

Pervasive Telemedicine System

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Abstract

The Pervasive Telemedicine System focuses on providing medical support to the Pace community at remote campus locations. The nursing school is situated at Pleasantville and Pace has campuses at New York City, Briarcliff, and White Plains. This system proposes to establish the capability for users at the above locations to communicate with the nursing school over a network. The system will be able to provide a remote login for the patient and a local login to the nurse. It will launch a videoconferencing session on both locations, gather necessary consultation information from the patient and transmit the diagnosis of the nurse. The purpose of this system is to build a cost effective system for Pace University utilizing the technology that already exists and provide better care to the Pace community overall. In this paper we provide an insight to some similar telemedicine systems that were initiated in other Universities and are being used to provide healthcare to surrounding areas of the University. We provide detailed comparisons and contrast our system to the existing successful systems. We suggest further scope and management of the project.

1. Introduction

Telemedicine in recent years has become a predominant issue in the health care community due to the advances in technology that can provide patients with faster, cheaper, and easier health care services. We can define telemedicine as using the latest communications technology to provide, enhanced and expedited health care services remotely. This can be accomplished by linking multiple health care systems and clients through visual communication devices for evaluation and diagnoses of a client's ailment. Advances in home health care technology allow a patient to use peripheral devices to collect data that a doctor would get from an in house visit and transmit that data to a health care provider for analysis. Telemedicine also allows health care providers access to remote databases with client information in order to evaluate a client's condition. This technology can be used to broadcast a consultation between providers at facilities in different geographical locations. In addition to remote monitoring, another term used in the Telemedicine field is Telehealth, which is used to describe all the possible

variations of healthcare services using telecommunications.

There are two different kinds of technology that make up most of the telemedicine applications in use today. The first, called store and forward, is used for transferring digital images from one location to another. A digital image is taken using a digital camera, ('stored') and then sent ('forwarded') to another location [2]. This type of technology is useful when the patient does not need an immediate response to a problem. Store and forward technology was used in many of the first telemedicine applications and provides a cheap solution for telecommunicating a diagnosis. One application for this type of solution is Teleradiology, the sending of x-rays, CT scans, or MRIs. This allows medical centers to store and forward these images to anywhere in the world.

The other type of telemedicine solution is a two-way interactive television system that is used when a face-to-face meeting is required. This allows a patient and a doctor to have a consultation via video conferencing technology that allows them to have real time interaction. There are many configurations of an interactive consultation, but most typically it is from an urban-to-rural location. It means that the patient does not have to travel to an urban area to see a specialist, and in many cases, provides access to specialty care when none has been available previously. Almost all specialties of medicine have been found to be conducive to this kind of consultation, including psychiatry, internal medicine, rehabilitation, cardiology, pediatrics, obstetrics and gynecology and neurology [2]. This is the model that our current telemedicine project is based on and will be the focus of this paper.

Due to telemedicine's many applications and potential to dramatically change the health care world many government and private organizations are looking into creating TeleHealth systems. At the University of Kansas Telemedicine Program, telemedicine technology has been used for several years for oncology, mental health care to patients in rural jails, hospice care, and most recently, to augment school health services by allowing school nurses to consult with physicians [2]. The military is also developing telesurgery applications where doctors remotely control robotic arms for emergency surgery on the battlefield [16] [19].

Although telemedicine provides a convenient solution to many health care issues there are still some barriers to

implementing these systems. One such barrier is funding for technology to develop an adequate system. Since these systems usually deal with new types of technology equipment and resources are expensive. Many potential telemedicine projects have been hampered by the lack of appropriate telecommunications technology. Regular telephone lines do not supply adequate bandwidth for most telemedical applications. Many rural areas do not have cable wiring or other kinds of high bandwidth telecommunications access required for more sophisticated uses, so those who could most benefit from telemedicine may not have access to it [2]. Some of these barriers may soon be eliminated with the use of high-speed Internet access. Another barrier would be the legal issue's involved with using telemedicine such as doctors practicing in states that they are not licensed in.

2. Related work

The telemedicine system is here to stay. We are in some of the most exciting times of the telemedicine arena of healthcare. More and more advances in the telecommunication industry along with healthcare and medical industries are being recognized everyday. With the advent of increasing costs in healthcare today, telemedicine affords the industry to be able to lower healthcare costs significantly.

The American Telemedicine Association (ATA), a non-profit organization in Washington, DC is the leading body promoting medical care for consumers and health professionals via telecommunications and deployment of telemedicine throughout the world [1]. ATA seeks to bring together many groups from traditional medicine, academic medical centers, technology and telecommunications companies, e-health, medical societies, government and others to aid the advancement of telemedicine through the professional, ethical and equitable improvement in health care delivery. It promotes research and education including the sponsorship of scientific educational meetings and the Telemedicine and e-Health Journal [1].

