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Design and implementation of a user interface for controlling computer games using a Kinect camera as part of physical therapy

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During the year, we've had several occasions to discuss the subject of machine learning and support vector machine (SVM) with our fellow students Victor Martens and Alexander Kerckhofs, who helped with making us aware of the pitfalls and shortcomings of the used techniques and joined us to discuss the requirements and come up with a creative solution concerning the use of SVM.

User testing is very important when designing an application with a specific audience in mind. As such, we are grateful for the useful feedback of physical therapist Dries Lamberts of Windekind, who took the time to meet us twice and evaluate both our prototype as well as the final result. But even more importantly, he shared with us his passion for taking care of children with disabilities, their need for physical exercise and the importance of making sure this is both meaningful and entertaining.

Last but not least, we would also like to thank our parents, family and friends, who not only have supported us during the course of past year while working on this master's thesis, but also for trying out our application and giving valuable feedback.

Abstract

- Motivating children to perform physical therapy exercises.
- Exercises are adjusted to the needs of the child.
- Economic necessity to support a multitude of existing games.
- SVM to learn new exercises.
- Graphical user interface focused around use by the therapist.
- Results

Key words: exergames, gesture recognition, Kinect, support vector machine, user interface

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Lijst van symbolen en acroniemen

Symbolen

d	Afstand
λ	Golflengte

Afkortingen

GUI	Graphical User Interface
SVM	Support Vector Machine

Chapter 1

Introduction

There are many different reasons for requiring physical therapy. They vary from recovering from a car crash to being born with physical disabilities. The goal of this therapy is respectively to make sure that the patient can recover as much as possible from his injuries or to train the muscles, preventing their situation from deteriorating.

Especially for children, the physical exercises performed during therapy can be demotivating. Combining these exercises with playing computer games leads to an increased willingness to continue with the exercises. However, the classic approach related to games that incorporate physical exercises is not economically sustainable.

The purpose of this thesis is to present a more sustainable solution to this problem in a way that offers more flexibility to the therapist, both in terms of the exercises that need to be done by the patients and the games they can control and play by performing the exercises.

1.1 Discussion of the problem

Patients often see exercises as a part of physical therapy as being fatiguing, monotonous and tedious. This problem is even more prominent with young patients and can quickly demotivate them, especially when the exercises are uncomfortable or painful to perform.

Computer games already exist that can support physical therapies. For instance, there are games that run on Microsoft's XBox console and accept user input through the Kinect 3D camera, or Nintendo's Wii console that use a controller with accelerometers. Additionally, there are also games that can run on a computer, using any combination of sensors for user input, and are specifically made for use by physical therapists and their patients. However, all these games have in common that they are very static by nature and are not often suited for the specific needs of a patient. For instance, a game that focuses on arm movement is not very effective at exercising the leg muscles of a patient. In other words, concerning the therapy, the game is meaningless for a patient that had leg surgery.

In addition, these static games have fixed input gestures the patients have to perform in order to control the action on screen. Even if the gestures perfectly fit the exercise requirements for a specific patient, the decrease in attractiveness of playing the same game over and over again is problematic and loses its long-term effect. Physical therapist Dries Lamberts has experience with children with disabilities and uses computer games as a form of exercise. The initial reaction of the children to these games is positive. They are more engaged in doing physical exercises and feel motivated while doing so. On the downside, this effect only lasts until the novelty of the game wears off. After that, the children lose interest in the game and, as such, in performing the exercises.

As games are expensive to develop, and motion-based games in particular, there is no wide variety of games that are tailor made for people with specific needs and at the same time offer varied gameplay mechanics to remain interesting over long periods of time. On the other hand, producing these kind of games is not economically sustainable. From the patient's point of view, the right type of exercises need to be supported by the game and the game itself has to be considered fun as well by the patients for them to keep invested in it.

1.2 Purpose of the research

This thesis focuses on an application that allows for a more flexible and dynamic solution to the above discussed problem. It lets the physical therapist choose what exercises the patient has to do and how these can be used as an input to control any computer game of choice. All of this can be done without requiring the therapist to have any programming knowledge.

The goal is to have an application the therapist can control mainly using the Kinect camera. It needs to be both simple and efficient to do, in order to minimize the setup time before a patient can start playing. It is necessary to research the type of interface that is required to meet these objectives, in addition to finding out the easiest way to interact with an on-screen application using a camera for input.

Chapter 2

Literature study

2.1 Human-computer interaction

- Papers/artikels over framework, natuurlijke interfaces,...
- ...

