UNIVERSITY OF CASTILLA-LA MANCHA
ESCUELA SUPERIOR DE INFORMÁTICA

COMPUTER SCIENCE DEGREE

FINAL DEGREE PROJECT

Aglaea
Stroke remote rehabilitation project

Pedro Manuel Gómez-Portillo López

July, 2017

AGLAEA
STROKE REMOTE REHABILITATION PROJECT

UNIVERSITY OF CASTILLA-LA MANCHA

ESCUELA SUPERIOR DE INFORMÁTICA

Technologies and Information Systems Department

SPECIFIC TECHNOLOGY OF
SOFTWARE ENGINEERING

FINAL DEGREE PROJECT

Aglaea
Stroke remote rehabilitation project

Author: Pedro Manuel Gómez-Portillo López

Supervisor: Dr. D. Carlos González Morcillo

Supervisor: D. Santiago Sánchez Sobrino

July, 2017

Pedro Manuel Gómez-Portillo López

Ciudad Real – Spain

E-mail: PedroManuel.GomezPortillo@gmail.com
Web site: `https://github.com/gomezportillo`

Abstract

Stroke is the result of stopping blood flow to the brain. It is usually caused by a blood clot that blocks a cerebral artery and its effects range from physical to cognitive problems of different severity, being death the worst-case scenario.

This pathology is quite common and does not discriminate by race or sex. Thus, countries all over the world struggle to reduce it and help those who suffer it and have to live with its effects.

The present Final Degree Project comes as a result of the development of *Aglaea*, the prototype of a tool developed by the spin-off from the University of Castilla-La Mancha Furious Koalas Interactive for the British company Kyenom Limited in order to help stroke patients in their rehabilitation making use of paradigms such as Computer Vision, Mixed Reality and Serious Gamification.

To this end, techniques and devices from the Motion Tracking area are used to capture the rehabilitation exercises performed by a patient. Then, *Aglaea* stores this exercises in a standardised file format and compares them using a temporal sequences analysis algorithm so as to evaluate the similarity degree between two exercises.

In addition, this project supports two different roles, clinician and patient, and will allow users to store both video and motion capture information from the exercises they perform, allowing them to reproduce it.

Aglaea is presented as a tool capable of analysing the rehabilitation exercises performed by a patient at home and comparing them with a reference movement or gold standard, informing both the patient and their clinician about the obtained results.

Resumen

Los derrames cerebrales o ataques cerebrovasculares son efecto de la detención del flujo sanguíneo al cerebro. Normalmente son causados por un coágulo sanguíneo que bloquea una arteria cerebral y sus efectos varían desde problemas físicos a cognitivos de diferente gravedad, y en el peor de los casos la muerte.

Esta patología es bastante común y no discrimina por raza o sexo, por lo que países de todo el mundo luchan por reducirla y ayudar a los que la sufren y tienen que vivir con sus efectos.

El presente Trabajo fin de Carrera surge como resultado del desarrollo de *Aglaea*, el prototipo de una herramienta desarrollada por la spin-off de la Universidad de Castilla-La Mancha, Furious Koalas Interactive, para la compañía británica Kyenom Limited con el objetivo de ayudar a pacientes de derrame cerebral en su rehabilitación haciendo uso de paradigmas como la Visión por Computador, la Realidad Mixta y la Gamificación.

Para ello, utiliza técnicas y dispositivos del área de Motion Tracking para capturar los ejercicios de rehabilitación que los usuarios realicen, los almacena en un formato estandarizado y los compara haciendo uso de un algoritmo de análisis de secuencias temporales con el fin de poder evaluar el grado de similitud de dos ejercicios.

Además, soporta dos roles diferentes, médico y paciente, y dará soporte para que sus usuarios almacenen tanto el vídeo como la información de captura de movimiento de los ejercicios que realicen, permitiendo que sean reproducidos desde dentro de la aplicación.

Aglaea se presenta como una herramienta capaz de analizar los movimientos de los ejercicios de rehabilitación realizados por un un paciente en su casa y compararlos con movimientos de referencia correctos, informando tanto al paciente como a su médico de los resultados obtenidos.

