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PhysioTelepy (2021.16)

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1 High-Level Description of Project

1.1 Motivation

Important demographic changes, including an aging population, increased life expectancy and a greater prevalence of chronic conditions are putting increased strain on health care systems worldwide [1]. The demand for physical therapy has outpaced supply in the US and this gap is constantly increasing, which drives the price up for patients [2].

Home-based physiotherapy can become an essential part of any physical therapy program. Telerehabilitation is defined as the provision of rehabilitation services at a distance using information and communication technologies. Consequently, in-home telehealth, including telerehabilitation programs, are becoming increasingly common as an alternative mode of service delivery [2].

1.2 Project Objective

The objective of this project is to design an interactive computer vision system that leverages motion data captured via a depth camera to analyze therapeutic exercises used in hand therapy, musculoskeletal dysfunction, and sports-related injuries. The patient's actions will be tracked and analyzed, in real-time, against a reference model doing the exercise to provide the patient with visual and quantitative feedback.

1.3 Block Diagram

The proposed solution is to use a depth camera capable of full-body skeletal tracking in amalgamation with a skeleton tracking middleware that offers an application programming interface (API). This API retrieves timestamped coordinates from the depth camera which will then be used to visualize the skeletal joints/structure of the user, via the user skeleton visualizer. This skeletal model is then fed into both the physiotherapist program and the patient program. The physiotherapist program, in conjunction with the exercise model creator, will allow the physiotherapist to create and store various exercise models to a database. The patient program will allow the patient to select the prescribed exercises from the database, which will then be mapped to a reference model. The reference model, along with the user model, will be analyzed in real-time to provide the patient with quantitative exercise feedback. Figure 1 shows the architecture of the solution.

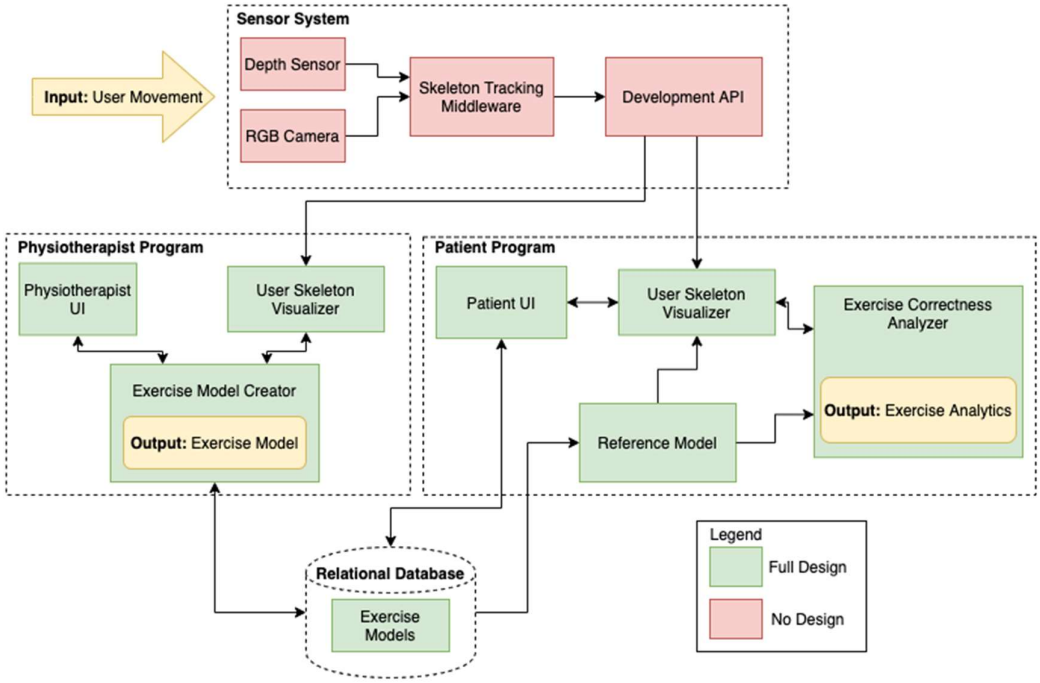

Figure 1: Block diagram

Table 1 below provides a brief description of the purpose of each subsystem and whether they are to be designed or selected.

