

A Kinect-based Monitoring System for Stroke Rehabilitation

Min Hun Lee¹, Daniel Siewiorek¹, Asim Smailagic¹, Alexandre Bernardino²
and Sergi Bermúdez I Badia³

¹Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA, U.S.A.

²Instituto Superior Técnico, Av. Rovisco Pais, 1, Lisbon, Portugal

³Madeira Interactive Technology Institute and Faculdade de Ciências Exatas e da Engenharia, Universidade da Madeira, Caminho da Penteada, 9020-105 Funchal, Portugal

1 OBJECTIVES

Therapists monitor and evaluate stroke patient's motor abilities with clinical tests to individualize clinical interventions. After a clinical session, a therapist designs task-oriented exercises for a patient and requests self-reporting of patient's adherence on exercise regimen. However, outpatients, who cannot receive feedback, often show low adherence (Proot et al., 2005) et al, leading to sparse self-reports. It is difficult for therapists to follow patient's progress.

To address this challenge, this paper describes a Kinect-based monitoring system that evaluates performance and provides real-time feedback for four stroke rehabilitation exercises. Our preliminary study showed that this monitoring system can accurately monitor in-home stroke rehabilitation exercises.

2 METHOD

2.1 System Design

We designed a monitoring system for stroke rehabilitation as shown in Figure 1. Even if a therapist is not present, this system can perform monitoring tasks. It provides feedback and guidance to support achieving therapist's prescribed exercise regimen.

During an exercise movement, this monitoring system tracks body joints in x, y, z coordinates using a Kinect sensor. Given this time series kinematic sensor data, it computes physical measurements and pre-processes coordinates of joint trajectory into

normalized trajectory features. Thus, it reduces the effect of user's varying physical characteristics.

This system extracts various features for modelling performance analysis. Performance analysis involves three tasks: exercise type recognition, incorrect movement detection, and performance evaluation.

Exercise type recognizer utilizes normalized trajectory features and Hidden Markov Models (HMMs) to recognize which exercise is performed.

After recognizing the type of an exercise, incorrect movement detectors determine the correctness of a movement with respect to three performance metrics: precision, compensation, and smoothness.

Precision represents the degree of alignment with the target posture of an exercise. Compensation calculates the extent of occurring compensatory movements. Smoothness indicates the degree of trembling movement patterns. This system models Decision Trees for the precision and compensation metrics and HMMs for the smoothness metric.

This system achieves the performance evaluation by executing a probabilistic reasoning process. It computes the correctness of three performance metrics as a performance score.

For user engagement, this system provides feedback based on performance analysis. Exercise type recognizer enables to count the repetitions of an exercise. If any incorrect movement is detected, this system can correct any detected errors. It motivates a user with a performance score.

2.2 Dataset

For a preliminary study, we utilize four stroke rehabilitation exercises (Figure 2). Exercise 1 (E1) is

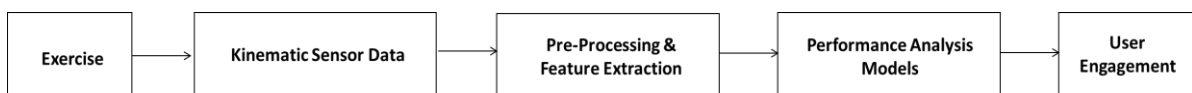


Figure 1: Overall Flow of Monitoring System for Stroke Rehabilitation.

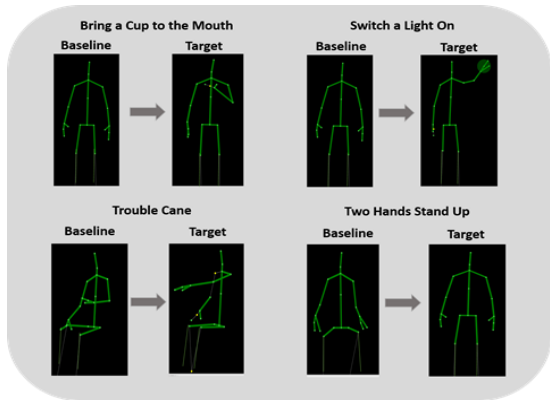


Figure 2: Four Stroke Rehabilitation Exercises.

Bring a Cup to the Mouth, Exercise 2 (E2) is Switch a Light On, Exercise 3 (E3) is Troubled Cane, and Exercise 4 (E4) is Two Hands Stand Up.

We collected both “correct” and “incorrect” datasets of four exercises using a Kinect v2 sensor (Microsoft, Redmond, USA). It was located at a height of 0.72m above the floor and 2.5m away from a subject.

For “correct” dataset, eleven healthy subjects (10 males and 1 female) with the average and standard deviation age of 32.3 ± 5.81 years participated. Each subject performed 15 correct repetitions of each exercise. The “correct” dataset contains 165 sample movements for each exercise.

For “incorrect” dataset, 5 healthy subjects (4 males and 1 female) with the average and standard deviation age of 30 ± 3.52 years participated. Each subject performed the different combinations of incorrect movements. The “incorrect” dataset contains 80 sample movements for each exercise.

3 RESULTS

We apply leave-one-subject-out cross validation and evaluate the monitoring system using “correct” and “incorrect” datasets. For exercise recognition, we achieved 96.7% accuracy. Accuracies of incorrect

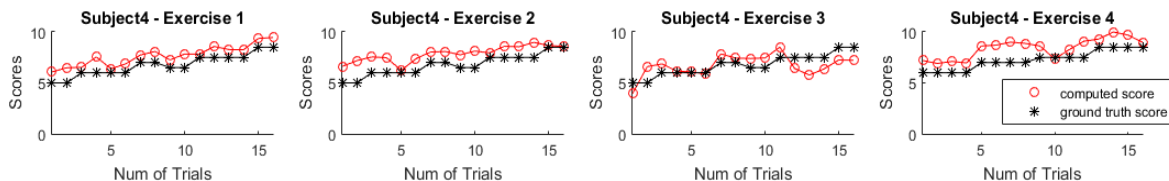


Figure 3: Plots of Computed Scores and Human Observation Scores.

movement detectors are presented in Table 1. For the accuracies of performance evaluation, we calculated the percentage of computed scores within ground truth scores \pm margin in Table 2. Ground truth scores indicate human observation scores and margin is selected as 1.

Table 1: Accuracies of Incorrect Movement Detectors.

Metrics	E1	E2	E3	E4
Precision	91.07%	99.69%	94.15%	98.15%
Compensation	94.68%	94.26%	88.16%	95.10%
Smooth	98.00%	97.50%	96.80%	94.25%

Table 2: Accuracies of Performance Evaluation.

	E1	E2	E3	E4
Accuracy	95.50%	87.50%	88.75%	91.25%

4 DISCUSSION

According to the preliminary evaluation, this monitoring system has a potential to accurately perform three monitoring tasks. This monitoring system can offer detailed feedback on an exercise performance without the presence of a therapist.

However, utilized datasets are collected from healthy subjects, who acted incorrect movements. Some trials of exercises involve exaggerated movements, which may be different from post-stroke survivors. Another limitation of this work is lack of therapist’s observation scores. It is necessary to compare ground truth scores from a therapist with computed scores of this monitoring system. In future, we plan to validate this monitoring system using datasets from stroke survivors and therapist’s observation scores.

ACKNOWLEDGEMENTS

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