

Progress towards a Service-Oriented Universal Access Telerehabilitation Platform

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Abstract—this paper addresses how UniTherapy, a telerehabilitation platform developed primarily for computer-assisted motivating rehabilitation applications, is being turned into an accessible service. This process has involved transformation to a service-oriented universal access infrastructure that also supports intelligent context-aware user interface generation that is dependent on current and emerging standards such as the V2 standard for Universal Remote Consoles. It also has involved support for a steadily increasing, diverse menu of approaches for performance assessment, and of interfaces for promoting universal access. Progress and key issues are discussed.

I. INTRODUCTION

UniTherapy is a telerehabilitation platform which builds on other efforts at web-based therapy [1] and targets software support for Computer-Assisted Motivating Rehabilitation (CAMR) [2] protocols that are intended especially for individuals with stroke-induced disability. It is designed to support both home-based assessment and therapy and neurorehabilitation research protocols. It includes a rich menu of assessment capabilities [3], and is being used for several research projects [4, 5].

Recent attention has focused on turning UniTherapy into a service. A key motivation has been to systematically develop a platform that is as universally accessible and flexible as possible. This enhanced access can benefit a greater diversity of clients and open up new possibilities for discovering and implementing optimized intervention strategies across the continuum of care. This also opens its functionalities to the neurorehabilitation community. It is suggested that the rehabilitation robotics field could benefit from such approaches; hence this paper.

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II. METHOD

A. Service-Oriented Infrastructure

There are certain advantages to exposing the functionalities of UniTherapy as a service rather than as a standalone application:

1) A service is platform independent and can be called from any other user/service via standard communication protocol (e.g. SOAP (Simple Object Access Protocol)).

2) A service is highly reusable in that other research/clinic groups can build their own rehabilitation program based on the existing functionalities of UniTherapy.

3) By choosing to only loosely couple a service with its user interface, emerging approaches become available for building up an accessible customized user interface for a new client.

4) Local services can be turned into a web service with less effort, including describing services as WSDL (Web Service Description Language) documents, which will facilitate access to UniTherapy platform and open the functionalities to authenticated user/service on the web.

In order to evolve into a service, UniTherapy was redesigned into seven modular layers (see also Figure 1):

- Service layer: directly provides functionalities and receives input from user.
- Agent layer: provides agent services between the Service layer and underlying library.
- Library layer: includes base framework libraries for UniTherapy (e.g., Microsoft's DirectX, Mathwork's Matlab library).
- Description layer: includes standard-compliant description documents for User Interface (UI) models, Data models and Task models.
- Discovery/Control layer (Optional): control connection and communication between client and UniTherapy service; control layer only exists when using another computer device as a remote control for UniTherapy.
- Network layer: includes various network communication protocol standards, such as TCP/IP internet protocol.
- Physical layer: includes various standard networks.

Functions within the service and agent layers which have been encapsulated into standard DLL components can be

distributed as a Software Development Kit (SDK), and be made available for other research groups to develop their own tailored rehabilitation programs. The description and discovery/control layers open the door to pervasive computing devices (e.g. mobile devices, intelligent appliances) for presentation and interoperation.

