THE DEVELOPMENT OF SONIFICATION MODEL USING PARAMETER MAPPING TECHNIQUE

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FACULTY OF COMPUTING AND INFORMATICS
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ABSTRACT

Most of the instructions given by trainers or therapists in body movements, such as walking, turning, rising arms or legs are mostly done through voice instructions or touches. This does not poses much problem to ordinary people as they can see the action at the same time. To follow these instructions without visual may cause confusion in terms of actions and directions. Unfortunately, there was no other option for the visual-impaired persons. Thus, this research studies on transforming those voices and touches form of instructions into non-speech sound instructions. The method involves transforming 3-dimensional data of body movements (kinematics) into sounds. This research expects to provide audio aid, and the user should be able to follow the exact body movements of another person or instructor without any speech commands or instructions. The novel contribution of this research is to produce a sonification model (converting the data into sound) that represents the actions and directions of the body movements in 3-dimensional space. Parameter Mapping is used as the conversion approach, where the movement properties will be mapped to sound properties. The parameter mapping involves three transformation processes - data, acoustics parameters and sound representations. This research used the Kinect (Microsoft Xbox 3D movement sensors) as the live 3D movements input data stream. Kinect technology was intentionally used due to its readiness and low cost. Experiments were conducted to examine the effect of audio 3D movement knowledge and training through the number of success performance between groups. The result demonstrates that given knowledge and training enhances the number of success performance compare to the control group. In Conclusion, the results show that the 3D hand movements can be represented using non-speech sound. From the finding, training is required beforehand to increase the ability to interpret the proposed 3D sound design.

Keywords: Sonification, 3D Body Movement, Parameter Mapping.

ABSTRAK

PEMBANGUNAN MODEL SONIFICATION *MENGGUNAKAN TEKNIK MENYAMBUNG PARAMETER*

Kebanyakan arahan pergerakan yang diberi oleh jurulatih atau pakar terapi dalam pergerakan badan, seperti berjalan, berpusing, menaikkan tangan atau kaki adalah dilakukan melalui arahan suara atau sentuhan. Ini tidak memberi masalah kepada orang normal kerana mereka boleh melihat. Namun, untuk mengikuti arahan ini tanpa melihat, ia boleh menyebabkan kekeliruan dari segi pergerakan badan. Malangnya, tiada pilihan bagi orang–orang yang buta. Oleh itu, kajian ini mengkaji bagaimana untuk menggantikan arahan berbentuk suara dan sentuhan kepada arahan berbentuk bunyi bukan berbentuk pertuturan. Kaedah ini mengubah data 3 dimensi pergerakan badan (kinematik) kepada bentuk bunyi. Kajian ini berharap hanya dengan mendengar bunyi, seseorang itu akan dapat mengikuti pergerakan sebenar tubuh orang lain atau pengajar tanpa apa-apa arahan suara atau arahan. Novelti kajian ini adalah untuk menghasilkan model sonification(menukarkan data kepada bentuk bunyi) untuk mewakili tindakan dan arahan pergerakan badan dalam ruang 3 dimensi. Pendekatan yang di gunakan adalah pemetaan parameter, dimana sifat-sifat pergerakan akan dipetakan kepada elemen bunyi. Pemetaan parameter melibatkan 3 proses transformasi- data, parameter akustik dan representasi bunyi. Keberkesanan pendekatan ini adalah bergantung kepada 3 proses transformasi tersebut. Kajian ini mengunakan Kinect (sensor pergerakan 3 dimensi Microsoft Xbox),sebagai aliran input pergerakan 3D. Peranti ini digunakan di dalam kajian oleh kerana kadar kesediaan dan kos rendah. Eksperimen telah dilakukan untuk mengkaji kesan pengetahuan dan latihan berdasarkan audio terhadap bilangan prestasi kejayaan antara kumpulan. Hasilnya menunjukkan dengan memberi pengetahuan dan latihan, ia meningkatkan bilangan prestasi kejayaan berbanding dengan kumpulan kawalan. Kesimpulannya, pergerakan tangan berbentuk 3D boleh di wakili menggunakan bunyi bukan pertuturan. Dari hasil kajian tersebut, latihan diperlukan terlebih dahulu untuk meningkatkan keupayaan untuk mentafsir reka bentuk bunyi 3D yang dicadangkan.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Rehabilitation requires a longer time to recover and required a lot of money in term of transportation and also time-consuming often last to 3 hours a day, 5 to 6 days a week for patients who stay in a facility (Post-Stroke Rehabilitation, 2014). For the normal persons, they may choose to do the rehabilitation at home, using video chat as the medium of communication with the trainer. The trainer no longer required to be present in the patient vicinity, which makes it way convenient called telerehabilitation (John Wiley & Sons, 2005) (Lisa Keaton, et al., 2011). Through the video chat, the patient and trainer can communicate, give feedback and understand each other. Unfortunately, patient who is blind that undergoes the same rehabilitation process have limited option compared to the normal people. They were unable to do the rehabilitation at their home, and they may have to spend more (in term of transportation) for each physiotherapy sessions. Imagine the difficulties on trying to follow the prescribed exercise with closed eyes.

