

Generative Design as a method to foster explorative behaviour in virtual motor rehabilitation

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ABSTRACT

The article contrasts the bottom-up with the top-down approach to the development of systems for virtual motor rehabilitation. A research project is presented that uses the top-down approach for the development of a system for virtual neurorehabilitation of amputees suffering from phantom limb pain. Artistic visualisations that are inspired by the field of generative design will be used to constitute the illusion of a moving phantom limb. The coupling between the movements of the patients and the visual effect is not straightforward but needs to be discovered through explorative behaviour. It is assumed that this will help the patients to concentrate on the treatment and therefore a strong therapeutic effect will be achieved.

1. INTRODUCTION

Since the advent of affordable motion capture systems – e.g. the Nintendo Wii Controller and the Microsoft Kinect/Primesense sensor – the application of Virtual Reality technology for motor rehabilitation is becoming increasingly popular. The technology serves a variety of purposes (Burdea, 2003), of which one of the most prominent is the motivational benefit. A number of therapeutic approaches have been reported to benefit from the integration of video game components in the therapy session (e.g. Cameirao et al., 2009; Holden, 2005; Prange et al., 2008; Pyk et al., 2008) and it is stated that the patient's compliance may be improved due to the entertaining nature of the virtual environments (Flores et al., 2008; Lange et al., 2009). Therefore in virtual motor rehabilitation the technology plays a central role for the effectiveness of the treatment and designing the virtual environment is a crucial step in the development of the therapy. Approaches towards this goal can be classified into two poles: bottom-up design and top-down design.

2. DESIGNING SYSTEMS FOR VIRTUAL MOTOR REHABILITATION

The bottom-up approach to the development of a system for virtual motor rehabilitation can be described as follows: an established therapy setting is transferred into a virtual environment and enriched with game components. The patient e.g. controls an avatar with his/her natural movements and reaches for targets or collects items in the virtual world. The game components are placed such that the patient needs to perform therapeutically relevant movements to accomplish the task. The therapeutic setting and the expected outcomes are defined through the established non-digital therapy. The bottom-up approach makes use of the virtual environment in ways that are naturally (physically or technically) conceivable in the real world. Thus it focuses on a close relation between the displayed elements (environments, avatars or objects) and their real world counterparts and encourages natural behaviour in or with these elements. This approach benefits from intense communication between the development team and the clinicians to include the practical experience with the established therapy. When using a modular software architecture iterative development is possible and early user tests can be performed in realistic settings to ensure continuous improvement of the system.

On the other hand, the development may also follow a top-down approach: for the design of the virtual environment the intrinsic properties of the digital medium are considered prior to the adaption of established therapy settings. The starting point for the development is the abstract description of the system: three-dimensional, temporal data (e.g. body posture or gesture) will be transformed according to predefined rules into real-time visual feedback. This way the reaction of the system to the patient's movements may be generated in various ways based on algorithmic transformations. Possible underlying rules for these

transformations are then explored to meet therapeutic goals. Emphasis is put on the innovative application of the technology for motor rehabilitation and this approach benefits from a loose focus on established settings. Inspiration may be found in artistic fields like media art or computer game design. A relatively advanced prototype will be needed before beginning with user testing when the system is not closely integrated with the established processes.

Though the bottom-up process has many benefits in terms of the integration in the clinical practise it may be difficult to put forward abstract or artistic ideas. In this article it is argued that the top-down approach is valuable for the development of innovative systems that lead to therapeutic treatment not possible without the technology. In the following section a research project is described in which this approach is applied to develop a new system for virtual neurorehabilitation of amputees. Along with this, the development environment and a middleware library are introduced, which can be used for similar research in this field.

3. GENERATIVE DESIGN FOR THE TREATMENT OF PHANTOM LIMB PAIN

3.1 Research project

The aim of the research project is to develop a system for the treatment of amputees with phantom limb pain. The system makes use of the principles of mirror therapy (Ramachandran & Altschuler, 2009) and it explores the application of artistic visualisations for this purpose. The patients will experience the illusion of controlling the system with their phantom limb. However, instead of using two virtual arms that move according to the movements of one arm of the patients – which would be a bottom-up adaption of the established mirror therapy – artistic visual output is displayed that gives the impression of being controlled by symmetrical movement of two arms. This output is generated through algorithmic transformations based on the recorded movement of the patients and these algorithms are inspired by the field of generative design. It is assumed that the system allows for an engaging experience and that the interaction with it will help to concentrate on the virtual environment, contributing to a strong illusion of a moving phantom limb. Furthermore, the reaction of the system to the patients' movements is not straightforward. Rather, the coupling between motor actions and visual feedback needs to be discovered through explorative behaviour in relation to the external effect. Fostering explorative behaviour while focussing on external effects can be beneficial for motor learning, as research in sport science has shown (Schollhorn et al., 2010; Wulf, 2007). Figure 1 shows an early prototype of the system that is currently under development.