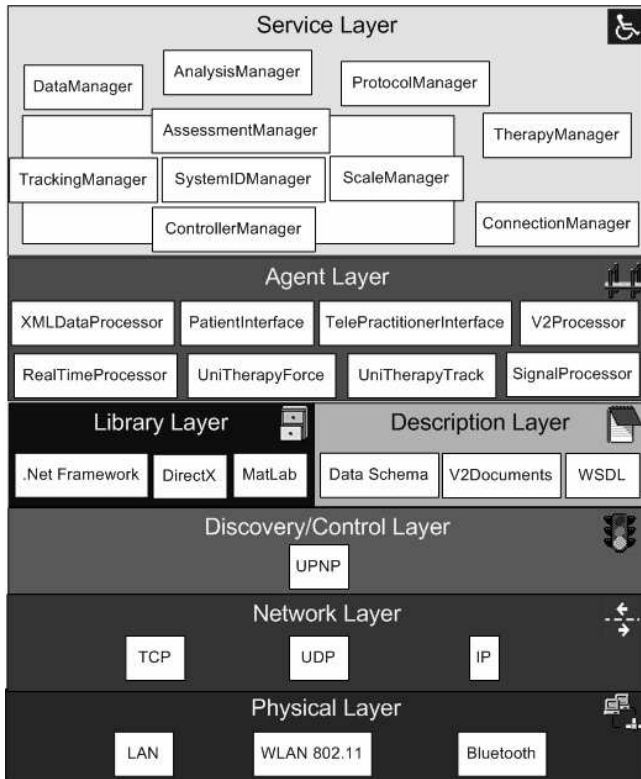


Fig. 1. UniTherapy is designed into seven modular layers. The upper part aims for functionality, and includes the service, agent and library layers. The bottom part aims for communication, and includes the description, discovery/control, network and physical layers; the latter three can be viewed as a Network Platform layer, which is necessary for a client to use a UniTherapy service. The primary software development environment is Microsoft Visual Studio .Net.

B. Intelligent Context-Awareness User Interface Generation

One of the key challenges in Telerehabilitation is the need for interfaces that are more user-centered, and support user preferences [6]. The goal of bringing UniTherapy into patient’s home gives added significance to addressing these challenges. However, until recently the lack of well-recognized specifications and standards made this process harder to implement.

We take advantage of International Committee for Information Technology Standards (INCITS) V2 [7]. This suite of emerging standards addresses operation of a device or service (called a Target in the V2 standard) through intermediate devices and intelligent agents (called a URC (Universal Remote Console) in the V2 standard). The standards describe methods in which a Target can be used

to provide descriptive information for any URC. This information is intended to be sufficient enough to dynamically construct a device-independent and full function user interface on the URC; the intent is to enable any of visual, audio or natural language interfaces to be constructed, given the appropriate describing documents [8]. In turn, a URC can be used to remotely control any V2-compliant targets. The V2 standard is network neutral; the URC and Target are communicated via diverse networking and control technologies such as Universal Plug and Play (UPnP) [9] standard. V2 standard can benefit us in:

- Generating a Universal Interface for UniTherapy on virtually any device that a user chooses, based on their preferences and capabilities.
- By embedding URC support into UniTherapy, UniTherapy can be used as an Environmental Control Unit (ECU) for V2-compliant targets.

The V2 infrastructure, expanded by non-V2 components specific to UniTherapy, is shown in Figure 2.