A mis padres, por tantos tuppers y
tantas madrugadas acompañándome a Ciudad Real.

Contents

List of Tables

List of Figures

List of Listings

List of Acronyms

BVH	Biovision Hierarchy
DTW	Dynamic Time Warping
FDP	Final Degree Project
FPS	Frames Per Second
FTP	File Transfer Protocol
GPU	Graphical Processing Unit
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HMM	Hidden Markov Model
HTTP	Hypertext Transfer Protocol
IDE	Integrated Development Environment
IP	Internet Protocol
JPEG	Joint Photographic Experts Group
JSON	JavaScript Object Notation
KISS	Keep it simple, stupid!
MO-CAP	Motion Capture
MVC	Model View Controller
RUP	Rational Unified Process
SDK	Software Development Kit
TCP	Transmission Control Protocol
TFG	Trabajo Fin de Grado
UDP	User Datagram Protocol
UPD	Unified Process Development

Chapter 1

Introduction

THE Information Age has opened the doors to automation in incredible ways. It has been possible for computers to analysed and perform **repetitive tasks** in a matter of seconds that previously had to be performed by people. Furthermore, computers are usually more accurate than people.

The use of this automation is very common and the number of companies that dedicate personnel to perform monotonous tasks susceptible to such automation is quickly decreasing. Instead of that, these companies develop systems that achieve it in a more quick, economical and effective way. These systems tend to be easily replicable and to allow high parallelism so that only a fraction of the initial staff is needed to monitor such system.

Thanks to the success of these systems and the advances in automation techniques, they are being deployed in areas that have nothing to do with factory industrialisation, including the area of physical rehabilitation.

1.1 Rehabilitation and gamification

Physical rehabilitation is part of the treatment a person must take to recover the state or part of the state lost due to an accident or illness. According to the World Health Organisation[1], rehabilitation is a *process aimed at recovering and maintaining an optimal physical, sensory, intellectual, psychological and social state*. In addition, they add, *rehabilitation provides disabled people with the tools they need to attain independence and self-determination*.

Therefore, it is easy to understand the importance of this process and the necessary it can be for those whose disorders have generated more serious sequels.

However, rehabilitation can be a slow and frustrating treatment for several reasons; usually entails a significant physical effort for the patient and they may not accomplish the expected

[1] `http://www.who.int/topics/rehabilitation/`

therapeutic results. Also, there are times when the patient has to overcome psychological problems such as learned helplessness [Mar04], where they genuinely think they cannot perform the exercises their doctor has proposed.

In an attempt to assist patients in their rehabilitation process, new techniques are being applied to this area. Among these techniques, the most famous one is the **gamification**.

Gamification aims to incorporate mechanisms obtained from games to a real scenario where it requires a certain effort on the people side, **motivating** people in order them to take the initiative.

1.2 Context

This section will address the context in which this FDP has been framed and that has conditioned its development. It will begin by introducing the two companies involved in the project to continue describing how the need for the development of *Aglaea* arose and what its expectations are.

Kyenom Limited[2] is a company located in Leeds, England, which in its own words is dedicated to providing intelligent technologies that improve the quality of life of people by providing hardware and software solutions to monitor and understand activities taking place in a home.

Figure 1.1: Kyenom logo

On the other hand, **Furious Koalas Interactive**[3] is a young spin-off from the University of Castilla-La Mancha with more than fifteen years of experience in R&D in the context of the design, development and deployment of interactive solutions that provides services in areas such as Gamification and Computer Vision.

Kyenom needed a **prototype** to show the potential of a tool to supervise remote rehabilitation focused on stroke patients. This prototype should be complete enough to be presented at investor meetings and allow this company to obtain sufficient funding to be able to develop a project with full functionality.

At the end of 2016 Kyenom contacted Furious Koalas Interactive to offer them the contract for the development of this prototype, since it fits perfectly with the services offered by

[2] http://www.kyenom.com/

[3] https://www.furiouskoalas.com/

Figure 1.2: Furious Koalas logo

the second company. This prototype, in addition to meeting the functional requirements, should be **scalable and modular** enough to allow to easily continue its development in a near future.