In a real-time situation, the therapist often may distracted from the contact with the patient due to having to operate the (visual) menu system and examining the (visual) results (Pauletto & Hunt, 2004) (Pauletto & Hunt, 2006) (Pauletto S. &., 2009). The question is; do we have any alternatives? Is there a way to instruct a person to move their body without using any speech and touch instructions? It would be a good idea, if a patient could understand and able to follow the body movements of the therapist (actions and directions) by only listening to the sounds that represent the movements.

Most of the previous researches were using high cost equipment such as Vicon motion tracking studio (Vicon, 2014) or requires to be developed, mostly were prototype using accelerometer to capture the data intended to be sonified.

This research may potentially produce an assistive tool for the disabled person (blind) and potentially improve the data analysis in physiotherapy. This tool may also motivate a much more fun exercise. Thus, this research focused on designing a model to transform the 3D body movement (hands) into the non-speech sound to represent the motion using readily available low cost device dubbed ”SonicMotionFollow”. For this research, the model is defined as the general process of transforming and mapping the raw data and finally produces a non-speech sound that represents the data. Three types of experiments were conducted to test the hypothesis.

1.2 Problem Statement

These are the statements of the problem of this research;

1) **Blind people that undergo physiotherapy rehabilitation have limited option compared to normal people**.

   Normal people, they may choose to do the sessions at home by communication via video chat called telerehabilitation (John Wiley & Sons, 2005) (Lisa Keaton, et al., 2011). Unfortunately, blind patients have limited option to do the sessions at their own home, and they may have to spend more for each session they went to at the physiotherapy rehabilitation facility (Post-Stroke Rehabilitation, 2014). Even though they may have friends or family that can assist them in the exercise, but it still may be too confusing to follow the action and movement by the therapist. Imagine the difficulties on trying to follow the prescribed exercise with closed eyes. It would be great if there is a tool that can assist them when performing the rehabilitation exercise in their own home.

2) **Prescribe exercise can be a difficult task.**

   In the rehabilitation service, one of the most valuable tools for the physiotherapy profession was the therapeutic exercise that requires on learning a complex motor skill (Kisner & Lynn, 212), which can be a difficult task. The prescribed exercise program was often performed with the manual instructions by the therapist. This excercise requires more practice on recreating the movement, proven difficult even with the help of visual aids and coaching. To follow these exercises without visual will be confusing and may cause mislead towards actions and directions. Unfortunately, there was no other option for the blind people. Imagine if the information about the motion can be conveyed into a sound that can assist the users while performing an exercise task. It will be exciting and fun.

