Design and implementation of a computer aided ergotherapy framework

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STUDENT RESEARCH PROJECT

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Declaration

I hereby declare and confirm that this thesis is entirely the result of my own original work. Where other sources of information have been used, they have been indicated as such and properly acknowledged. I further declare that this or similar work has not been submitted for credit elsewhere.

Stuttgart, June 4, 2018

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Contents

Acronyms

AR	Augmented Reality. v
VR	Virtual Reality. v

Abstract

After carrying out hand surgeries, the patient often has to undergo a lengthy recovery period in order to get hand mobility back to the original, healthy state. This recovery phase is usually accompanied by a dedicated ergo therapist in various therapy sessions, requiring the physical presence of both the patient and the ergo therapist.

In a joint venture of the DHBW Stuttgart and the Katharinenhospital Stuttgart, the possibility of computer aided recovery is explored. The long term goal of the collaboration is for the patient to be able to complete some of the recovery exercises at home, saving time and resources for both the patient and the clinic.

This student research project is exploring one particular possibility of achieving this: combining low cost hand tracking devices with the modern web. Hand tracking devices are small hardware devices containing various sensors, capable of producing a virtualized representation of the hand. Hand tracking devices are normally used in the field of Virtual Reality (VR) and Augmented Reality (AR), but can arguably also be used to track the post surgery recovery progress. A well known and relatively inexpensive Hand tracking device is the Leap Motion Device Platform. This is the Tracking device primarily used for this project, although the project architecture allows for the possibility to implement support for other tracking devices.

The essence of the project is to gamify the recovery exercises: the patient should be able to play games through a web interface, controlled by Hand Gestures (for example, spreading the thumb to make a spaceship shoot). The Hand Gestures correspond roughly to recovery exercises that would normally have been done together with a therapist. The therapist should be able to configure gestures for a patient that he or she has to get better at in order to aid in recovery. These gestures must then be used by the patient in order to correctly navigate the game. The gameplay should finally be producing monitoring information for the therapist to review, and thus provide evidence for the recovery progress of the patient.

This work presents a possible Architecure and Minimal Viable Product (MVP) implementation for such a system. The core system components are identified and implemented. Furthermore, advise on extending the system and the recommended next steps are given. Finally, concrete Usage Manuals are provided for both the potential end users and future developers.

Chapter 1

Introduction

1.1 Problem description

In 2016, approximately 60.000 german residents have been hospitalized due to hand or wrist injuries [3]. The initial treatment of such injuries is often followed by a lengthy recovery phase in which ergotherapeutic treatment occurs in order to further aid recovery. As ergo therapy sessions are usually held in one-on-one sessions, this results in a significant time and resource both by the patient and the treating clinic. Additionally, the sessions themselves are often described by patients as boring and unmotivating by their repetitive nature.

Ergo therapists of the Katharinenhospital Stuttgart are currently researching alternative treatment methods that could be an improvement to all three of these fundamental problems. The aim of the research is to introduce various gamification aspects to the recovery sessions. The patients should be enabled to do repetitive parts of the recovery exercises at home by means of successfully executing them while controlling video games. This methodology of executing prevention and rehabilitation measures is an active and well known field of research commonly referred to as Exergames[1]. In a more general sense, games that are designed with a second primary purpose (apart from entertainment) are referred to as serious games [2].

1.2 Requirement Analysis

Outsourcing recovery exercises into a space where no direct therapeutic supervision is available generates a series of challenges that have to be overcome before successfully integrating Exergames in the recovery sessions. In the software development industry, the challenges a system has to solve in order to become useful are called functional requirements. The most notable functional requirements are outlined as follows.

1.2.1 Functional Requirements

Domain Virtualization In order for Exergames to fundamentally function, they require an accurate, real-time virtualized representation of the problem domain. For example, in order to develop Exergames for trating hand injuries, a virtual representation of the hand must be available.

Exercise Classification The most important capability of an Exergame is to correctly classify whether a recovery exercise has been executed. This information can then be used to control the Exergames.

Patient Adaptibility One-on-one therapy sessions in ergo therapy are required because of the huge variety of different hand injuries, each requiring a different set of recovery exercises. Additionally, the recovery exercises themselves have to be adaptable to how far the patient has progressed so far in recovery. For example, if the patient is making progress in recovery, the exercises have to be increased in difficulty in order to remain effective.