So in this context *Aglaea* was born, a project that pretends to show the potential offered by remote rehabilitation.

1.3 Environment

The execution environment of *Aglaea* consists of a **Microsoft Kinect 360** camera which was selected after an appropriate market study (see chapter 6), a **software system**, and a **personal computer**, so that both patient and clinician can use their own computer without having to acquire a more powerful one.

This camera, which will be discussed in depth in further chapters, in addition to generating colour and depth images offers a motion tracking system that will be used to detect the movements performed by the users and a voice recognition system that allows controlling part of the application by using voice commands.

The software system is light enough to be deployed on a personal computer and complete enough to meet the requirements imposed by Kyenom.

In addition, the application supports **two interaction roles**. On the one hand, the clinician, who can register new rehabilitation exercises, assign them to patients and consult their results. On the other hand it is the role of patient, who can perform assigned exercises and obtain the results in in real time.

Figure 1.3 reflects a typical execution scenario with a patient. As it can be seen, the patient is sitting in front of the camera performing exercises and getting feedback on the computer screen.

1.4 Socio-economic impact

This project will have associated both social and economic impacts. Given its main objective, *Aglaea* pursuits to automate the supervision of rehabilitation exercises, so it is expected that the price of rehabilitation therapies using this tool decrease and its number of users increase for several reasons.

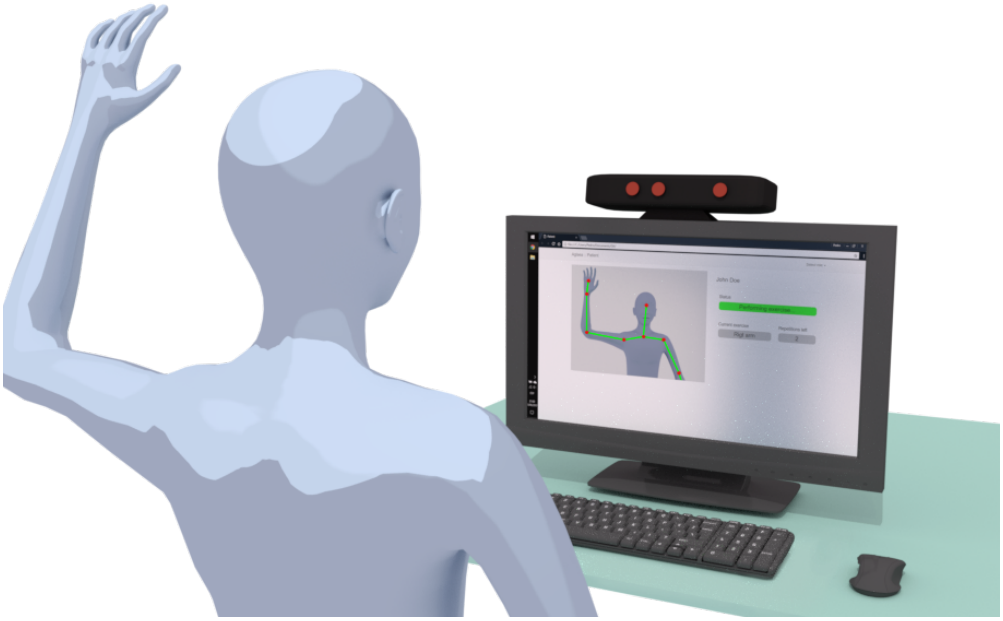

Figure 1.3: Environment diagram

- A single clinician will be able to **monitor a larger number of patients** in parallel, as instead of having to spend a large time on each patient being physically with them along the sessions, the clinician will be able to directly consult the results that a patient obtains.
- In addition, people who could not easily access to rehab sessions due to **geographical reasons** may find it very interesting to do so from home.
- Likewise, patients will not need to travel so frequently to their clinician's office, avoiding in this way to drive, use public transport or rely on someone else to accompany them.
- On the other hand, this system could be installed in **hospitals** to assist clinicians in their task, helping to reduce the congestion of waiting rooms.
- In addition, a gamification-based approach allows repetitive rehabilitation exercises not to be so mechanical for patients.

