

METHODOLOGY FOR ANALYZING AND DEVELOPING INFORMATION MANAGEMENT INFRASTRUCTURE TO SUPPORT TELEREHABILITATION

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ABSTRACT

The proliferation of advanced technologies led researchers within the Rehabilitation Engineering Research Center on Telerehabilitation (RERC-TR) to devise an integrated infrastructure for clinical services using the University of Pittsburgh (PITT) model. This model describes five required characteristics for a telerehabilitation (TR) infrastructure: openness, extensibility, scalability, cost-effectiveness, and security. The infrastructure is to deliver clinical services over distance to improve access to health services for people living in underserved or remote areas. The methodological approach to design, develop, and employ this infrastructure is explained and detailed for the remote wheelchair prescription project, a research task within the RERC-TR. The availability of this specific clinical service and personnel outside of metropolitan areas is limited due to the lack of specialty expertise and access to resources. The infrastructure is used to deliver expertise in wheeled mobility and seating through teleconsultation to remote clinics, and has been successfully deployed to five rural clinics in Western Pennsylvania.

Keywords: Telerehabilitation, Information Management, Infrastructure Development Methodology, Videoconferencing, Online portal, Database

INTRODUCTION

Advances in telecommunication technologies have opened new possibilities to deliver rehabilitation services to rural and remote areas. This approach, commonly known as telerehabilitation (TR), has the potential to bring rehabilitation services to previously limited areas. For example, in teleconsultation, a clinician from rural clinic can remotely consult an expert clinician from a metropolitan specialty center during an assessment?

In a TR application, an information management infrastructure is required to deliver rehabilitation services over telecommunication networks. The infrastructure is responsible for managing information across multiple sites. Properly addressing the requirements of the TR application allows the infrastructure to efficiently support rehabilitation services.

Within the University of Pittsburgh's Rehabilitation Engineering and Research Center on Telerehabilitation

(RERC-TR), researchers created an Internet-based information management infrastructure to support TR. The infrastructure was developed through a design process that focused on the following characteristics: openness, flexibility, extensibility, cost-effectiveness, and security (Parmanto, Saptano, Sugiantara, Brienza, & Nnaji, 2006). The presence of these five characteristics contributed to the creation of an ideal TR platform, referred to as the PITT Model.

In this paper, we explain the methodological approach to employ the PITT Model in the design and development of an information management infrastructure to support TR. The remote wheelchair prescription project was chosen as a case example to explain the implementation of the model in an authentic TR application. In this project, the methodology is used to develop the information management infrastructure to deliver expertise in wheeled mobility and seating through teleconsultation to rural clinics.

BACKGROUND

Telerehabilitation (TR) is the application of telecommunication technology to provide long-distant support, assessment, and intervention to individuals with disabilities (Ricker et al., 2002). The field of TR exists under the assumption that the barrier of distance can be minimized to deliver rehabilitation interventions remotely across the continuum of care (Winters, 2002). Specific TR advantages include: 1) decreased travel from rural communities to specialized urban health centers; 2) enhanced clinical support in local communities; 3) improved access to specialized services; 4) expanded delivery of local healthcare in rural communities; 5) educational benefits for remote clinicians participating in teleconsultations; 6) reduced feelings of isolation for rural clinicians; 7) improved service stability in regions with excessive staff turnover; and 8) multimedia communication (Lemaire, Boudrais, & Greene, 2001). Information technology (IT) is central to TR in minimizing the barrier of distance and achieving these advantages (Bashshur, Shannon, & Sapci, 2005).

The common approach to building an IT infrastructure to support TR application is to purchase IT systems that will create experiences that are similar to those experienced in traditional face-to-face encounters. These systems can typically be deployed quickly and easily to support common tasks and services. For example, popular videoconferencing systems are commonly purchased to provide real-time communication in a remote assessment. The complexity of the TR application determines the number of systems that must be utilized. A simple TR application can employ only one or two systems, while a complex TR application may utilize more than three systems.

Brennan & Linsey (2008) argued that usability of the technology to provide TR is the key to TR's adoption in day-to-day activities. Two components of usability were listed: ease of use and efficiency. In a complex TR application, clinicians are required to use multiple IT systems. These IT systems are not tailored for TR setting; they are usually multi-purpose equipments. For example, the videoconferencing equipment used in TR is the same as the equipment used for providing videoconference in corporate meetings. For these multi-purpose equipments to work, clinicians must be trained to follow the complex steps required to manually set up each piece of equipment.