2.2 Similar research

- Vergelijking van opzet met andere oplossingen
- Te trekken lessen uit deze oplossingen (vb: feedback voor de kinesist is belangrijk, opstellen van het systeem mag niet veel tijd in beslag nemen,...)
- ...

Chapter 3

Design

The properties of the application are chosen in function of solving the problem discussed in the introduction. The focus is on simplifying the setup process for the therapist, while still providing all tools needed for the patients to play a game using gesture input.

The developed application can roughly be split up into three major parts. Firstly, the graphical user interface allows the therapist to interact with the application, providing him with feedback and feedforward on inputting exercises for the patients. Secondly, gesture recognition is done as part of machine learning using support vector machines (SVM). Thirdly, all other back-end software connects the first two parts and provides a structure in which all data is managed and stored.

3.1 Properties of the application

The developed application can be seen as the link between the physical exercises and a game.

The physical therapist comes up with exercises that fit the needs of a patient. He uses the Kinect camera to interact with the application via a graphical user interface (GUI). Next, the therapist lets the application record what exercises need to be done by the patient. Using all of the recorded exercises, an SVM model is created, which is used to evaluate what exercise is performed by the patient while playing a game.

The therapist assigns a keyboard button to each exercise. This means that when the patient mimics one of the therapist's exercises a keyboard button is pressed. If this application is running in the background while a computer game is opened in an active window, performing an exercise and thus indirectly pressing a button interacts with the game.

INCLUDE FIGURE SHOWING A GENERAL OVERVIEW OF
THE APPLICATION STRUCTURE IN BROADER CONTEXT

By mapping exercises to keyboard buttons, a vast majority of available games can be played using gesture-based input. It is however limited to button presses, pointing with the cursor like when using a mouse is not supported.

Application is for Windows only, C++

The application has to be flexible enough to support exercises that are unknown beforehand; same with the games played.

- Op voorhand ongekende oefeningen
- Op voorhand ongekende game
- Systeem = link tussen oefening en game
- ...

3.2 Graphical user interface

- Klassendiagramma voor GUI
- Algemene/schematische beschrijving van de voorgestelde oplossing.
- Procesbeschrijving, opties tussen verschillende types van interfaces (mime/dirigent)
- (Experimentele manier om tot prototype te komen door gesprek met kinesist (?))
- GUI + bespreking
- ...

3.3 Back-end software

- Klassendiagramma van de code (niet voor GUI)
- Uitleg structuur
- ...

3.4 Gesture recognition

In order to provide enough flexibility concerning the type of exercises, SVM is used.
Downside: multiple trainings, always returns a label to the most similar gesture

As stated in the previous section, a gesture consists of multiple frames. Each frame contains 25 joints and each joint consists of an x, y and z component. This results in a total of 75 features that are being considered for each frame.

Two approaches are considered when it comes down to learning how to recognize gestures.

The first one is to add a time stamp to each frame as an extra feature, indicating the time relative to the first frame of the gesture. This results in having 76 features per frame. If performing a gesture takes about 3 seconds and is captured at a rate of 30 frames per second, this amounts to 2280 features for a 3-second gesture. In other words, the number of features of one entry depends on the length of the gesture. The entire gesture is classified as a single gesture.

The second approach is to split up one gesture into a number of smaller gestures and classify each of them differently.

Chapter 4

Implementation

- Bespreking van werking van belangrijkste softwareonderdelen
- Belangrijkste deel/delen uit code
- ...

4.1 Requirements and setup

List of requirements and setup due do design and implementation decisions.

These are Kinect requirements:

64-bit (x64) processor
Physical dual-core 3.1 GHz (2 logical cores per physical) or faster processor
USB 3.0 controller dedicated to the Kinect for Windows v2 sensor or the Kinect Adapter for Windows for use with the Kinect for Xbox One sensor
4 GB of RAM
Graphics card that supports DirectX 11
Windows 8 or 8.1, Windows Embedded 8, or Windows 10

Other requirements:

Install Kinect drivers
Position of the Kinect camera
Start application, setup gestures, start browser with game or similar

4.2 Graphical user interface

4.3 Back-end software

4.4 Gesture recognition

Chapter 5

Results

- Korte samenvatting van bereikte resultaat
- [belangrijker] Resultaten gebruikerstest
- Interpretatie van de resultaten
- . . .

Chapter 6

Discussion

- Reflectie behaalde resultaat
- Reflectie proces
- Voorstellen voor verbetering (efficiëntie,. . .)
- Voorstellen voor toekomstige projecten (vb: focus op besturing door kinderen ipv kinesisten)
- . . .

Chapter 7

Conclusion

- Samenvatting probleemstelling, implementatie en resultaten
- . . .

Appendix A

Explanation about the appendix.

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