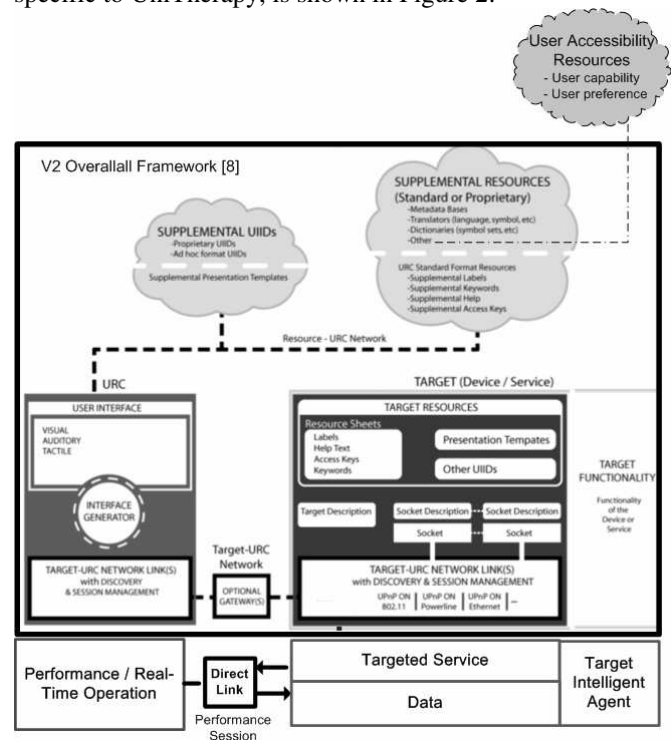


Fig. 2. Relation between V2 overall framework (in the black box) and UniTherapy specific components. The discovery and control session between target and URC is connected by Target-URC Network. The lower blocks in line with the “direct link” are specific to UniTherapy and provide a high-speed connection for a performance session. A Target Intelligent Agent may be used to optimize the Target functionalities based on user’s performance data and context information such as loaded protocol. The supplemental User Accessibility Resources (top right) are needed by a URC to customize user interface design when using UniTherapy.

Our approach is to treat UniTherapy as a Target service, and thus provide descriptive information in V2-compliant documents such as the User Interface Socket (UIS)

description document and the Presentation Template document [7]. This information is intended to be sufficient for a URC to construct a full-function custom-tailored user interface for UniTherapy. Thus, with only one user interface description plus resource information on the user's abilities and preferences, UniTherapy can be directly/remotely manipulated in the future by URCs ranging from desktop computers to mobile devices, and by voice recognition and natural language technologies. Of course, the direct link of the actual targeted service of Figure 2 is outside of V2. Currently we are investigating an intelligent context-aware UI builder. Automatic user interface generation has been investigated by many researchers in the past [10], and there are some benefits to addressing this within the framework of the V2 standard. A critical part of this process is having user to complete a short survey on user accessibility and preferences (see Figure 2). UniTherapy's own assessment tools can be used to augment information on a user's performance capabilities.

C. Universal Interfaces

One of the tenets behind the name UniTherapy is that this platform should support universal interfaces that help break down access barriers. In ergonomics, it is common to break human-technology interfaces into three categories: controls, displays and communication. This provides a good starting classification for analyzing interface usability:

1) Controls: Potentially, any input device that provides an I/O driver can be used within UniTherapy. For instance, UniTherapy supports force-feedback/non-force-feedback joysticks, force-feedback/ non-force-feedback driving wheels, various pointing devices (e.g. mouse, trackball, PDA stylus pen) and windows keyboard. Some features in UniTherapy, though, are only available to force-reflecting devices. Our group has designed a larger, customized joystick device called TheraJoy [4]. This device extends a commercial mass-market force-reflecting joystick so that it is applicable to vertical as well as horizontal arm movements that include high use of the shoulder. A utility called "JoyMouse" in UniTherapy can capture a joystick's signal and use it to control the mouse cursor. This provides an accessible way for specific motor-impaired users to use a joystick to perform regular windows mouse tasks. Other input devices such as a windows keyboard and simple voice recognition also have been implemented to control a mouse cursor).

2) Displays: UniTherapy supports two display coordinates: cartesian or polar, which can be intelligently chosen during the initialization phase by both automatic input device identification (e.g. joystick, driving wheel) and the user's preference. Different groups of assessment tasks have been designed and implemented for various degrees of freedom (DOF) input devices (1 DOF, 2 DOF).

The user also has the option to run tasks designed for 2 DOF devices by using a 1 DOF device (e.g. driving wheel), with the second DOF either not controlled, automatically tracked, or controlled by an alternative button or pedal on the device. The preferred size, color and shape of objects and fonts can be specified by the user (e.g., targets, graphical input and output windows). Visual and sound cues are selectively given to the subject in response to their success/failure in the task.

