# Remote Console for Virtual Telerehabilitation

Jeffrey A. LEWIS[1,2,*], Rares F. BOIAN[2], Grigore BURDEA[2], Judith E. DEUTSCH[1]
[1] *RIVERS Lab, Program in Physical Therapy, UMDNJ*
[2] *VR LAB, CAIP Center, Rutgers University*
[*] *Contact Author: lewisje@umdnj.edu*

**Abstract.** The Remote Console (ReCon) telerehabilitation system provides a platform for therapists to guide rehabilitation sessions from a remote location. The ReCon system integrates real-time graphics, audio/video communication, private therapist chat, post-test data graphs, extendable patient and exercise performance monitoring, exercise pre-configuration and modification under a single application. These tools give therapists the ability to conduct training, monitoring/assessment, and therapeutic intervention remotely and in real-time.

## 1. Introduction

The priorities of a successful telerehabilitation system are training and counseling, monitoring and assessment, and therapeutic intervention [1] from a distance. Telerehabilitation implementations are currently being developed, providing different remote capabilities. The first Virtual Reality-based telerehabilitation system was developed by our group, in collaboration with Stanford university. It was intended for the training of musculo-skeletal patients [2] and used a server-client architecture with asynchronous patient data uploading, and an Internet video link. Subsequently researchers at the University of California – Irvine developed Java Therapy [3], in which therapists prescribe a set of exercises via the web. These exercises can then be accessed and executed by the patient through a web browser. Therapists may monitor the patient's performance on the web page and asynchronously modify the therapy, however, there is no real-time interaction or training. Another telerehabilitation application [4] uses a video conferencing link (VC) with commercial video-capture software, to provide audio/visual communication between the patient and the therapist. The same exercise environment is displayed at each site to allow for real-time monitoring and assessment. Data transfer is hindered by the fixed speed requirements of the VC link, forcing this application to reduce the rate at which remote updates are made.

Our first telerehabilitation application for the lower extremity was a real-time web based remote monitor [5], which coupled 3rd party audio and visual communication with real-time patient data, performance gauges, and simplified 3D graphics updated in real time based on the patient's exercise simulation. This monitoring system was subsequently tested for ease of use by five physical therapists [6]. While feedback was generally positive, the subjects raised several issues on the quality of audio communication, and the therapist's inability to make modifications of exercise parameters remotely. In response to these limitations, we have developed the "Remote Console" (ReCon), a telerehabilitation system described in this paper.

## 2. Telerehabilitation System Description

The ReCon was designed for both upper and lower extremities, as illustrated in Figure 1. The patient interacts with VR-based therapeutic exercises using custom interfaces (the Rutgers Master glove for the UE and the Rutgers Ankle and Rutgers Mega Ankle for the LE). The simulation exercises are presented to patients on one PC display, while a Pan-Tilt-Zoom (PTZ) camera captures their image. Patient video, voice and VR exercise parameters are transmitted in real-time to a remote therapist over the Internet. This information is then accessed from a PC, in this example a laptop, using the ReCon.

