# Medical Augmented Reality

1 - Goal

Even before COVID-19, telemedicine was already a rapidly growing medical domain. It reduces the amount of resources hospitals need to dedicate to patients (beds, waiting rooms, examination rooms) and reduces the burden on the patient who can stay at home with their condition. With the introduction of the camera and microphone also come new opportunities for innovation on automation, machine learning and artificial intelligence. The following describes one such innovation my colleagues and I explored at Memorial Sloan Kettering Cancer Center. Specifically, we were interested how useful augmented reality (AR) and computer vision were in a mobility assessment setting.

## 2 - Data

After major surgery to the legs, pelvis, or torso, it is not uncommon for patients to suffer a temporary loss or reduction in mobility. It is important for the patient to rehabilitate through physical exercises, and it is important for the clinician guiding this rehabilitation to have a good sense of any progress or setbacks the patient might experience. In a traditional setting, the patient would come to one of the outpatient treatment centers for a mobility assessment through a variety of tests. One very common test of mobility is the sit-to-stand test. The patient is asked to sit upright on a chair, arms cross over the chest, and stand up, and sit down again, and repeat this process for 30 seconds. The number of full sit-to-stands is a useful number of the clinician to track the progress of the patient over time, through multiple visits. In addition, the clinician can observe the patients movement and determine what precisely is causing the mobility to be impaired. For example, the patient might put much weight on foot, rising asymmetrically, to unburden the other perhaps painful leg. Or the patient might show tremors, indicative perhaps of an overall loss in muscle tone and strength.

Through a telemedicine visit all of these things are still possible, but with some caveats. First and foremost, the environment in which the patient is performing the test is poorly controlled, at least from the clinicians point of view. Viewing a patient perform a sit-to-stand test through a webcam is perhaps the biggest bottleneck. In a hospital setting, the clinician would be able to view the patient from multiple angles to better examine any issue in mobility. In a telemedicine setting, the patient is on screen and the webcam allows the clinician only a single point of view.

## 3 - Technology

My team and I therefore build a mobile application using augmented reality and computer vision to automatically track the patient during the sit-to-stand and overlay this information on top of the video feed. Specifically, we used posture-recognition machine learning algorithms (IOS Vision toolbox) that track the location of several key body landmarks, mostly joints. This is similar to facial recognition where key facial features (eyes, nose, mouth) are being detected and tracked. Once detected in the image, the algorithm convert them into points in 3d space, creating a skeleton model. In addition, the landmarks and their connections can be overlayed on the video feed, increasing the information available to the clinician when viewing the feed. The resulting data (both the absolute and relative landmark positions over time) can be used to automatically count the number of completed sit-to-stands. However, more importantly, it allows the exercise to be a) replayed and b) replayed from any angle deemed informative. The skeleton model can be seen as it displaced from the side, whereas the feed itself was only ever strictly from the front. Finally, by analyzing the relative positions over time, different medically relevant metrics can be computed. For example, how much tremor was observed. Or whether the patient performed the exercise asymmetrically.

## 4 - Analysis

I analyzed the resulting data mostly by first transforming it into the time / frequency domain using the Fast Fourier Transform. The algorithms are not 100% accurate and people differ in size and shape. In addition, the camera angle is likely to vary between sessions, and definitely between different patients. All of this makes analysis of the data in the space/time domain, even when considered in relative terms, extremely hard and cumbersome. Converting the data into the frequency domain removes a lot of the ambiguity, leaving the dominant frequency and phase of each landmark. Based on conversations with the rehabilitation staff, I created three metrics that we deemed important to assess progress or the need for possible medical intervention. First, outside of any medical relevance, I created a metric that measured the amount of noise in the measurement. Noise was measured as the ratio between the main component (the frequency at which the patient was performing the sit-to-stands) and the average across all other frequences up to the Nquist limit. The second metric was left-right assymetry. I defined left-right assymetry as the difference between the mean phase of the left landmarks and the mean phase of the right landmarks, divided by the the maximum phase shift of 180 degrees. The bigger the difference between the phases on each side, the more they move out of phase in space and time, for example by lifting the left side of the body consistently before the right side of the body. Finally, I computed a tremor metric. This metric was similar to the noise metric, with the difference being that it compared the main component with a specifc range of other frequencies, frequencies that the clinicians indicated were the once usually observed in patient tremor. I tested these metrics on a number of my colleagues who would simulate these three scenarios, in addition to performing the sit-to-stand exercise in a normal way.

5 - Visualization

Below I render the detected skeletal positions of 4 example exercsises, using data recorded from using our AR application on my colleaguges.

5 - Impact

Visualized in this way, with the metrics added, a wealth of data becomes available to the clinician that otherwise would not have been available during a telemedicine visit. In addition, the metrics can be computed automatically and stored for comparison with past and future measured, giving the clinical staff a holostic and quantified overview of the progress made by the patient in regaining mobility after surgery.

6 - Technologies Used

XCode

IOS

ARKit

Python

Scipy