3) **Therapist may often distract from contact with the patient.**

   In a real-time situation, the therapist may often distract from contact with the patient due to having to operate the monitor menu system and examining the (visual) results (Pauletto & Hunt, 2004) (Pauletto & Hunt, 2006) (Pauletto S. &., 2009) It would be good if the menu system can be transformed into a sound representation, then the trainer will be able to focus more on the patient.

4) **Using a prototype equipment to extract 3D coordinate human movements**

   Some researches were required to develop at least a prototype such as one that used the accelerometer to capture data to be sonified. Thus, this research will use a readily available device to capture the data to be sonified on representing the actions and directions of body movements in 3-dimensional spaces.

1.3 Research Goal

The research goal was to design, develop and evaluate the model of non-speech sounds to represent the action and direction of the 3-dimensional body movements through parameter mapping sonification technique.

1.4 Objective

There are three objectives of this research;

1) **To collect and review the previous literature works**

   This process is to define the key terms and to identify the potential sources of information for this study.

2) **To design and develop the sonification model for transforming 3D body movement using parameter mapping technique**

   A series of experimental research were conducted and a sonification model was produced. The selected coordinate (x, y, and z-axis) were mapped to the three sounds properties. A low-cost system was also developed and used as the platform of the research experiment.

3) **To evaluate the result of the design model.**

   Experimental research was conducted to test the effectiveness of the design model using different types of motions.

1.5 Research Question

In general, the research intends to answer the following question: is it possible to sonify the human 3D motions information using parameter mapping technique to help the users to understands the movements only by listening? The design inspection was referred from the systematic usability inspection approach (Asri & Hunt, 2007). There are three research questions for this research;

1) **How to transform and manipulate the data from Kinect technology into a new form of sonifiable data?**

   Some raw data may need to be filtered before it can be used for the mapping process and often requires to be changed into something more suitable for a sound transformation, which refers to the data transformation. Some of it then may require to be scaled into more suitable range of scale, for example: from range 0 to 1 or change in decimal place. The raw data coordinate was calculated based on the center point (head).

The head was chosen as the center point because the human perceives sounds from their left and right ears.

2) **How to transform the sonifiable data into the acoustically ready data?** This process was to transform the sonifiable data into the acoustic parameter data called acoustics ready data, where the sonifiable data was suitable to be used in the mapping process. This data then will be mapped into the three sound properties, which is the frequency, volume, and tempo. More explanations for the mapping process are described on Chapter 3.

3) **How to combine and manipulate the acoustically ready data into the final sound transformation to represent the actions and directions of 3D body movement?**
The outputs of the transformation are then converted into the sound which can be listened using a headphone. Final sound transformation is referred as the process of manipulating the output from the acoustic parameter mapping transformation. Further details are presented in the model of the design in the Chapter 3.

1.6 Research Hypothesis

Actions and directions of the 3-dimensional body movements can be effectively represented using the non-speech sounds through parameter mapping technique.

1.7 Significant of Study/Contribution

The main focus of this research was to produce an effective sonification technique to convert the data (signified) into a sound (signifier). In this research, the data to be "signified" is the 3D body movements, and the "signifier" is the sound to represent the 3D body movements.

1.8 Research Structures

The approach of this study could be divided into four different sections. Figure 1.1 shows the research processes: (1) literature review, (2) sonification of 3D body movement, (3) experimental design, (4) and the result analysis.