1.5 Project proposal

The development of this FDP has meant the deployment of a displaying system with Real Time graphics by means of different modules that must work synchronously and concurrently to offer a correct result. In addition, it has to be adapted to personal computers, thus avoiding latency and performance issues.

Figure 1.4 the overview of the modules and subsystems that form the application and how they relate and communicate with each other. These modules will be widely described in chapter 6.

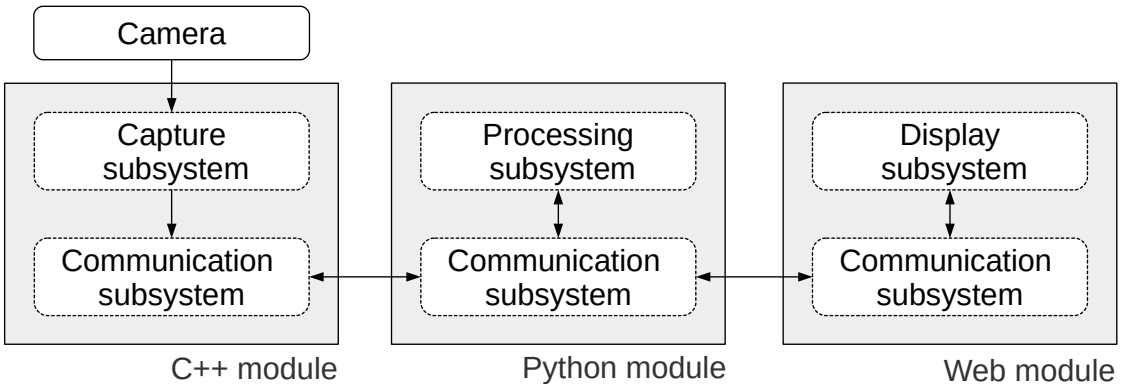

Figure 1.4: Subsystems in *Aglaea*

- **Capture subsystem.** This subsystem is responsible for retrieving images and information regarding skeleton tracking and voice commands from the camera through its SDK.
- **Processing subsystem.** This subsystem is responsible for working with data obtained from the camera, as well as data generated by patients and clinicians.
- **Communication subsystem.** The development of this project has lead to work with a large amount of generated data, which has meant to have intercommunicated correctly and fluidly the system modules. In total, the system has three different communication subsystems, one for each module.
- **Display subsystem.** This module is devoted to the interaction of users with the system. It will display images, videos and information related to tracking movements and voice commands in addition to other data in patient and doctor browsers.

Therefore, the development of this project involves an effort for integrating different technologies from very different Areas of Knowledge, such as motion capture and temporal sequences analysis, and synchronise them in order to achieve the expected results.

Similarly, several threads will work concurrently to send the data through the system and take it to those modules that need it while working with the lowest possible latency.

1.6 Document structure

This document has been structured following the FDP normative from the Escuela Superior de Informática of the University of Castilla-La Mancha through the following chapters.

Chapter 3. Objectives

This chapter describes the objectives and sub-objectives for the *Aglaea* project.

Chapter 4. State of the Art

This chapter presents a presentation of the current status of the areas covered in this FDP, collecting and exposing relevant information related to MO-CAP, Mixed Reality and Gamification, among other areas.

Chapter 5. Methodology

This chapter justifies and explains the working methodology chosen to be applied during the development of this project, as well as the hardware and software resources used.

Chapter 6. Architecture

This chapter details the design and implementation of this project and discusses the relevant problems that have arisen throughout the development and the solutions that have been given to them.

Chapter 7. Results

This chapter presents the results of the project, as well as the efforts devoted to improve it, the costs derived from its development and a small statistical study about the source code of the project.

Chapter 9. Conclusiones

This chapter presents the objectives achieved and propose future working lines that could be applied in a future development.