Table 1: Subsystems

Subsystem	**Description**	**Designed or Selected**
Depth Sensor	Acquires multi-point timestamped distance information.	Selected
RGB Camera	Obtains conventional image frames for depth info to be layered onto.	Selected
Skeleton Tracking Middleware	Processes sensor data to track the skeleton.	Selected
Development API	API for communication with the 3D sensors.	Selected
User Skeleton Visualizer	Joint-wise analysis to visualize/map user joints to a virtual skeleton.	Designed

Physiotherapist UI	Displays an interface for the physiotherapist to view, configure, and add exercise models to the database.	Designed
Patient UI	Displays an interface for the patient to select an exercise to work on.	Designed
Exercise Model Creator	Facilitates the creation of exercise models to be prescribed to the patient.	Designed
Reference Model	Selected exercise model to be performed by the patient.	Designed
Exercise Correctness Analyzer	Provides visual and quantitative feedback to the patient regarding their exercise performance.	Designed
Exercise Models Storage	Stores the exercise models created by the physiotherapist.	Designed

2 Project Specifications

The project specifications are classified as either functional or non-functional. The functional specifications describe what the system is supposed to do. These are also called features. The non-functional specifications describe what the system is supposed to be. These are the constraints under which the system should work. Each specification is further sub-categorized as essential or non-essential (rated based on importance to the overall design). Essential specifications are those that must be met for the design to be satisfactory. Non-essential specifications make the final product more than satisfactory when they are met.

2.1 Functional Specifications (Essential & Non-Essential)

Table 2 below outlines ten essential functional specifications for the PhysioTelepy solution to be satisfactory. Table 3 follows listing four non-essential functional specifications.

Table 2: Essential functional specifications

Specification	Component	Description
Transfer of sensor data	The sensor system, skeleton visualizers	The sensor system must be able to seamlessly send data to the skeleton visualizers
Sensor range	Sensor System	The distance between the player and the sensor should be a minimum of 1.5 meters
Noise	Skeleton visualizer	Visualizer must be able to minimize avatar jitter caused by tracker noise.
Accuracy	Sensor system	Ensure accurate gesture recognition via sensor calibration to a world reference system.
Latency	The sensor system, Skeleton visualizer	With a single skeleton to track, the program must maintain a mean latency of less than 200ms.
Resolution	Sensor system	Ensure lateral resolution agrees with the depth sensor specification (through averaging or interpolation across the user skeleton)
Tracking	Sensor system	Sensor subsystem must be able to accurately track user trajectories, in real-time, via a full-body skeleton (minimum 18 joints)
User visibility	The sensor system, Patient/Physiotherapy program	Ensure the user's entire body is visible and within the frame dimensions (sensor dependent)

Analyzer correctness	Correctness Analyzer	The analysis must be able to address problems such as inaccurate movements, improper speed, and range of motion.
Data accessibility	Patient-interface, Exercise Model Creator	The components must be able to, faultlessly, access the database for exercise model queries.
Data storage	Database	The database must be able to read, write and store exercise models at any given time (no data corruption)

Table 3: Non-essential functional specifications

Specification	Component	Description
Environmental lighting	Sensor system	It is recommended that the area does not have direct sunlight in the field of view of the sensor
Idle notification	Patient/Physiotherapist Program	The interface must be able to detect an idle/inactive user and notify them.
Background occlusion	Sensor system	It is recommended that there be minimal background obstacle overlapping, as this may affect tracking.

2.2 Non-functional Specifications (Essential & Non-Essential)

The five essential non-functional specifications describing essential characteristics of the PhysioTelepy solution are described in Table 4, while Table 5 lists the three non-essential non-functional specifications.

Table 4: Essential non-functional specifications

Specification	Component	Description

Cross-platform compatibility	Overall	PhysioTelepy must be able to integrate with popular operating systems (Windows, Linux, etc.).
Portability (size)	Sensor system	The size of the sensor must not exceed 20 cm x 20 cm x 20 cm.
Fault Tolerance	Overall system	Ensure the system responds gracefully to failures at runtime (depth data error, calibration errors, etc.).
Usability	Physiotherapist UI, patient UI	The system must have an intuitive and easy-to-use interface.