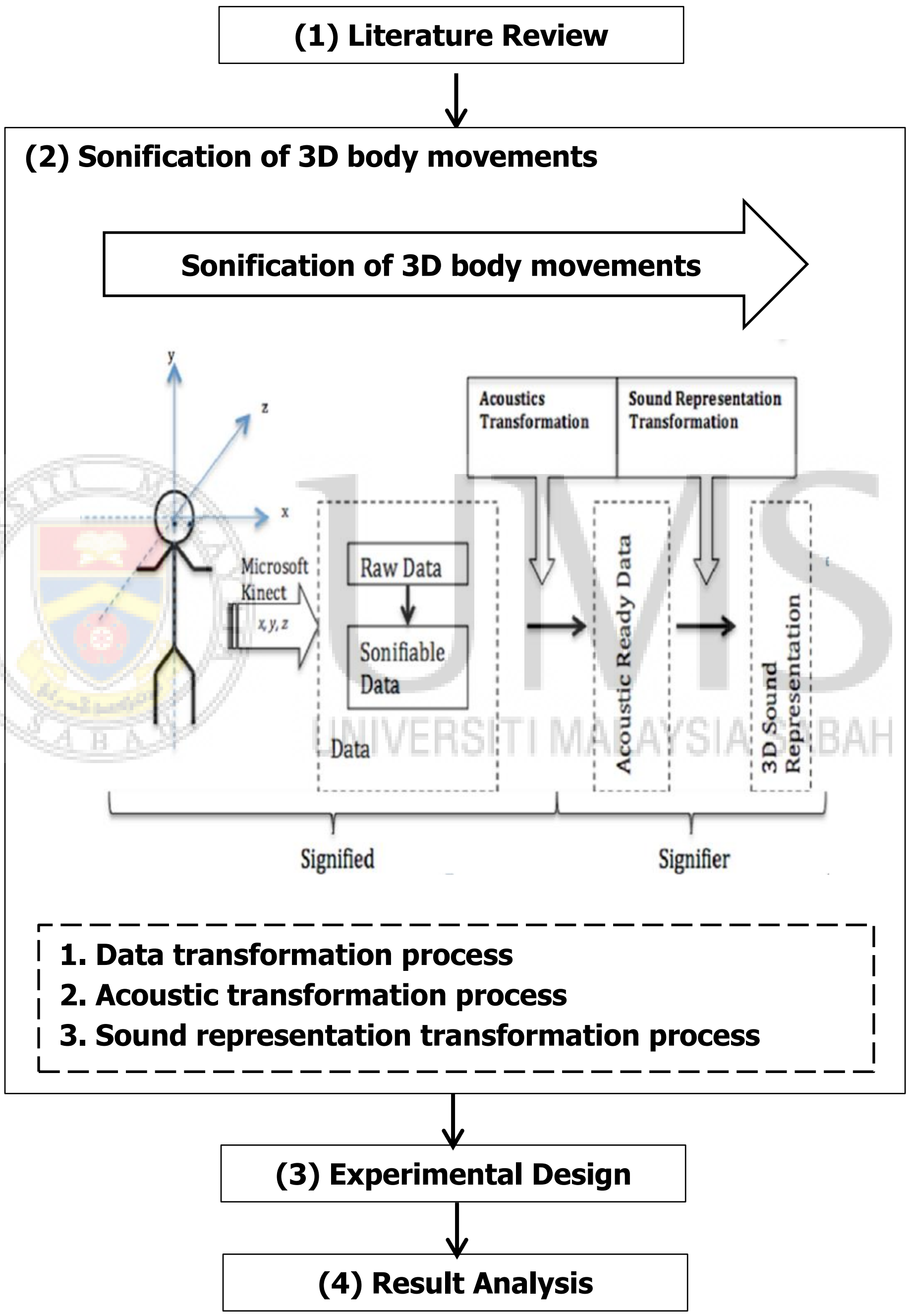

Figure 1.1: Research structure (Ibrahim & Embug, 2014)

1) **Literature review**

During this phase, previous researches based on the keyword of: Sonification; kinematics; 3D movements; Parameter Mapping were selected and reviewed. The reviews also involve the understanding on how the human perceive sounds. This process is described in the Chapter 2.

2) **Sonification of 3D body movement**

This part describes the process of data transformation the raw data taken by using Kinect 360, then processed for transformation to a more suitable form for the mapping process and finally produced a sound that properly represents the human motion. In addition, this section explains how the sound properties are mapped and shows the overview design of the model "SonicMotionFollow". This process is described in the Chapter 3.

