VR Solutions for Improving Physical Therapy

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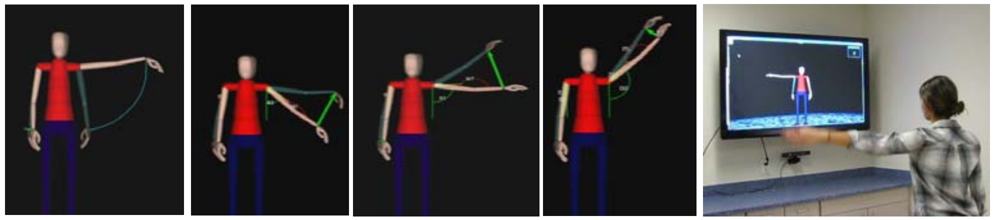
Abstract

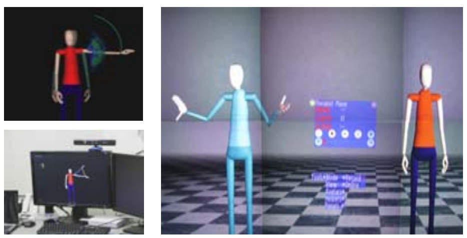
We present new solutions based on Virtual Reality technologies for improving the delivery of physical therapy and rehabilitation. Three main aspects are addressed:

- the ability to allow therapists to create new exercises and therapy programs intuitively by direct demonstration;
- automatic therapy delivery and monitoring with the use of an autonomous virtual therapist that can monitor and quantitatively assess the motions performed by the patient;
- networked collaborative remote therapy sessions via connected applications displaying the motions of both the real therapist and the patient.



Visualization helpers are available for real-time feedback or post-analysis of motions. From left to right: Trajectory trails; Display of angles and distances while following a motion; Kinect configuration in a Clinical setup.

System Implementation



The virtual collaborative system can run in two configurations: an inexpensive Kinect-based setup for home and clinical use (left) and a high-end Immersive setup for improved motion capture and visualization (right). Two avatars are displayed (side-by-side or overlapped) representing both the therapist and the patient.

- **Immersive VR configuration:** allows the therapist to immersively model customized exercises by demonstration and provides high-end visualization of the performed motions. The patient's motion can be visualized in real-time or be loaded from previous sessions. The user's upper body motions are tracked using a precise motion tracking system (based on Vicon cameras). The system can be configured to only track markers attached to the hands, torso and head [1]. When connected to a remote site, two avatars are displayed for representing the connected patient and the therapist.

- **Kinect configuration:** designed to assist patients when they perform their prescribed daily therapy. The system provides real-time monitoring, feedback and logging. This configuration also provides two avatars when a networked connection is established.

Virtual Exercise Modeling, Delivery and Monitoring

The proposed solution can be adopted in different ways:

- **Modeling:** both systems provides tools for the creation of new exercises by demonstration. Any tracking device can be used, however the accuracy of the device will play a significant role in the quality of the modeled exercises. Both applications also provide advanced tools to parameterize exercises and define therapy programs.

- **Delivery and Monitoring :** The system can be employed as a tool for automated delivery of exercises at home and as a tool to measure and investigate the performance of a patient during clinical appointments. Main steps:

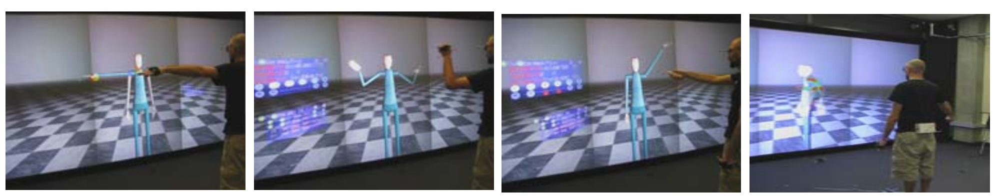
  - the virtual therapist starts the session by demonstrating the exercises to the patient;
  - the user is asked to follow the exercises while the application is recording the sensed motion;
  - If the motion is detected to be significantly different than the demonstrated exercise, the appropriate visual feedback is provided.

The level of expected compliance and repetitions until compliance can be personalized by the therapist specifically for each patient.

Remote Patient-Therapist consultation

Example of using the system in on-line mode. Left: Kinect and Immersive VR Therapy session. Right: dual Kinect configuration.

In on-line mode two application instances (immersive or Kinect setup) are connected together enabling a virtual consultation session. The motion of each user participating to the virtual collaboration is mapped directly to each respective avatar. The avatars can be superimposed with transparency or appear side-by-side in the applications.
All feedback tools will be available during virtual collaboration. The therapist can demonstrate exercises, analyze the patient motion, load preset exercises from the database, watch the patient's performances and even record a patient motion in real time.



Example of using the Immersive Virtual Reality setup in offline mode. From left to right: calibration process; recording an exercise; modifying the exercise, and exercise analysis.

Visual Feedback

Visual feedback provides visual and quantitative information about the user motions in real-time. They can be activated anytime during collaborative sessions or for analysis of recorded exercises. Visual feedback is customizable from a configuration file and can be readapted to any skeleton joint.

- **Trajectories**

Trajectory trails of selected joints can be updated in real-time, displaying positions of a fixed past period of time, or of complete motions. The visualization can be based on polygonal segments for precise analysis of tremors, or smoothly generated by B-Spline interpolation.

- **Angle estimation (virtual goniometer)**

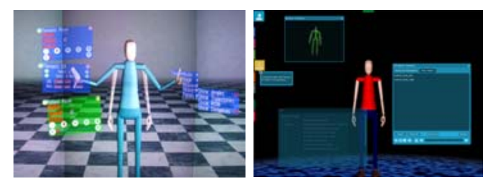
Joint angles are visualized with a floating label showing the angle value and the local lines representing the angle measurement. In default behavior, angles are only displayed when significant motion is detected.

- **Distances**

Colored 3D arrows showing the distance between corresponding pairs of joints, each belonging to a different character, are useful for the patient to track compliance with the demonstrated exercises. The feedback is useful in individual sessions or in remote physical therapy sessions. The arrows being visualized can be programmed to automatically disappear if the corresponding distance is under a given threshold.

- **Range of motion**

The system also provides new ways to log and visualize improvement of range of motion during rehabilitation.



Example of GUI for motion database handling in the immersive VR (left) and Kinect configuration (right).

References

[1] C. Camporesi, Y. Huang and M. Kallmann, ***Interactive Motion Modeling and Parameterization by Direct Demonstration,*** *IVA 2010.*

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