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| Smart Leg Physical Therapy  Using SensorTile  Project Report  DGMD E-14 | | |  | |
| Physical therapy may be underestimated due to several reasons with catastrophic consequences to patients. This project brings *Intelligent Help* available 24/7 for faster and friendly recovery.  By Alvaro Ramírez, Harvard Extension School, December 2021 | | |  | |
| Motivation Alvaro’s best friend is brilliant ex-NASA physicist, successful entrepreneur and, in his youth, a renowned Peruvian rock star that, due to a second brain surgery to extract a cancerous tumor, ended on a wheelchair with the right side of his body paralized. Even though he is very intelligent, the lack of movility pushed him to a deep depression. His condition requires a lot of physical therapy but having a therapist all those hours at home is costly and logistically complex. This is where a better solution is needed to complete the work of the physical therapist, something like a friendly system that tells him if the exercise is done correctly or not and that do not complain if the same exercise must be repeated dozens of times, or at any time of day or night. Project Classification This project fits into the following categories:   * Wearable Inertial Sensor Application * Physical activity Monitoring * Monitoring of Physical and Physiological Changes in Daily Life * Data visualization and data analysis * Real time data visualization (future implementation) * Gesture recognition * Human Activity Recognition * Pose estimation and recognition * Physical rehabilitation * Artificial Intelligence Application * General event detection application | | | |  |
|  | *The main project goal is to “improve life quality by giving back physical mobility***”** |  | |  |
| Description The project explores how wearable technology can transform the rehabilitation of people with physical disabilities by providing feedback that could help improve the effectiveness of therapy and improve recovery time.  Physical therapy is a common treatment for individuals with various physical disabilities and injuries. It can improve muscle strength and mobility, decrease pain levels, relieve stress on joints and tissues in the body, restore independence and improve quality of life. A typical physical therapy session includes a range of activities that target the damaged or impaired muscles and joints. The physical therapist specifies a set of activities to engage in during each therapy session and coaches on the proper form or posture required. Technology The first approach for this project was to use three SensorTiles as shown in figure 1:    Figure 1  The purpose of having three sensors was to create a triangle with the spatial position that combined, would tell us if the leg was flexed and how many degrees. In this approach, the distances that matter are the distances among the three sensors, which play perfectly for any calculation. But this approach has several challenges, where the most critical is reading the three sensors to process the data as one unit. After a lot of research and trials with three SensorTiles as well as with three SensorTile.boxes and a few algorithmic tricks to match the samples, I got the readings in the computer ready to be processed by the neural network.  However, analyzing in more detail the purpose of the project, I found that only one sensor at the extreme of the limb, in this case the ankle, would provide enough information to determine if the leg went up or down, or if the knee was flexed or extended. It can even tell us if the leg was twisted. This finding simplified the code and the entire solution, bringing to a patient not only ease of use but also a better price. For these reasons, the final design was defined to have only one sensor in the ankle, as shown in figure 2:    Figure 2 Use Case The use case for this project is based on a patient that fully or partially lost the mobility of a leg. SensorTile wearable device is used to take advantage of its accelerometer, magnetometer, and gyroscope, although other features such as the microphone could be used in future versions. With these sensors, the system measures movements and changes in posture while storing data captured and providing feedback. | | | |  |
| For leg exercises, the SensorTile must be located at the end of the limb to obtain the maximum change in acceleration and position. | | | |  |
| To obtain the position of the limb, the system uses a SensorTile attached to the patient’s ankle as shown in figure 3 below:    Figure 3 Objectives The objectives of the project are mainly oriented to the physical and mental health of the patient. These are the main objectives:   1. Improve life quality by bringing back physical mobility 2. Enhance the effectiveness of physical therapy process 3. Enable physical therapy to be properly and safely performed without physical therapist presence 4. Cost effective solution  Tools Required The equipment used for development is:   * SensorTile Development Kit STEVAL-STLKT01V1 * STM32 Nucleo-64 Development Board NUCLEO-F303RE * USB-C 3.1 10-Port Hub with Power Adapter - 36W Powered (12V/3A) * USB 2.0 A-Male to Micro-B Cable * USB 2.0 A-Male to Mini-B Cable * Laptop computer * iPhone   The software used in this project includes:   * STM32CubeIDE * VS Code * Jupyter Notebook * Bleak * Edge Impulse * Tableau * Excel with VBA  Proof of Concept or Minimum Value Product The initial proof of concept was defined to recognize a set of physical therapy leg movement activities and provide real time feedback on proper form by placing three SensorTiles on the patient leg to track movement, as shown in figure 1.  These sensors are intended to be placed one on the ankle, one on the knee, and one on the hip, sending accelerometer and gyroscope data to a Raspberry Pi over BLE.  Under this architecture, the Raspberry Pi fuses or combines the samples of the three SensorTiles (one sample of each SensorTile at a time), to classify the activity and provide visual feedback.  The system processes the data using a trained classifier to identify if proper physical therapy motion was performed.  But the evolution of the project and the research performed suggested that there is a more efficient way as mentioned in section Description/Technology. Going through a huge change in the project, the number of SensorTiles was reduced from three to one, magnetometer data was added and, as listed in Tools Required, a Windows computer was used instead of a Raspberry Pi. The specific reasons for these changes were:    the new proof of concept utterance is as follows:  Recognize a set of physical therapy leg movement activities and provide feedback on proper form by placing a SensorTile on the patient ankle to track movement, as shown in figure 3.  This sensor will send accelerometer, magnetometer, and gyroscope data to a Windows computer over BLE.  Under this architecture, the system processes the data using an unsupervised neural network for anomaly detection to identify if proper physical therapy motion was performed. Final Project deliverable The solution will include a package with the following components:   * Three SensorTiles programmed to obtain the data described in XXX * A Raspberry Pi that controls the sensors (it would be great if we could replace this with the phone) * The software described in XXX to process the data * The software described in XXX to interact with the user  Workplan  |  |  |  | | --- | --- | --- | | Week | End Date | Goal | | 1 | October 12 | * Additional hardware required ordered * Software required identified * Project proposal ready | | 2 | October 19 | * Data collecting software for one sensor developed * Data collecting software for one sensor tested * User interface software designed * Physical implementation designed | | 3 | October 26 | * User interface software development started * Raspberry setup to control three sensors completed * Statistics to be applied defined | | 4 | November 2 | * Tests with three sensors started * Initial data collection started * Statistics preliminary analyses performed | | 5 | November 9 | * Training and testing data for machine learning model collected * Machine learning model developed * Machine learning model tested * Statistics adjusted | | 6 | November 16 | * Machine learning model trained * Machine learning model deployed * User interface software development completed | | 7 | November 23 | * Integration testing * Final adjustments to statistics implemented * Final adjustments to machine learning model implemented * Final adjustments to user interface software implemented * Final adjustments to physical implementation implemented | | 8 | December 7 | * Presentation development * Presentation ready | | | | |  |



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