The use of multiple IT systems to deliver TR application also leads to information being scattered across many systems. To gain access to a client's complete information, clinicians must retrieve data from multiple sources, including printed documents, outcome measurement tool results, and annotations derived from recordings of TR sessions. This scenario increases the potential for latent problems that include but are not limited to: inefficiency in service delivery due to limited

access to data; lost and misplaced data which results in reduction of data integrity and security; and inefficient use of the clinician's time to engage in manual data management.

A solution to mitigate the problems of multiple IT systems is to develop an integrated information management infrastructure. The integrated infrastructure functions as a bridge for the information and data flow between systems supporting TR application. This approach allows the data to be streamlined and stored in a centralized, secure location, thus ensuring the integrity of the data. As a result, the overall usability of the system for clinicians is expected to increase. Proper management of data will also increase the efficiency of the TR application, resulting in the reduction of the total cost of service (Goldschmidt, 2005).

To develop an integrated infrastructure, the IT platform must be able to: bridge multiple IT systems/components; interface with centralized data management system; provide clinicians access to different types of data; and provide access from any location. These requirements make the Internet an obvious platform to build the integrated infrastructure for TR.

Until recently, use of the Internet was not considered an option due to several limiting factors, including small bandwidth size, limited access from rural areas, and lack of integrated environmental support. However, by the end of 2006, access to broadband connections among Internet users in the United States (US) was estimated to reach 80% (Madden, 2006). The availability of these high-bandwidth connections provides a channel for various types of data to be transmitted between locations. The advent of Web 2.0 further increases the appeal of the Internet as a platform for a wide range of services from simple services such as online document storage to demanding, interactive services such as videoconferencing.

METHODOLOGY

Fitting Internet technologies to build an integrated infrastructure to support TR involves extensive customization to properly meet the requirements of a TR application. To overcome this challenge, RERC-TR researchers developed a methodology that simplifies the process of customizing and developing the integrated infrastructure.

THE PITT MODEL

Prior to the formulation of the integrated infrastructure development methodology, we identified five important characteristics for a TR infrastructure: openness, extensibility, scalability, cost-effectiveness, and security. These characteristics were used to develop a model TR

infrastructure that is generalizable across various TR applications, and led to the development of the PITT model (Figure 1):

- **Openness.** Openness denotes the ability of the infrastructure to interface with any IT component required by the TR application and manage data exchanges between each component. This characteristic allows the infrastructure to add or remove components according to the TR application's requirement, including videoconferencing, document management, or task management.
- **Extensibility.** Each TR application has specific needs; these often require customization of the infrastructure. An extensible infrastructure allows customization that conforms to the needs of TR applications, such as modifying the user interface to show only the tools that clinicians need to complete a specific assessment process.
- **Scalability.** The scalability characteristic allows the infrastructure to grow according to the demands of the TR application. A scalable infrastructure allows the addition of new TR sites and services, which may bring new expertise into the service or new populations to be served.
- **Cost-Effectiveness.** The rising cost of healthcare demands that the infrastructure to support TR application be as cost-effective as possible, incurring minimal cost to the TR providers and clients, while maximizing the benefits gained. An example of this characteristic is the use of low-cost open-source components for the infrastructure.
- **Secure.** The increasing demands to protect confidentiality and privacy in a healthcare system and the potential liability issues drive the need for a secure system. The security characteristic has an important role in building the trust that clinicians need to adopt the system into their daily practice. Employing proper security measures, such as utilizing a role-based access system, is an example in creating a secure, trusted, and confidential environment.

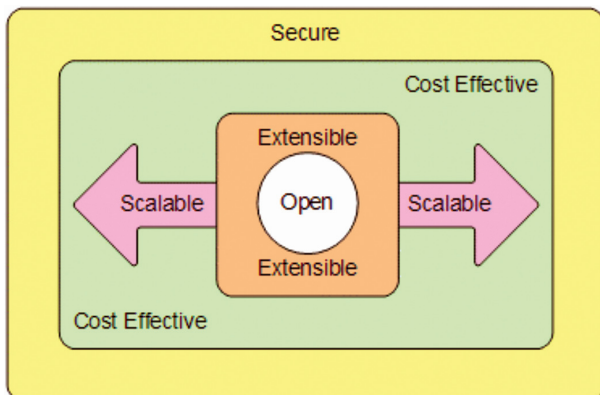


Figure 1. The PITT Model

In multiple IT system environments, each IT component requires specific interfaces to interact with other components. With the PITT Model, these complex interfaces can be simplified by creating a single interface to the centralized IT platform (Figure 2).

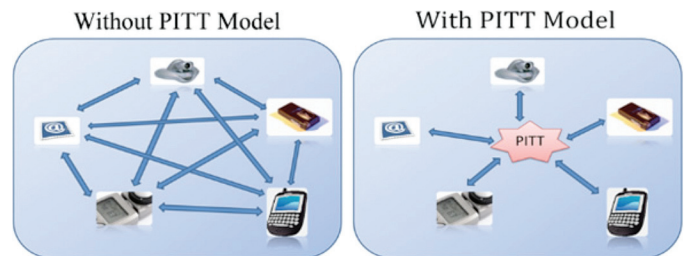


Figure 2. Integration of System: With and without PITT Model

DEVELOPMENT PRINCIPLES OF THE TR INFRASTRUCTURE

- The need of a usable platform and the characteristics presented in the PITT model allows the formation of principles to guide the development of an integrated infrastructure for TR. These guiding principles are applicable across various TR applications:
- **Utilize user-centered design concept:** Users should be actively involved in the design process to ensure compliance of the system with the real needs of TR application.
- **Focus in usability:** The infrastructure should be evaluated and refined to remove problems that hinders users from using the system efficiently and effectively to accomplish their tasks. The system should also be intuitive and easy to use to minimize the need of individual training.
- **Choose proper technology:** The infrastructure and its components should be based on the Internet protocol, including its derived technologies, to absorb the natural advantage of the Internet network, including access from anywhere-anytime, extensible, scalable, and openness.
- **Control cost:** the infrastructure should maximize the use of open-source technology or other low-cost, off-the-shelf technology.
- **Ensure security and confidentiality:** The infrastructure should comply with common security policies. The infrastructure should also allow for new security improvements as they become available.

SYSTEM DEVELOPMENT LIFE CYCLE (SDLC)

The development of the integrated infrastructure follows the standard information system development life cycle methodology. However, TR development principles are utilized in each step of the process to shape the

infrastructure according to TR characteristics. In each cycle, the development of the infrastructure follows these systematic steps:

- Identify and analyze TR application requirements. The first step focuses on understanding the rehabilitation service to identify the TR components required to perform the service remotely. The method to elicit the requirements of the service includes, but is not limited to: daily observation of the face-to-face rehabilitation environment; interview with stakeholders; and analysis of the documents used daily by clinicians.
- Design TR infrastructure based on the requirements. The second step is to create a matrix describing the relationship between requirements and IT components. The matrix consists of information on how each component will be used to support a corresponding requirement and what type of data is required. This matrix directs the selection of IT components for the infrastructure.
- Develop and weave the components into a cohesive infrastructure. The third step focuses on the actual development of the infrastructure. In this step, developers must ensure that each requirement has a matching IT component in the infrastructure. Developers also need to implement security policies into the infrastructure to protect the confidentiality and integrity of information.
- Deploy the infrastructure to support TR application. In the fourth step, developers deploy the infrastructure in all participating TR sites. This step requires developers to understand the limitations of each TR site. Developers need to accommodate these limitations into the infrastructure for successful deployment.
- Conduct a usability study to refine the infrastructure. This step focuses on understanding how the infrastructure is used in daily TR activities. The results are usability recommendations that can be used in the next cycle of the development process to refine the infrastructure.

CASE IMPLEMENTATION: REMOTE DELIVERY OF WHEELCHAIR PRESCRIPTION

The rehabilitation field considers wheelchairs one of the most successful assistive technology devices to improve independence and enhance physical functions (Russell, 2007). Assessing a user's needs and matching them to an appropriate wheelchair is essential to a successful outcome. This process requires clinicians to look beyond the physical needs of the wheelchair user to other external factors, such as the functional environment and funding issues. The delivery of wheelchair prescription services in rural areas is limited due to several issues,

including inadequate availability of clinicians with the proper assessment skills, and their limited knowledge of wheelchair prescription.