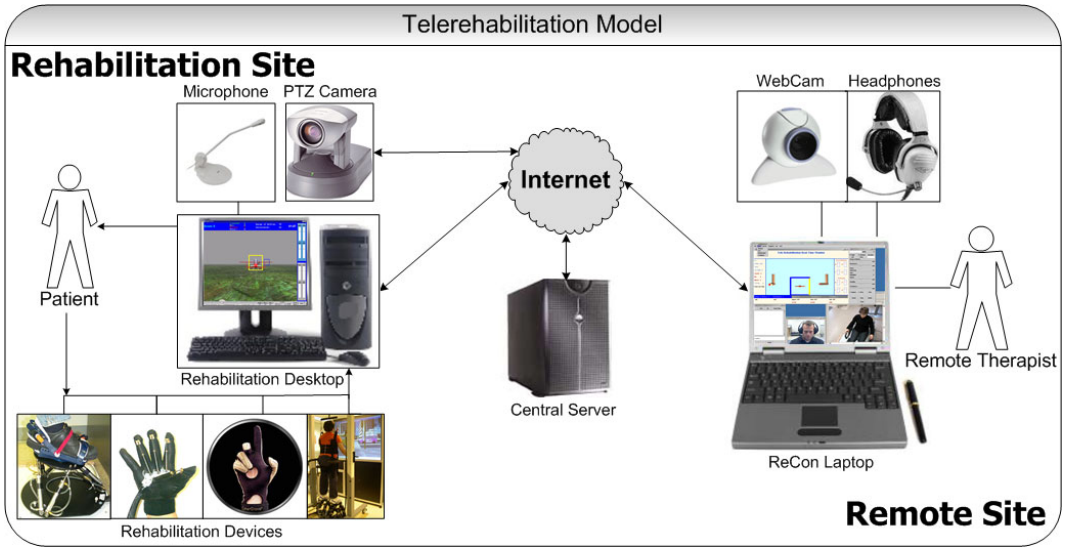


**Figure 1.** Telerehabilitation Model using the ReCon

A remote therapist may start the ReCon application from either a desktop icon or a web link. This prompts Java Web Start to download the latest package of the application as well as the appropriate Java version. On startup, it will initiate a connection with a central server that communicates with each ReCon and rehabilitation site. The therapist may then choose to open a communication channel (audio, video, and chat) with one of the active rehabilitation sites running a copy of the media package built into the ReCon. When this connection is established with the rehabilitation site, the chat window indicates that the therapist is connected. The therapist is then able to hear the sounds at the rehabilitation site through headphones, and a small window will pop up to show the therapists face to assist in positioning the camera. In addition, a Logitech QuickCam is used for automatic face-tracking by panning and zooming in on the therapists face as it moves. This face-tracked video is received at the rehabilitation site. By opening a PTZ camera window, the therapist gains control of the camera movement at the rehabilitation site. Preset viewpoints are accessible on the bottom of the PTZ window to automatically position and zoom the camera to a specified location. For the purposes of this study the PTZ camera views were preset to point to patients' upper body, or to their ankle to watch their movement during an exercise.

The ReCon desktop (shown in detail in Figure 2) incorporates patient simplified 3D exercise graphics, which are updated in real time. The same screen includes numerical exercise performance monitoring, patient video, remote configuration and modification of exercise parameters, and a private therapist chat window. The ReCon allows the therapist to remotely position the PTZ camera and to view post-test data graphs to gauge patient's performance objectively.

The ReCon is implemented using Java [7] with the Java3D API [8] for three-dimensional movement and exercise representations, Java Media Framework (JMF) [9] for

audio/video communication, and Java Web Start [10] for deployment and to allow updates to be quickly propagated to users.

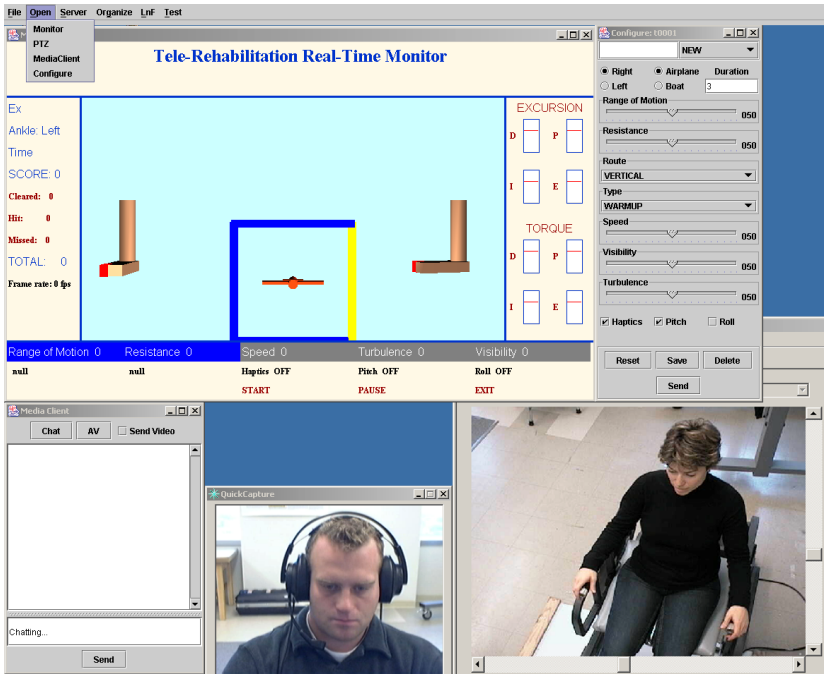


**Figure 2.** ReCon monitoring screen for LE telerehabilitation: plane exercise monitor (top left); ankle exercise configuration utility (top right); chat window (bottom left); therapist monitor (bottom middle); PTZ camera view and controls (bottom right)