Table 5: Non-essential non-functional specifications

Specification	Component	Description
Setup-time	Overall system	The user must be able to connect the sensor and initiate a session in under 5 minutes.
System cost	Overall system	The cost of the overall system should be less than 600 CAD.
Sensor Mass	Sensor system	The total physical sensor system mass must be under 1kg.

3 Risk Assessment

Table 6 below outlines the risks to the completion of this project, their impact, probability, as well as mitigation strategies.

Table 6. Risk assessment

Potential Risk	Mitigation
Acquisition of sensor parts: The hardware parts are to be selected from different vendors with varying delivery times. Supply chains across the world are also delayed due to the	In 4A, all project members will focus on researching vendors with the lowest delivery times and guarantees of delivery to Canada. A priority will be placed on

COVID-19 pandemic and this will affect how soon the parts can be acquired. Impact: High Probability: High	vendors that have suitable stocks available within North America.
Location of group members: Project members are in different areas across the world, including multiple different time zones. Due to the pandemic, it is very difficult to meet in a single area so direct in-person collaboration will likely not be possible**,** and this may affect the efficiency at which the work is done. Impact: Medium Probability: High	Virtual meetings will be scheduled biweekly at times that are suitable for everybody and strict deadlines (in addition to 498A deliverable deadlines) will be set so that all milestones are achieved on time. Furthermore, work will be modularized into tasks that can be completed individually and assigned to project members as seen fit.
Technical competency: The design for this project will require good knowledge of sensors, video processing, and data compression algorithms. These are all areas that the project members have not worked with extensively in the past. This could lead to low quality-work and in the worst case not being able to complete the project. Impact: Medium Probability: Low	In 4A, all project members will be required to ramp up on unfamiliar topics, and meetings will be scheduled with the project consultant when necessary, to get professional input and guidance.

References

[1] “The Aging Population: The Increasing Effects on Health Care,” Pharmacy Times. [Online]. Available: https://www.pharmacytimes.com/publications/issue/2016/january2016/the-aging-population-the-increasing-effects-on-health-care. [Accessed: 09-Jun-2020].

[2] G. Henderson, “Virtual Physical Therapy Could Help Fill Gaps in Treating All Too Real Pain,” Scientific American, 21-Aug-2019. [Online]. Available: https://www.scientificamerican.com/article/virtual-physical-therapy-could-help-fill-gaps-in-treating-all-too-real-pain/. [Accessed: 09-Jun-2020].

ECE498A: Marking Sheet for Project Specifications and Risk Identification Document			
Group number: 2021. 16			
			Marks
Presentation and layout	Follows required formatting, layout, structure, page limit:	up to 2 marks	**/ 06**
	Correct spelling, grammar, captioning, referencing, units:	up to 2 marks	
	Readability, professionalism of language, flow, graphics:	up to 2 marks	
Block diagram	Includes well-labelled inputs, outputs, subsystems; graphics are crisp with a good layout and easy to follow:	up to 2 marks	**/ 12**
	Clearly indicates which subsystems will be designed and which will not be designed:	up to 3 marks	
	Overall structure is clearly explained; the block diagram layout is logical with a reasonable level of granularity:	up to 7 marks	
Specifications	Specs are reasonably categorized as functional/ non-functional and essential/non-essential:	up to 4 marks	**/ 26**
	Each specification is verifiable, open-ended, & appropriate:	up to 12 marks	
	Set of specifications is complete:	up to 5 marks	
	The specifications are at a good level of challenge for a capstone engineering project:	up to 5 marks	
Risk assessment	Includes 3 situations that could hinder project completion:	up to 2 marks	**/06**
	Nature, potential impact, and probability of each risk are included and seem reasonable:	up to 2 marks	
	Good suggestions for what can be done to reduce likelihood of and to reduce damage from high impact/probability risks:	up to 2 marks	
	Deduction for late submission: (-10 marks if miss deadline, and -10 marks off for every additional 24 hours)		
	Final Mark:		**/ 50**
Additional comments from course instructor: