Identifying Exercise Correctness for Home-Based Rehabilitation

James Tolbert, II

1. Introduction

Rehabilitation patients perform a variety of exercises to help them recover their range of movement and strength after injury or surgery. Patients often perform the rehabilitation exercises correctly during training with their physical therapist but fail to do the exercises correctly or to perform a sufficient number of repetitions when they return home. This research project investigates an approach for identifying whether a patient is performing their exercise correctly at home. We focus on knee rehabilitation exercises with the goal of expanding this project to other exercises. Our research is in its initial stage and this paper describes current strategy, our planned implementation, and expected goals from this research project. This project is a collaboration with Judy Matthews (Nursing, Pitt), Reid Simmons (Robotics, CMU), and Kelly Fitzgerald (Physical Therapy, Pitt).

2. Related work

There has been a variety of research in using motion capture data for physical rehabilitation. [1] discussed using accelerometers to study physical rehabilitation. They extracted sampled acceleration data from a PDA, which was configured for patient monitoring. When the patient passed a certain threshold set by their therapist the system warned the monitored patient. [2] described an feedback system approach for arm rehabilitation. Their feedback system combines multiple sources of patient feedback, which they called a biofeedback system. This system focused on neurological impairments. [2] used domain knowledge to break the motion into features which they then extracted to determine correctness. These features included acceleration representing different points in the motion and consistency in the motion's speed. [4] and [5] explain a motion tracking system that tracks arm motion using a color tracking algorithm. Their goal was to have an inexpensive tool for home-based rehabilitation. Although they had a way to capture motion, they did not implement a way to compare the motion to determine whether a patient was rehabbing correctly. We planned to build on previous research by applying machine learning techniques on features extracted from the motion capture data.

3. Strategy Overview

Our approach leverages large amounts of data, specifically motion capture data, and supervised machine learning, i.e. adaboost, to determine whether a patient is performing an exercise correctly. The strategy for our approach has the following sections. First, collect a huge database of motions that represent the incorrect and correct versions of exercises that the patients must perform. Second, process these motions through segmentation and alignment. We segment out the portion of the motion data that only includes the exercise. The motions in our database are not assumed to be performed in the same place nor by the same subject. We align the data to handle these situations.

Third, group the processed motions based on the exercises they represent, extract their features, and trained our adaboost classifier. Presently, we are running adaboost on the segmented data of a single subject. We plan to use the results from this data to determine what alignment is necessary to optimize our approach. Once we have verified the effectiveness of our approach's third section to a reasonable degree, we will focus on other optimizations, e.g. reduction. This optimization refers to finding the minimum amount of motion data to differentiate between correctness and incorrectness in an exercise. In our case, markers on the subject represent motion data so we want to reduce the markers from full body marker set to a minimum number necessary to determine correctness and that is inexpensive for home-based rehabilitation.

To support our strategy we have made several assumptions. We assume that we have willing subjects. This assumption states that the patient is trying to follow the exercise and not deliberately being disobedient. Our next assumption is that our system knows the exercise it analyzes. This allows us to separate our training sets for adaboost into groups where the motions represent the same exercise. Our last assumption is that we know the leg the patient is rehabilitating.

4. Strategy Implementation

We collect motion data as follows. Using a Vicon MX system with 12 MX40 cameras, with 4-megapixel resolution per camera, the subject is captured performing the exercise motions at 120 frames per second. Presently, we capture the subject's full body motion using 52 markers. The data is processed and then exported in the c3d format. This format contains the x, y, and z positions of each marker during each frame throughout the duration of recorded motion.

Currently, we have motion capture data of knee rehabilitation exercises from three different capturing sessions. The first session we captured the subject performing all the exercises with no prior knowledge of correctness except for the written document given to patients who are doing home-based rehabilitation. For the second session, we captured the subject performing the exercises with the aid of physical trainer. In the third session, the subject performed the exercises correctly and incorrectly using the prior knowledge from the previous sessions. However, the third session focused on one exercise, specifically standing hamstring curls with cuff weight exercise.

Our initial tests focus on the curling exercise motion from the third session. This session contains 10 correct and incorrect curling motion samples, which we use as the training set for adaboost. Once trained, we plan apply the adaboost classifier through cross validation on its training set in addition to applying the classifier on this curling motion samples that were recorded in the other two sessions. We use the machine-learning tool WEKA to train adaboost classifier and test the classifier on the motion data.

5. Conclusion

We have several goals for this physical training project. First, we want to determine what segmentation and alignment of motion capture data is best for classifying exercise correctness. Along with segmentation and alignment, we are looking for what additional features are necessary in increasing our classifier's efficiency. We may also look at other classifiers if adaboost proves to be ineffective. Once we have tested our approach on the curling exercise, our next goal is to expand to the other knee rehabilitation exercises and determine a general approach to classifying these exercises. Third, we want to expand our approach to handling not only multiple exercises but also patients. Finally, we want to reduce the amount of motion data, e.g. minimize number of markers, so that our approach can be an inexpensive viable option for home-based rehabilitation. That might required tailoring our approach to use accelerometers instead of markers like in [1] or another motion tracking algorithm like the one suggested in [4] and [5].

6. References

1. M. Milenkovic, E. Jovanov, J. Chapman, D. Raskovic, and J. Price, “An accelerometer-based physical rehabilitation system”, in Proceedings of the Thirty-Fourth Southeastern Symposium on System Theory, 2002, pp. 57-60.
2. W. Xu, Y. Chen, H. Sundaram, and T. Rikakis, “Multimodal archiving, real-time annotation and information visualization in a biofeedback system for stroke patient rehabilitation”, in Proceedings of the 3rd ACM workshop on Continuous archival and retrieval of personal experiences, 2006, pp. 3-12.
3. Y. Chen, H. Huang, W. Xu, H. Sundaram, et al. , “The design of a real-time, multimodal biofeedback system for stroke patient rehabilitation”, in Proceedings of the 14th annual ACM international conference on Multimedia, 2006, pp. 763-772.
4. Y. Tao and H. Hu, “Colour Based Human Motion Tracking for Home-based Rehabilitation”, in IEEE International Conference on Systems, Man and Cybernetics, 2004, pp. 773-778.
5. Y. Tao, H. Hu, and H. Zhou, “Integration of Vision and Inertial Sensors for Home-based Rehabilitation”, in IEEE International Conference on Robotics and Automation, 2005.
6. H. Zhou, and H. Hu, “A Survey - Human Movement Tracking and Stroke Rehabilitation”, 2004.