In our previous implementation, a remote therapist had to rely on communicating with a local therapist, who was present with the patient, to configure a new exercise or adjust an exercise in progress. The exercise had to be configured before each session by the local therapist. To make a modification, the remote therapist either contacted the local therapist using the microphone, interrupting the patient's exercise, or communicated with the local therapist over a chat mechanism, drawing their attention away from the patient. In both cases, the desired modification to the exercise would take more time than necessary and affected the efficiency of the action and the session as a whole. To remedy this situation, an additional layer of interaction has been added to ReCon, by allowing remote therapists to manipulate a rehabilitation session from their remote location. While monitoring the progress of an exercise, the therapist can create or modify an upcoming exercise using the remote configuration utility. This allows the therapist to select a pre-configured exercise from a pull-down menu. Any individual exercise can be modified or deleted before it is transmitted to the remote patient station. Before the rehabilitation site starts the next exercise, the therapist may remotely send one of the pre-set configuration lists and start the exercise trial. Several of the simulations contain exercise configurations that can be altered while the exercise is in progress. In addition, a therapist monitoring the session can select one of these modifiable parameters and update the exercise instantly and remotely during run-time. As an example, the therapist may decide that the exercise should be shortened (Figure 3*a*) or the airplane speed should be increased (Figure 3*b*). Once the therapist clicks on the appropriate item, a modify toolbar appears underneath to accept the proper input. For time, the therapist must enter the new duration, for speed, the therapist moves the slider to the desired position and selects the green check mark to accept and transmit the new value to the running exercise. Once the value is changed at the rehabilitation site, the update will appear as the current value on the monitoring window for that exercise. Figure 3*c* shows how the remote therapist can affect an exercise in progress. After the green check mark is selected, the turbulence is increased causing a change in the

virtual environment (thunder, lightning and stormy skies) and the addition of haptic perturbations of the Rutgers Ankle platform.

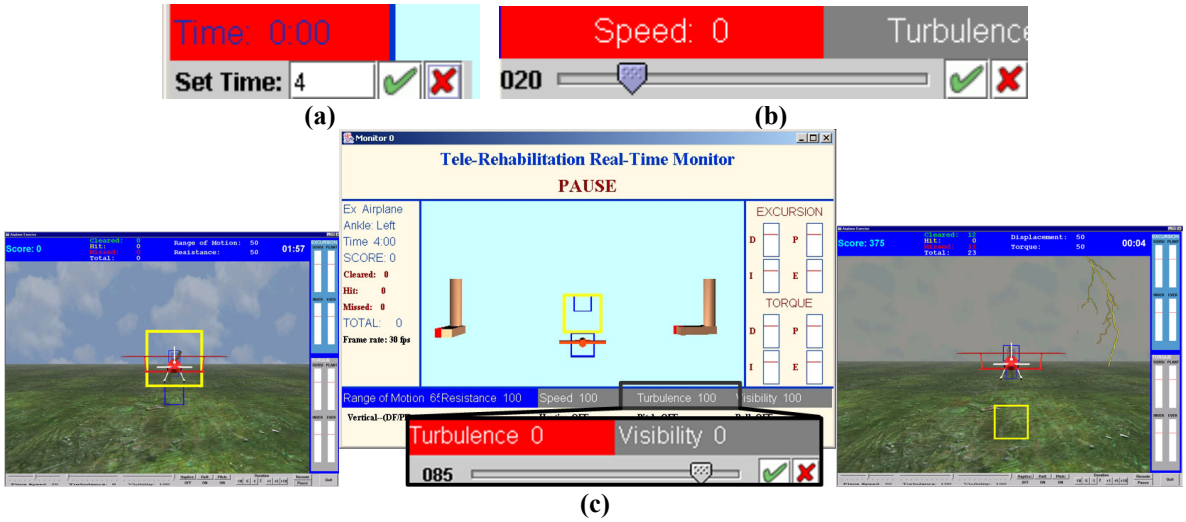


**Figure 3.** Remote real-time exercise parameter setting: a) time; b) airplane speed; c) airplane exercise; remote modification of turbulence; resulting airplane exercise;

