used has five main steps:

a- Define the clinical problem(s) through literature review and discussion with clinicians
b- Define the engineering approach including the VR system and its requirements
c- Evaluate the performance of the VR system by recruiting healthy adults
d- Pilot system evaluation in the clinical environment
e- Analyse preliminary results and discuss them with clinicians followed by further engineering changes and clinical trial.

In conjunction with a clinical team, we have endeavoured to review the clinical problems that are related to children with CP and gait rehabilitation. As a result of this, we have designed the Surrey Virtual Reality System (SVRS) – a passive stereo, semi immersive system. The SVRS includes game scenarios developed for re-education of balance and walking. For the latter, a treadmill speed control algorithm has also been developed, based on [40]. The SVRS consists of the following hardware components (Figure 2 shows some of these components):

- A personal computer (PC) that uses an Intel (R) Core(TM) 2 Duo CPU E8500 (operating at 3.166Hz) and a NVIDIA Quardro FX 570 graphics card, with Windows XP SP3
- A pair of InFocus IN2104 DLP XGA2500 Lumens projectors that display the right and left images onto the screen
- A pair of circular passive polarising filters (150 mm^2) mounted in order to polarize the two images

- A rear projection screen (4.00 x 3.00 metres RP3D cut square that is mounted on an Easi-Rect Folding Frame, Harkness Screens International LTD, UK)
- Passive polarized glasses to deliver the proper view to each eye.
- A PPS WoodWay treadmill (WoodWay, Germany) integrated with the SVR system to allow users to walk through virtual scenes.
- Qualisys ProReflex system *(* Qualisys AB, Sweden) that is supported on a computer running Windows XP SP3

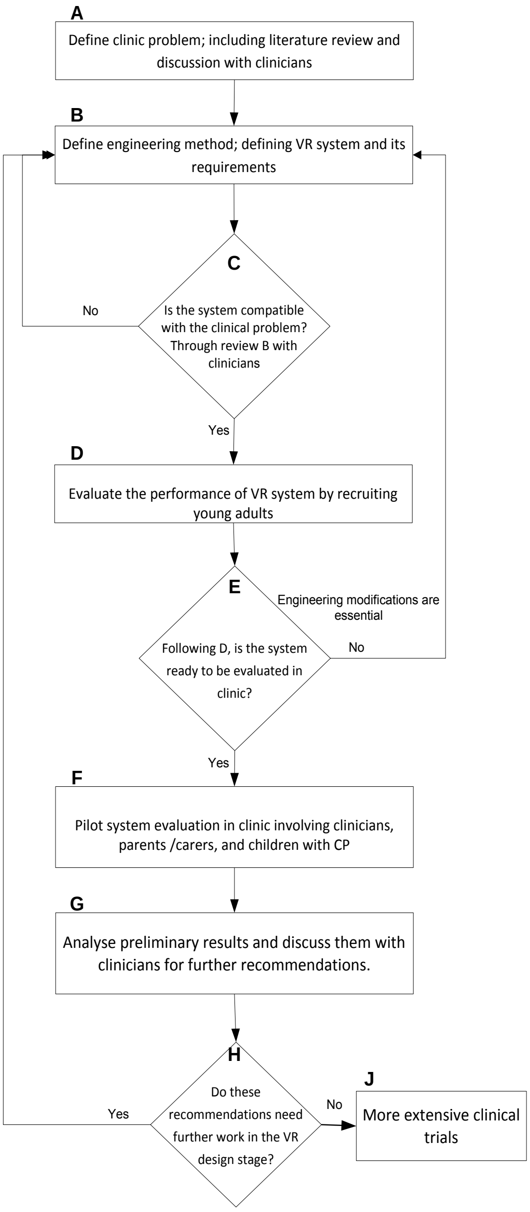

Figure 1 : A flowchart of the strategy used to design the SVRS

The software packages of the SVRS are:

- Vizard Virtual Reality Toolkit (version 3.18.0002, WorldViz LLC,USA) under Windows XP SP3
- Qualisys Track Manager (version 2.4.546, Qualisys AB, Sweden)

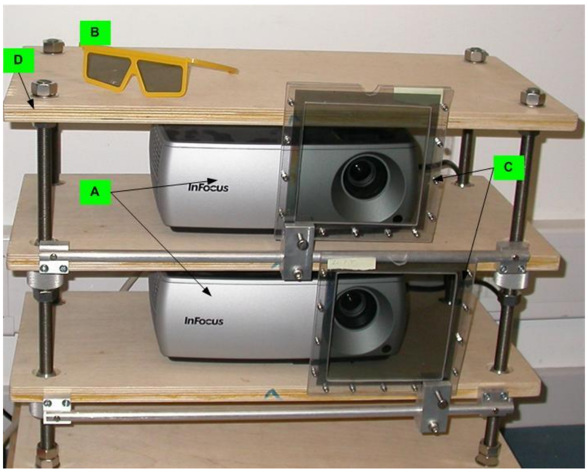

Figure 2: The main projection components of the SVRS. A: projectors; B: passive polarized glasses; C: circular passive polarising filters; and D: an in-house developed projector stand

Figure 3 shows a block diagram of the system. It uses two computers connected by Ethernet to drive the SVRS. The first computer (PC1) is connected to the projectors by using the graphic card channels and to the treadmill by using the serial port. Vizard Virtual Reality Toolkit is also compiled on the same computer with 1024 x 768 pixels display resolution at 60 Hz timing. The Qualisys ProReflex motion capture system is controlled through Qualisys Track Manager on the second computer (PC2). While it is true that projector stands can be quite expensive it is possible to use a locally developed projector stand that allows the authors to adjust the projectors within two planes as illustrated in Figure 2. The images are projected onto a rear projection screen 5.5 m behind the screen to present an image size 2 m tall and 2 m wide.

Ethical approval has been granted by the University Ethics Committee to evaluate the performance of the SVRS with young healthy adults who may have similar comments on computer games as children of secondary school age [41]. This will enable the research team to collect data by evaluating replies from a questionnaire that has three components. The first comprises questions on the quality of the SVRS presentation of 3D static images and 3D scenarios. These questions were adapted from the study of Witmer and Singer [42]. The second component comprises questions on the overall performance of the SVR system, e.g. the integration between the interfaced treadmill and the virtual environment. The third component consists of questions related to the performance of the treadmill speed control algorithm.

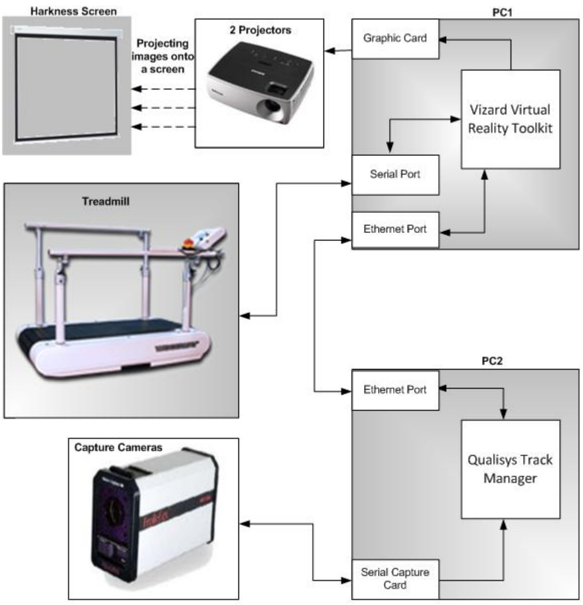

Figure 3: *A block diagram of the SVRS*

Analysing results of the above study, together with general feedback from the volunteers will help the team to decide whether the SVR system is ready to be evaluated with children with CP or if engineering modifications are required.

When the initial patient trail begins, the core focus of the evaluation will be directed at: satisfaction (how enjoyable is it to use the SVRS); comfort (how easy is it for children to complete tasks, once they have learned the system); safety; and to some extent utility (is it considered that the selected scenarios will benefit the gait rehabilitation of children with CP effectively). The analysis will consist of questionnaires, structured interview, and visual observation, involving the children, their parents/carers, and their treating physiotherapist. The results of this evaluation will then lead onto further engineering modifications if necessary, followed by detailed plans for investigating the clinical effectiveness of the SVRS.

4. Summary

The literature suggests that although current rehabilitation methods can help children with CP improve their mobility, a new rehabilitation tool would be beneficial as issues such as availability of clinical time, and patient motivation and safety remain. VR based rehabilitation does appear to have the potential to address a number of these issues, but further work into system design and evaluation is required. The paper describes our ongoing research in which we have attempted to develop a system by considering the clinical issues first. It is hoped that this research will help in assessing the practicality of VR-based gait rehabilitation for children with CP

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