3) **Experimental design**

This section defines and formulates the hypothesis, dependent and independent variable of the study. It also includes the detailed explanation of the model "SonicMotionFollow", the raw data collection process, the data transformation process, and the mapping process. Possible threats that may affect the experiments and the steps involved in conducting the experimental study were also listed. Selection of the sample of subjects, identification and controlling the nonexperimental factors are conducted along with the construction of the outcome measurement. Pilot-testing was also conducted and the duration of the experiments was determined in this phase. The process is described in the Chapter 4.

4) **Result Analysis**

This phase involves the analysis and the interpretation of the collected quantitative data. The result findings will be discussed and concluded. This process is described in the Chapter 5.

1.9 Summary

A model of transforming the 3D body movement into sounds was developed to enable the blind patients to understand the rehabilitation training and learning motion through listening. It may help the therapist to examine their patient exercise result with less distraction. The next chapter explains the literature reviews that are related to this three keywords; sonification, 3D body movement and parameter mapping. The design or model from the related researches is reviewed based on the criterion such as: the type of sound properties, possible sound properties, and different types of data for mapping technique. The review also intends to understand the process of parameter mapping as well as how to transform raw data into sonifiable data.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The previous chapter stated the problem that needs to be studied on the growing demand of global physiotherapy rehabilitation and the challenges for the blind patients to follow the prescribed programs. In addition, in most real-time situation, the therapist often may distracted from the contact with the patient due to having to operate the (visual) menu system. Also, the researcher has explained about the type of research question need to be answered, and the objective that needs to be achieved.

In this chapter, the thesis reviews on the three related keywords; sonification, 3D body movement and parameter mapping. Then, the chapter reviews on the related literature work and identify the type of data and the sound properties that were used in those researches.

2.2 Sonification

What is Sonification? Sonification was defined as "the representation of information using non-speech sound to help in understanding of data or processes by listening" (Kramer G. , 1994) or "the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation" (Kramer G. , 1994). Referring to these definitions, the sonification applications should have the following three main elements; the goal, tasks and objectives to achieve (e.g. interpretation, communication, emotion etc.); Input (data) and output (non-speech sound); and the technique(s) of transforming data into sound

The sound can be produced by using a synthesizer and designed by manipulating its perceptual qualities such as the pitch, timbre, loudness, spatial location, and extent. Sonification techniques is the process of manipulating the perceptual qualities and changing data into sound. It is important to understand the existing sonification technique before designing a framework or model.

There were several existing sonification techniques that were currently available and most widely accepted among the research community which was described in detail in the Sonification Handbook (Dombois F. a., 2011.), audification (Dombois F. , 2001) (Dombois F. a., 2011.), parameter mapping (Grond & Berger, 2011; Kramer G. , 1994), model based sonification (Hermann, 2004; Hermann, 2011.), earcons (McGookin & Brewster, 2011) and auditory icons (Brazil & Fernstorm, 2011)

2.2.1 Audification

Audification is the direct translation of a data waveform into sound (Dombois & Eckel, 2011) and the series of data might not even belong to the sound domain. A common way of displaying this visually would be the Cartesian graph. If the visualized data have a wave-like shape, for example an EEG signal, audification would mean to attribute their values to air pressure and transferring the result to a loudspeaker, whereby the data then become audible.

The aim behind this media shift, as in all the sonification techniques, is that the other mode of representation discloses or makes emerge aspects of the data that might not have been discovered before (Dombois & Eckel, 2011). The most profound audification technique was carried out by Pauletto and Andy Hunt (2005), they tried to understand the advantage and the disadvantages of audification in general (Pauletto & Hunt, 2005).

Audification also contributes in the medication domain such as the work by Jesus Olivan, Bob Kemp and Marco Roessen (Olivan, Kemp, & Roessen, 2004) that investigates on the EEG sleep recordings. Moreover, audification were also used in seismology (Meier & Saranti, 2008), physics (Martini, Hermann, Anselmetti, & & Ritter, 2004) and stock market (Frysinger, 1990).