A training session with the RARS starts with a baseline trial where the patient's ankle range of motion and torque capabilities are measured. This stage is followed by a configuration stage where the therapist specifies the upcoming exercise parameters. Once this stage is complete the exercise is loaded on the patient's station and the exercise may begin. When monitoring a patient remotely, the therapist is involved with every step. The therapist may monitor the baseline values and instruct the remote patient in the proper ankle movements to record the data. Once therapists are satisfied with the results, they may open the configuration screen and load a configuration that was pre-set and saved. Alternatively, the local therapist may set the exercise configurations and the remote therapist may interactively make modifications to what is set. The remote therapist may then choose to start the simulation on the patient's station by selecting the "START" button on the patient monitor. During the exercise, as described above, the therapist may make any of the desired modifications, but may also pause or exit the exercise and move on to another trial. This allows the remote therapist the freedom to manipulate the exercise routines without interfering with the flow of the session.

## 3. Initial Experimental Results

During Summer 2004 the ReCon system underwent pilot clinical testing as part of a training protocol with individuals in the chronic phase post-stroke. During the first three weeks of the study, the therapist and a therapist assistant were onsite with the patient. Telerehabilitation was introduced during the last week of the four-week training regimen. The remote therapist conducted three telerehabilitation sessions for each of three subjects participating in the trails. During the remote sessions, the therapist assistant remained with the patient while the therapist interacted from a different room in the same building. This allowed the ReCon to be tested under most favorable conditions (on a single Local Area Network) without being subjected to network delays or poor quality of network service.

The remote therapist, who is considered an expert domain user, had pilot tested the original version of the tele-monitoring system in a study conducted using the same design [5]. Therefore she was able to compare the current version of the system with its earlier prototype. The improvements noted by the therapists were a decrease in communication lag

(although some audio communication challenges remained), the ability to pre-configure exercises and save them, and the ability to configure and monitor exercises from the remote station. The domain expert user reported that the ReCon was much easier to use and certainly more useful than the earlier version of the software.

After the remote rehabilitation sessions, each subject was asked to fill out a questionnaire, which made several statements about the system and the interaction with the remote therapist. For each statement they rated their agreement on a scale of 1, "Strongly Disagree," to 7, "Strongly Agree". After the first session, two subjects partially agreed (5) with the statement "I felt something was missing because the therapist could not see me in person". After two complete sessions, the two subjects disagreed with this statement (2), while a third subject strongly disagreed with this statement from the first session (1). Several statements regarding their video interaction indicated that the subjects were comfortable being on camera and were not concerned that others may be watching or listening in during the session. In response to "I would feel more comfortable seeing the therapist in a face-to-face session," the responses ranged from indifferent to partial agreement (4-5). In general the patients felt that the therapist did not miss too much information from being out of the room and they still received the same advice that they would have if the therapist were in the room. Another section of the questionnaire asked the patient to order different scenarios of patient-therapist interaction during a rehabilitation session. One individual ranked "Performing exercises at home with therapist available by video connection" as most desirable. Each of the other subjects consistently chose "Performing exercises in the clinic with therapist in room" followed by "Performing exercises in the clinic with therapist available by video". While some of the subjects would prefer to have the therapist in the room, they did not object to telerehabilitation as an alternative.

## 4. Conclusions and Future Work

The Remote Console was intended to provide a larger set of telerehabilitation tools under a single application to minimize the challenges of the telerehabilitation platform. Further, this system incorporates therapeutic intervention by allowing a therapist to remotely access performance measures and make exercise modifications in real-time.

Patient and provider acceptance of telemedicine is integral to the future success of related technologies [11]. For this reason, we captured patient and therapist responses after using the ReCon system to remotely interact with training. After three weeks of training with the therapist and therapist assistant present, two of the patients agreed that they would prefer to have a session in a clinic with the therapist still present, while a third would have preferred to exercise at home with the therapist present only through video. Though some subjects would prefer a face-face sessions, in general, the patients did not oppose the telerehabilitation sessions and felt that the therapist was able to actively follow a session. Under our testing conditions, the subjects became comfortable with the routine of having the remote therapist training the subjects face-to-face for the first three weeks. In addition the therapist assistant was present for all four weeks, making the telerehabilitation sessions we conducted more closely resemble a clinical telerehabilitation environment than a home telerehabilitation setup. To accurately test patient acceptance, the involvement of the remote therapist in face-to-face sessions will have to be varied to determine levels of comfort with a remote provider.