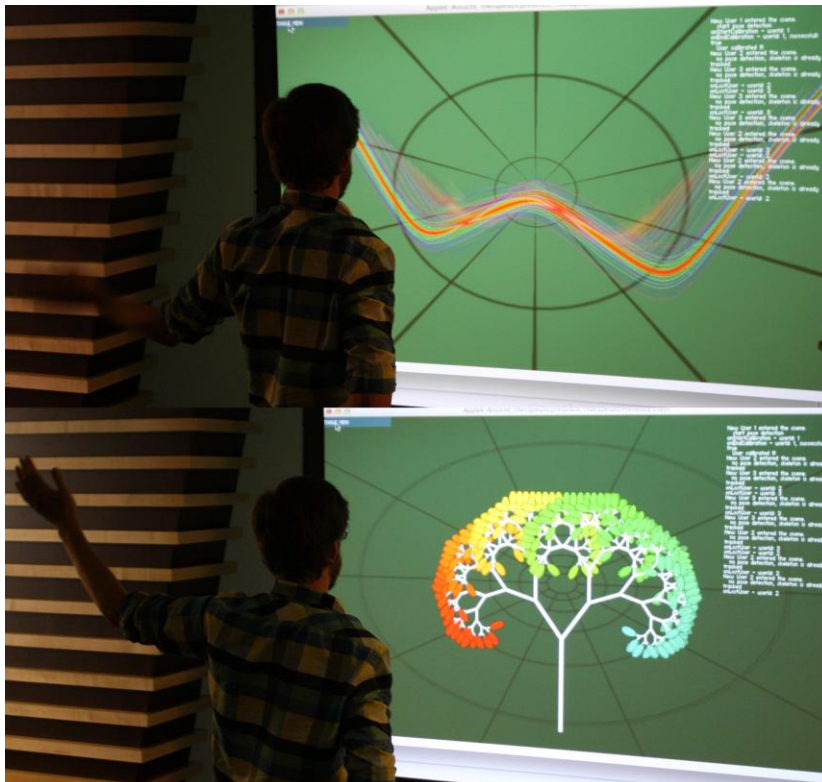


Figure 1. A system for virtual rehabilitation of amputees suffering from phantom limb pain

3.2 Generative Design

The field of generative design inspires the algorithms that generate the visual output of the system. In media art the method of transforming data algorithmically into expressive (visual) output is known as generative art or generative design (McCormack et al., 2004). John Maeda and Paola Antonelli describe this idea as the challenge to "discover the intrinsic properties of the new medium and to find out how the stroke you can 'draw' via computation is one you could never draw, or even imagine, without computation." (Maeda & Antonelli, 2001, p175) In interactive generative systems the elements that form the output are not shaped or constructed prior to the interaction but rather generated during and as a reaction to it. Thus no two experiences with the system will be the same. Only the rules that generate geometric forms, colours and transitions are predefined and given in form of algorithms. This way the input data defines the output. Artwork and research on generative design have found a large set of algorithms demonstrating the vast amount of variations that are possible (Bohnacker et al., 2009). To give a simple example, figure 2 shows a two-dimensional tree and the generating algorithm.

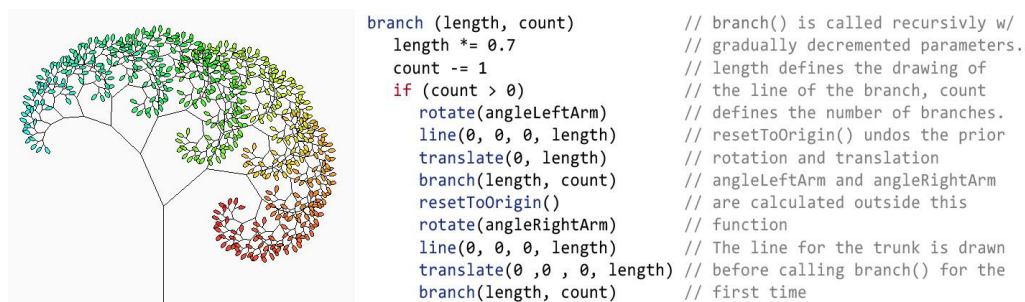


Figure 2. A tree and its generating algorithm

When natural movements are used as input data, algorithms can be developed that transform expressive behaviour into aesthetic visualisation. For the application of generative design in virtual motor rehabilitation the definition of expressive behaviour in terms of the therapeutic goals is important. Biomechanical descriptions of the therapeutically relevant movements can be used to define body postures and gestures that are used as input data. These descriptions are given by kinesiology (Neumann, 2010).

3.3 Processing IDE

For working with generative design the Processing IDE (see www.processing.org) has become popular. It is based on the Java programming language and provides a framework and simplified syntax for the creation of software. The IDE and the framework were created to give artists and designers with little programming knowledge a tool to experiment with generative design. It focuses on rapid software prototyping in order to enable the designer to produce output and variations in an easy and fast manner. One of the strengths of Processing is its large community. Developers provide a growing number of libraries, tutorials and open source examples to build new software on and to use hardware components through programming interfaces (e.g. the Microsoft Kinect/Primesense sensor). This makes Processing an ideal environment to experiment with the top-down approach towards the development of systems for virtual motor rehabilitation.

The software that is developed for this research project is build with Processing and it is publicly available under the following link. A library that gives access to the posture and gesture of the patient is separately available to be used in similar research projects (see <http://github.com/thschul/>).

4. CONCLUSIONS

In this article the top-down approach to the development of systems for virtual motor rehabilitation was proposed. With this approach innovative systems may be created that explore the possibilities of the digital medium for therapy. It was argued that artistic visual output may be used to foster explorative behaviour of the patients and that this helps concentrating on the treatment. Generative Design was introduced as a method to create this kind of output. Furthermore a research project was described that demonstrates this idea. The software for this project is developed using the Processing IDE and a middleware library is available for download to aid similar research. The design of the virtual environment plays a central role for the effectiveness of virtual motor rehabilitation applications and therefore exploring this approach may be valuable for other applications, too.

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