Access to clinicians with specific training and knowledge skill sets in wheeled mobility and seating is limited, thus narrowing the locations where individuals with mobility impairments can receive appropriate care. A small number of experts in this specific field are expected to serve 2.2 million people who use wheelchairs for their daily mobility (Kaye, Kang, & LaPlante, 2000). This number will continue to grow as the baby boomer generation comes of age, and individuals increasingly survive traumatic events due to medical advancements.

Individuals with mobility impairments who reside in rural and/or remote areas are often underserved (Cooper, Trefler, & Hobson, 1996; Batavia, Batavia, & Friedman, 2001). To overcome this challenge, TR is viewed as a potential option to deliver clinical service in these areas (Kinsella, 1998). For example, the process of assessing an individual for a wheeled mobility device by a generalist practitioner at a remote clinic can be supported by an expert practitioner through the use of a TR consultation using an integrated infrastructure.

The goal of the integrated infrastructure is to provide expert practitioners real-time access to any client sessions held at the rural clinic (synchronous collaboration), and to support online collaboration efforts to document and archive the results of the sessions (asynchronous collaboration) for clinical processes. In this project, a videoconferencing component is used for synchronous collaboration, and an online portal used for asynchronous collaboration.

STEP ONE: REQUIREMENT IDENTIFICATION AND WORKFLOW ANALYSIS

The following are the requirements identified to support the synchronous collaboration in the remote wheelchair prescription project:

- The need to use remote assessment to expand and support rural clinics by providing expertise from the metropolitan area (Burns et al., 1998);
- The need of high-clarity video streaming between expert clinician and client during remote assessment session (Malagodi, Schmeler, Shapcott, & Pelleschi, 1998);
- The need to share documents during remote assessment session;
- The need to communicate securely for privacy and confidentiality; and
- The need for archiving to enable review of sessions at a later time.

In addition to the synchronous collaboration requirements, the following are the requirements identified to support asynchronous collaboration:

- The need for a document management and collaboration system that is accessible from anywhere, anytime (Lemaire et al., 2001);
- The need to manage any collaboration activities to ensure efficient and timely completion of service (Schein, Schmeler, Brienza, Saptono, & Parmanto, 2008);
- The need to share client information to help any decision making processes; and
- The need to secure the collaboration system to ensure data integrity and confidentiality.

Figure 3 illustrates the team members and workflow of the remote wheelchair prescription project. The project is composed of an expert practitioner from the University of Pittsburgh Medical Center – Center for Assistive Technology (UPMC-CAT) in Pittsburgh, PA, and a multi-interdisciplinary team from a rural clinic.

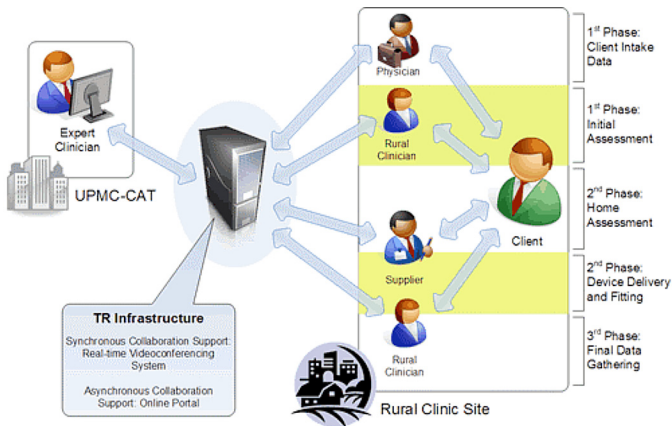


Figure 3. Conceptual Interaction Flow of the Remote Wheelchair Prescription Service Team

Figure 4 lists the phases and activities identified for the workflow in the remote wheelchair prescription service. These activities require support from either the synchronous or the asynchronous collaboration component of the infrastructure, or both. For example, assessing a client's physical ability requires the use of synchronous collaboration support to allow seamless remote interaction between the expert practitioner and the multi-interdisciplinary service team. Creating and storing documentation requires the use of the asynchronous collaboration infrastructure. The fitting and (if needed) reassessment activities require both synchronous collaborative support for assessing the client and asynchronous collaborative support for providing access to client's pre-existing data.

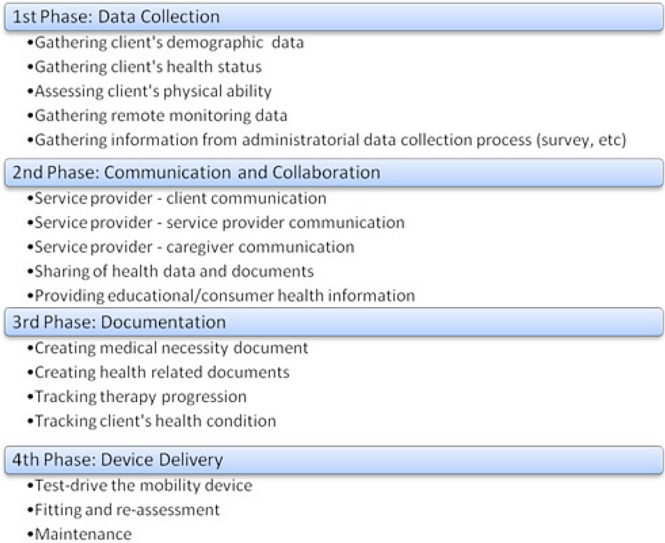


Figure 4. Phases of Remote Wheelchair Prescription Service

STEP TWO: SYSTEM DESIGN

Based on the requirements, a matrix is created to map the workflow with infrastructure components. The matrix ensures that all workflow phases have corresponding support technologies within the infrastructure (Table 1).

Workflow Phase	Components in Infrastructure		
	Videoconferencing System	Data Management System	Database System
Data Collection	- used for real-time interaction between expert clinician and client	- used to create client profile information, including health status and physical abilities - used to share device related information	- used to store client data - used to archive assessment session
Collaboration and Communication	- can be used for virtual conference between clinician and expert clinician outside assessment	- used to share information about client	- used to store new data about client
Documentation		- used to create documents to prescribe device	- used to store prescription documents
Device Delivery	- used for real-time interaction during device fitting	- used to finalize documents about service	- used to store finalized documents

Table 1. Matrix of Phases and Components

Three infrastructure components are identified to support the remote wheelchair prescription project: videoconferencing, content management, and database systems.

STEP THREE: DEVELOPMENT OF COMPONENTS AND INFRASTRUCTURE

VIDEOCONFERENCING COMPONENT

ConferenceXP was chosen as the core of our videoconferencing component. This videoconferencing technology originates from Microsoft Research and is based on AccessGrid (Daw, 2005), an open source web conferencing system developed from the Internet2 project.

In this project, developers redesigned and simplified the interface of ConferenceXP to provide easy access to all real-time interaction features, such as archiving and document sharing tools. Additionally, developers built an interface component to seamlessly connect videoconferencing with the content management system. This interface provides clinicians with easy access to client information stored in the online portal.

DATA MANAGEMENT COMPONENT

The data management component provides a platform to store, manage, and collaborate using stored textual and non-textual data. In the remote wheelchair prescription project, Windows SharePoint Service (WSS) was used to build the online portal (Figure 5).

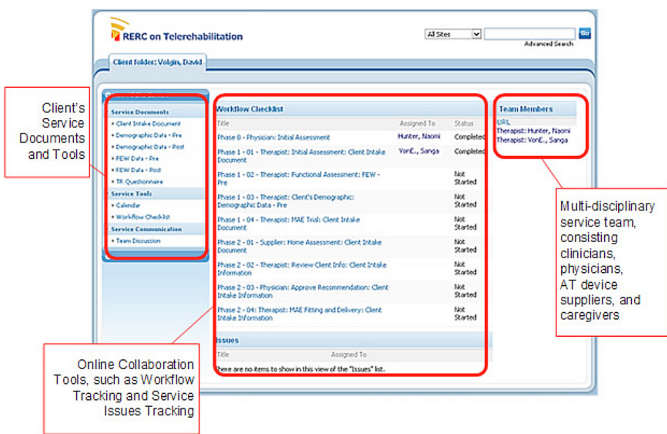


Figure 5. Remote Wheelchair Prescription Online Portal

One of the advantages of WSS was the ability to create Webparts, small modules within the portal designed to do specific tasks. These components are lightweight, can interact with each other, and are reusable across the project. Another advantage was the ability to create automatic workflow tracking. With workflow tracking, the portal can manage documents automatically with little or no intervention required from clinicians. In addition, service team members can track the progress of the service to solve any issues encountered during service delivery.