3) Control-Display Mapping to the User-Ability Space: UniTherapy will also map between the input device workspace range and the user capability range. This mapping is based on a 2-step range-of-motion (ROM) task that is normally taken upon first use. As the first step, the ROM task prompts the subject/patient to draw a circle as big as they can on the screen. UniTherapy then grossly decides their ROM and its center by fitting the data with a rectangle. Since the ROM for a person with neural impairment can be history and direction dependent, to help ensure the patient's full ROM is captured a second step requires the subject/patient to track radial lines from the estimated center of their ROM. The task helps refine the estimate of the client's "ability space," which is then stored as both a transformation and performance metric. A five-parameter fit algorithm is used to perform a 2D-transformation and re-map the screen to the user-ability space (or vice versa):

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{pmatrix} S_x & 0 \\ 0 & S_y \end{pmatrix} \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix} \quad (1)$$

where x and y are actual user position, S_x and S_y are scale transform parameters, θ is rotation transform parameter, t_x and t_y are translation parameters, and x' and y' are mapped positions on the screen. This helps ensure that the user can reach most of the space for subsequent tasks.

4) Communication: A communication infrastructure between a patient interface (PI) and telepractitioner interface (TI), which is supported by TCP/IP network, has been implemented. Both the TI and PI display the patient's performance data in real-time. Through TI a practitioner has the capability to design the task and supervise the user at PI remotely; TI also can change the patient's force field and rehabilitator's impedance settings, based on the task and patient's performance. Subsequent results can be viewed at both sides in graphical and report formats. As an option, practitioner at the TI can decide if the patient can participate in the task design phase. Instant messaging (IM) and internet videoconferencing is integrated with UniTherapy. A videoconferencing server in our lab enables us to use various standards-compliant internet videoconferencing tools (e.g. IM, Polycom ViaVideo).

D. Additional Accessibility Features and Assessment Toolbox

Additional accessibility features are being systematically integrated into the design, with examples including the use of available embedded accessibility features within Windows (e.g., to adjust the mouse pointer's speed) and third-party accessibility packages.

Since UniTherapy can be used in both a protocol design mode and a simpler protocol implementation mode, designers such as practitioners can also use their own knowledge of the client to design an easy-to-implement protocol sequence.

The assessment toolbox provides a diverse menu of capabilities for clinical research studies involving persons with disabilities, such as performance assessment (e.g. target tracking protocols, system identification tools), and we are gradually adding support for various clinical assessment scales.

III. RESULTS

In several research studies [3, 4, 5] involving subjects with varying degrees of stroke-induced hemiparesis, UniTherapy has been used as a comprehensive clinical research tool. In a pilot study involving eight chronic stroke subjects and eight controls, features included having subjects first assessed by a ROM task so that subsequent tracking assessment and therapy tasks were remapped in their ability space. They also used a Joystick to play a computer game via the "JoyMouse" utility and participated in a teletherapy session with a remote practitioner. Tasks were done by both affected side and unaffected side of subjects for the purpose of comparison. These studies include an ongoing focus on the usability of the UniTherapy system, using the Mobile Usability Lab (MU-Lab) of the RERC on Accessible Medical Instrumentation [11]. Preliminary results showed that the subjects can reach most of the tracking targets in their ability space, can complete a variety of assessment tasks, and can successfully play windows computer games using joysticks. Feedback from a teletherapy session was also positive.

Our next steps are: i) to evaluate the usability across a range of the devices supported by UniTherapy, including the remodeled joystick [4], a conventional force-reflecting joystick, and driving wheels [5]; ii) to deploy and evaluate V2-compliant interfaces for a collection of subjects with differing abilities and preferences; and iii) to then deploy UniTherapy software and appropriate interface devices within subjects' homes, with truly remote assessment between two remote sites with a broadband network connection, and then study issues related to using UniTherapy as a home-based CAMR service.

IV. CONCLUSION

In summary, a basic service-oriented universal access infrastructure for a low-cost telerehabilitation platform is being systematically implemented, using the multi-faceted approach described in this paper. Ongoing work includes fine tuning of existing multi-modal interfaces such as speech interface, and full implementation of UniTherapy as a V2-compliant service that is accessible for a diversity of clients.

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