The previous version of our monitoring software was only able to present data from an airplane and boat simulation for the Rutgers Ankle Rehabilitation System (RARS). The ReCon monitor package is structured to be extendable by adding new modules. Currently,

the system has been extended to connect to simulations for hand exercises, using a Cyberglove and/or Rutgers Master II Haptic Glove (RMII)[12], and simulations for the Mobility Simulator currently under development [13]. For each of these simulations, the remote monitor displays a three-dimensional representation of the exercise simulation and several angles of the body part being exercised in the center of the screen, using the Java3D API. Exercise configurations, patient data, and performance gauges are shown along the sides and bottom (Figure 4). Multiplexed telerehabilitation is potentially achieved by initiating multiple monitoring windows to interact with several remote patients, each performing different exercises. Multiple monitors could be opened during the same ReCon session and may access multiple rehabilitation sites.

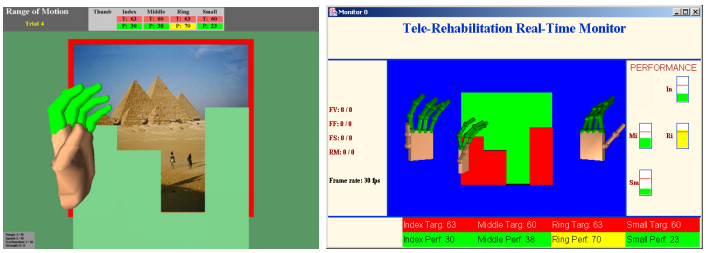


**Figure 4.** Exercise and the respective monitor displays for the upper extremity

The development of a complete telerehabilitation system is an iterative process that will continue to require feedback from both patients and providers. A usability study will be conducted with practicing physical therapists to gain a broader sense of the ease-of-use and acceptance of ReCon. Improvements will be made to reflect the input from these therapists. The current framework that allows commands to be passed to the rehabilitation site will be extended to provide greater flexibility to the therapist.


## Acknowledgements

Research reported here was supported in part by the NSF Grant BES-0201687.


## References


[1] Rosen MJ. Telerehabilitation. Neurorehabilitation, 3:3–18, 1999.

[2] Popescu, V., G. Burdea, M. Bouzit, M. Girone, and V. Hentz, "PC-Based Telerehabilitation System With Force Feedback," *Proceedings of Medicine Meets Virtual Reality (7) Conference*, "The Convergence of Physical & Informational Technologies: Options for a New Era in Healthcare," IOS Press, Amsterdam, Vol. 62, pp. 262-267, 1999.

[3] Reinkensmeyer DJ, Pang CT, Nessler CA, Painter CC. Web-based telerehabilitation for the upper-extremity after stroke, IEEE Transactions on Neural Science and Rehabilitation Engineering, vol. 10, no. 2, 2002, pp. 102-108.

[4] Holden MK, Dyar T, Schwamm L, Bizzi E. Home-based telerehabilitation using a virtual environment system. Proc. Second Int. Workshop on Virtual Rehabilitation, pp. 4-12, September 2003.

[5] Lewis JA, Boian RF, Burdea GC, Deutsch JE. "Real-time Web-based Telerehabilitation Monitoring, Proceeding of Medicine Meets Virtual Reality 11, Newport Beach, CA, January 2003, IOS Press, pp. 190-192.

[6] Deutsch JE, Lewis JA, Whitworth E, Boian RF, Burdea G, Tremaine M. Formative Evaluation and Preliminary Findings of a Virtual Reality Telerehabilitation System for the Lower Extremity, (In press) Presence Special Issue on Virtual Rehabilitation 2005.

[7] SUN Microsystems, Java API Specification for the Java 2 Platform, Standard Edition, v1.4.2, 2003.

[8] SUN Microsystems, The Java3D API Specification, Java3D v1.3.1, 2001.

[9] SUN Microsystems, The Java Media Framework API Guide, JMF v2.1.1e, 1999.

[10] SUN Microsystems, Java Web Start Guide, v1.5 2004.

[11] Collins K, Nicolson P, Bowns I. Patient satisfaction in telemedicine. Health Informatics Journal, pages 81–85, Feb 2000.

[12] Adamovich SV, et al. A Virtual Reality Based Exercise System for Hand Rehabilitation Post-Stroke, (In press) Presence, Special Issue on Virtual Rehabilitation 2005.

[13] Boian RF, Burdea GC, Deutsch JE, Winter SH. Street Crossing Using a Virtual Environment Mobility Simulator, *Proceedings of IWVR 2004*, pp. 27-33, September 2004.