

# **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

Georg Grab

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# Acronyms

**NFR** non-functional requirement. 3

# 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.

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 Architecture 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. The work concludes with the assessment that the modern web is mature and performant enough to successfully allow the implementation of the project. Every sub-component, from data preprocessing to playing games can be implemented using web technologies with adequate performance and robustness, without the need for any external dependencies. The Appendix of this work contains both an end-user and developer manual.

# Chapter 1

## Introduction

### 1.1 Problem description

In 2016, approximately 60.000 german residents have been hospitalized due to hand or wrist injuries [5]. 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[3]. In a more general sense, games that are designed with a second primary purpose (apart from entertainment) are referred to as serious games [4].

### 1.2 Project Scope

The scope of this student research project is to design and provide implementations for a software solution acting as an underlying framework on which the Exergames can be executed. The framework should be capable of meeting the determined requirements as outlined in section 1.3 either directly through the provided implementation, or, if some requirements cannot be fulfilled with the reference implementation, by way of easy extensibility. The framework should also contain a user facing component where relevant measurements and game configurations can be made and from which the games are executed. Additionally, the framework should contain various tools that will make it easier for future developers to develop and debug subcomponents.

## 1.3 Requirements Analysis

Outsourcing recovery exercises into a space where no direct therapeutic supervision is available generates a series of challenges that have to be identified and overcome before successfully integrating Exergames in the recovery sessions.

### 1.3.1 Functional Requirements

In a software development context, the challenges a system has to solve in order to become useful to the stakeholders are referred to as functional requirements. The most notable functional requirements are outlined as follows.

#### 1.3.1.1 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 treating hand injuries, a virtual representation of the hand must be available.

#### 1.3.1.2 Exercise Classification

The most important capability of an Exergame is to correctly classify whether a recovery exercise has been executed. In the domain of hand and wrist injury recovery, a recovery exercise may for example be the spreading of the thumb, where the remaining fingers of the hand remain closed. Other examples for recovery exercises have been outlined by [1]. The result of the exercise classification can then be used as a gameplay element in the Exergame. For example, if a thumb spread exercise as described above has been executed well enough, a *Space Invaders-like* Exergame could trigger the space ship to shoot.

#### 1.3.1.3 Patient Adaptability

One-on-one therapy sessions in ergo therapy are required because of the large variety of different hand injuries, each requiring a different set of recovery exercises. Additionally, the classification logic (see 1.3.1.2) for 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 progressing well in recovery, the relevant exercise has to be increased in difficulty in order for the treatment to remain effective.

#### 1.3.1.4 Monitorability

The ergo therapist has to be able to view monitoring information related to the patients playing activity. Most fundamentally, the 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. If the therapist determines that the current exercise has to be adapted in some way, or for exchanging other kinds of information with the patient, such as providing hints



or agreeing on the next physical appointment date, this should be possible through an integrated messaging platform.

#### 1.3.1.5 Gameplay and Frontend

Finally, the system should provide a frontend component, from which the actual games are executed and configured, and where display components relevant for resolving other software requirements can be found.

### 1.3.2 Non-Functional Requirements

In addition to the functional requirements, the following non-functional requirements (NFRs) have to be considered while designing and implementing the system. NFRs are global requirements that are not directly related to function, but refer to the development or operational costs of the system, such as performance, reliability, and maintainability [2].

#### 1.3.2.1 Modularization

On a technical level, the program logic responsible for classifying if an exercise has been completed (see 1.3.1.2) should be separated from the actual Exergames logic (see 1.3.1.5). This would pose the advantage of introducing a modular aspect to the system, as both exercise classifiers and games could be exchanged, both keeping the patients engaged in the platform by allowing them to train their assigned exercise using a variety of games, and greatly simplifying the work of future developers, as they will be enabled to develop games for the platform without any prior knowledge of exercise classification, and vice versa.

#### 1.3.2.2 Performance

Performance is a critical NFR for the system. All data coming from the device providing the relevant domain virtualization has to be ingested, preprocessed, and classified in real time. If this is not the case, the patient will experience a significant lag between the performed exercise and the feedback of the Exergames, quickly resulting in frustration. Additionally, the execution of the Exergames themselves should be performant enough so that the gameplay experience isn't negatively obstructed.

#### 1.3.2.3 Ease of deployment

The system should ultimately be primarily executed on a patient provided device. As such, deployment of the application should be easy, and robust with respect to a multitude of possible, previously unknown target environments.

#### 1.3.2.4 Extensibility

As the system is acting primarily as an underlying framework on which other developers should build upon in the future, it should be written in a way that allows for easy extensibility. It should especially be written in a computer programming language that

is well known to the potential target developer audience, so minimum prior knowledge is required before starting development with the project. Additionally, the framework should be future proof: it should be simple to exchange subcomponents with more modern equivalents in the future. For example, it should be simple to add support for more modern hardware devices providing domain virtualization, or more modern graphics libraries for developing the Exergames in the future.

## 1.4 Solution Design

### 1.4.1 Available Alternatives

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

- fully featured web platform, doing everything
- GUI Application

### 1.4.2 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.

## 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: Separation 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 Classifiers

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

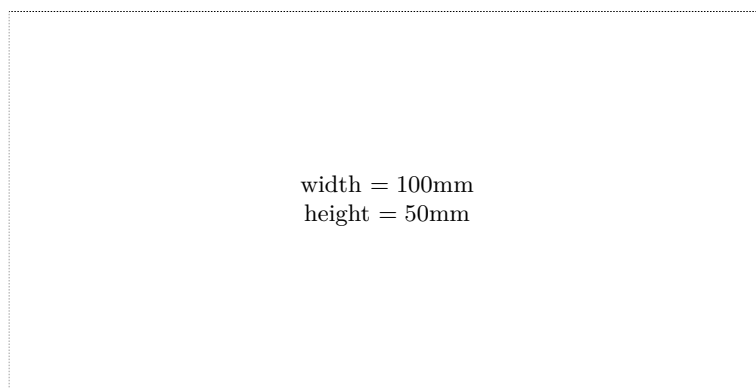
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