DATABASE COMPONENT

The database component is used to store any information gathered during service delivery. Information stored within the database comes in many forms, including demographic documents, client intake data, assessment related files, and records of the TR consultation sessions. This information can be retrieved anytime for review at a later point in time.

A role-based access system is employed to protect the database. Information stored in the database can only be retrieved by individual with proper access rights represented by the individual's role in the service.

STEP FOUR: DEPLOYING THE SYSTEM IN PILOT SITES: PA RURAL CLINICS

To deploy this infrastructure, a set of videoconferencing equipment (USB Web Camera, USB desktop microphone, and external speakers) were sent and installed on a personal computer within the RERC-TR and several rural clinics located outside of Pittsburgh, PA. The initial TR consultation efforts with these sites were successful; all participants were able to collaborate in real-time without disruption, both in audio and video. Figure 6 shows a snapshot of the infrastructure being used by practitioners during a remote assessment session. The infrastructure was able to connect an expert practitioner with generalist practitioners from Dubois Regional Medical Center, located in Dubois, PA, 100 miles away from Pittsburgh, PA.

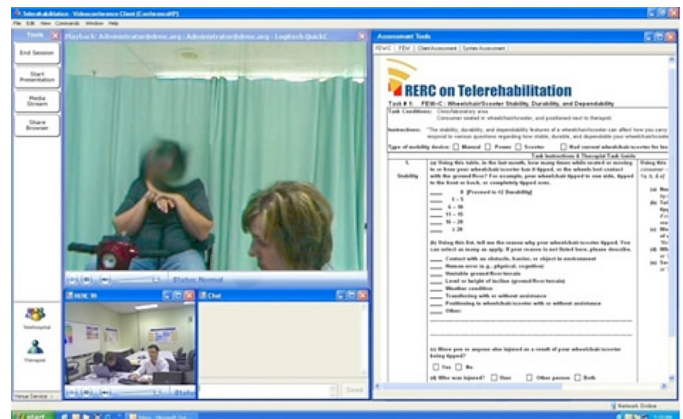


Figure 6. Customized Videoconferencing System

DISCUSSION

TR has obvious advantages in remote or rural areas where there are relatively few experts in a concentrated field. Even in urban areas, the introduction of TR has been shown to speed the referral process, reduce unnecessary referrals, and improve the consistency and quality of healthcare (Lemaire et al., 2001). In this paper, we presented a methodology to build an integrated IT infrastructure, and used the methodology to build an infrastructure to support the remote wheelchair prescription project. We believe that the PITT Model and this methodology will be helpful across other TR applications to further improve healthcare service delivery in remote areas.

LIMITATIONS

Although newer network technologies, such as fiber optics, have become available for commercial use in metropolitan areas, it will take some time for the same technologies to be available in rural areas. However, despite the limited bandwidth, services were still able to be effectively provided (Schein et al., 2008).

FUTURE WORK

Proponents argue that TR integration into mainstream healthcare delivery must be supported by scientific evidence demonstrating its efficacy, effectiveness, and acceptability (Grigsby, Schlenker, Kaehny, Shaughnessy, & Sandberg, 1995; Mair & Whitten, 2000; Whitten & Mair, 2000). This issue is being addressed in the fifth step of the System Development Life Cycle. Future reports will include client perceptions and satisfaction, and the advantages and disadvantages of TR personnel, technology acceptance, and utility in other clinical services.

CONCLUSION

We have shown that the PITT Model can guide the development of an integrated information management infrastructure for TR application. The PITT Model is a design process which focuses on five important characteristics of a TR platform: openness, extensibility, scalability, cost-effectiveness, and security. This model was applied in the development of the infrastructure of a TR application: remote wheelchair prescription. Using these guiding principles, researchers were able to build an integrated information management infrastructure that conformed to the needs of a specific TR application. This infrastructure has been successfully deployed to provide TR services to rural clinics in Western Pennsylvania.

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