Monitorability The ergo therapist has to be able to view monitoring information related to the patients playing activity. Most fundamentally, the ergo therapist should be able to view the number of times and total duration of Exergames played in order to verify if the agreed upon exercise volume has been completed. Additionally, specific information that aid the ergo therapist in assessing the recovery progress of the patient should be available.

Modularization On a technical level, the program logic responsible for classifying if an exercise has been completed should be separated from the game logic. This would pose the advantage of introducing a modular aspect to the system, as both exercise classifiers and games could be exchanged.

1.3 Solution Design

1.3.1 Available Alternatives

"dumb" web platform for visualizing, main work happening in server processes running locally

fully featured web platform, doing everything

GUI Application

1.3.2 Elected Alternative

fully featured web platform, because modern web technologies allow it, GUI Application does not fit the requirements, and separating main work into server thread is, while potentially more performant, both potentially insecure and unnecessarily complex.

1.4 Project Scope

framework for others to build upon. minimum viable product covering as much of the overall required architecture as possible.

Chapter 2

Related Work

Chapter 3

Technologies and Methods

Chapter 4

Framework Implementation

4.1 System Architecture

4.2 Development Pipeline

Webpack 4
    VueJS 2, Vue Router, VueX, inversify Dependency Injection
    Karma Unit Tests
    THREE.js

4.3 Implemented Subsystems

4.3.1 Device Driver Interface

Describe Generalized Device Driver Interface. Point out that adding different devices is possible with this architecture.

4.3.2 Device Facade

Justify for a need of a Facade in Front of the raw Device Driver: Seperation of Concerns and Recording (Mock data) Functionality. Ease of Testing.

4.3.3 Device Debug Interface

Describe Component: Raw Device Logger, Device Status Log, Device Graphical Log

4.3.4 Graphical Hand Logger

THREE.JS, OrbitControls, Smoothing, Prop Configuration

4.3.5 Device Recorder

Record Segments of hand movements in order to aid in development, make classification errors reproducible

4.3.6 Persistence Provider

Describe Abstract Persistence Provider Interface

Describe Concrete Persistence Provider Interface Implementation: IndexedDB

4.3.7 Preprocessing Framework

Justify need for Preprocessing: Lots of useless data coming from the device. Preliminary clean up of data may be relevant for all classifiers

4.3.8 Classification Framework

Describe how Classifiers receive the preprocessed data frame stream, and transform the stream in order to emit another stream of classifications, along with relevant metadata

4.3.9 Game Execution Engine

Describe how Games are receiving the Classification Stream and using that in order to drive the gameplay.

Chapter 5

Recommended Future Works

5.1 Proposed Subsystems

5.1.1 Data Postprocessing Framework

Generic interface that does something with classification data / game data. For example logging it to a remote location, like a backend

5.1.2 Backend Component

auth -> classification data -> backend

5.1.3 Progress Analysis Dashboard

Component that gets patients postprocessed classification / game results, and visualizes progress

auth -> backend -> select patient -> patient view

5.1.4 Messaging Platform

Therapist Requirement. Ability to send messages to / from patients

5.2 Proposed Enhancements to existing Components

5.2.1 Classification Metadata

Anti Cheat (Therapist requirement)

Log Classification Specific relevant Metadata for Therapist Analysis

Chapter 6

Conclusion

Possibility of Project Confirmed, Modern Web is evolved enough to tackle this task. But lots of extensions should be made in order to make the project actually useful

Appendix A

User Manual

A.1 Installing the Hardware Device Driver

A.2 Verifying the Installation Success

A.3 Configuration

A.3.1 Preprocessors

A.3.2 Classificators

A.4 Gameplay

Appendix B

Developer Manual

B.1 Building and Running the Project in Development Mode

B.2 Executing Unit Tests

B.3 Extending the Framework

B.3.1 Adding a Preprocessor

B.3.2 Adding a Classifier

B.3.3 Adding a Game

References

Literature

[1] Erik Guttman. “Exergames: More fun with rehabilitation and exercise through games”. *Rehacare International Magazine* (2018) (cit. on p. 1).

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