With increased funding and interest by the Federal Government, defense sector [15], telecommunications industry and organizations like ATA, there are many universities today researching and implementing a telemedicine system. Some of them are listed below:

Texas Tech University in Lubbock, Texas is recognized as one of the leaders in Telemedicine. Designed in 1990 originally, to connect the four campuses of the Health Sciences Center located in Lubbock, Amarillo, Odessa, and El Paso, it now has a wide variety of programs for different areas of telemedicine like connecting rural areas together, assisted living, training and instructions, telepharmacy, Border telemedicine as

well as other programs. It has been recognized as one of the top 12-telemedicine programs in the world and has been listed in the Telemedicine Hall of Fame [3].

Yale University has a Telemedicine Center that disseminates educational activities at Yale to a wide variety of universities and health care institutions and provides interactive clinical consultations in every specialty. One of their interesting projects was at the Special Olympics connecting the Smilow Field House with the Emergency Radiology Department at Yale New Haven Hospital. Physicians at the Field House used teleradiology equipment to transmit X-rays in as little as 10 seconds each to Yale for consultation with radiologists. Their website says that there are a number of current and pending telemedicine projects at the School of Medicine: the Saudi-US Universities Project (SUSUP), the NASA Spacebridge Project, and other projects connecting Yale to other hospitals in Connecticut and nationwide [4].

East Carolina University successfully has been able to implement a TELE-Homecare - home telemedicine program with Albemarle Home Care in Elizabeth City, NC. This program in rural Eastern North Carolina is designed to increase access to home care for a large underserved patient population in the city. Another program, Eastern AHEC's School Based TeleHealth Program is an interdisciplinary program designed to improve the health status of rural Eastern North Carolina through the use of the North Carolina Information Highway (NCIH) and the World Wide Web. Educational programs are developed and presented by East Carolina University faculty and health care professionals [5].

University of Virginia Health System is now available to patients and other healthcare professionals through the University of Virginia Telemedicine Program. Using advanced computer applications and broadband telecommunications technologies, University of Virginia Health System regularly facilitates communications between remotely located patients and health professionals throughout the Commonwealth of Virginia and beyond through the University of Virginia Telemedicine Network and other telecommunications networks. Their services include providing confidential clinical consultative and medical education services [6].

University of Pennsylvania School of Dental Medicine and Oregon Health & Science University have developed and tested a prototype called Remote Dental Consultation System (RCDS) which provides an easy to use, internet accessible application that general dentists can employ to send consultations to specialists. Full documentation (history, present findings, diagnostics, radiographic and clinical images) is included in a logical, easy to navigate format [7].

Currently the Arizona Telemedicine Program initiated by the University of Arizona is providing medical services

via both real-time and store-and-forward technologies in twenty communities. The Arizona Telemedicine Program has created two additional statewide programs, Project Nightingale and e-Healthcare Arizona. Project Nightingale, created is a unique, dedicated broadband healthcare infrastructure which functions as a telecommunications collaborative providing access to T-1/ATM telecommunications on a private network throughout the state on a cost-sharing basis. e-Healthcare Arizona provides state agencies with a vehicle for collaborating on various programs in disease prevention, public education, correctional telemedicine and, more recently, children's healthcare and home health nursing. In addition, the Arizona Telemedicine Program has recently instituted innovative programs in home health care for patients with artificial hearts awaiting transplantation, patients requiring ostomy home-nursing services, and children in need of occupational and physical therapy. Telenursing services are being implemented in Phoenix schools. The greatest accomplishment of the Arizona Telemedicine Program has been to create strong ties between the University of Arizona College of Medicine, various healthcare providers, and the state legislature are fostering a high level of awareness of the importance of telemedicine and e-health to achieving the state's healthcare goals [8].

A point and click software developed at Penn State for use with handheld computers is enhancing patient care by helping ambulance personnel collect data more efficiently and provide more information to hospital emergency departments [9].

A veterinary telemedicine research and development project entering its second stage at Kansas State University is attempting to create the infrastructure to monitor the health of cattle remotely, and if the researchers are successful, the system would give livestock producers and veterinarians heads-up to emerging Foot and Mouth disease for the cattle [10].

More information regarding other telemedicine projects in US and other countries can be found in [11]. It is categorized under university related projects and other funded projects. More information about different programs in Universities and States has also been published and can be obtained from [15][17].

2.1. Related work in other countries

The Memorial University of Newfoundland in Canada has developed a system called Telemedicine TETRA. Their services include consultation. Audio and video conferencing, medical data transfer, audio graphics and instructional design. Their current research includes Rural Teleconferencing project for Breast Cancer and is testing

a tele-consultation system to link a remote Labrador nursing station (Black Tickle) to Melville Hospital in Goose Bay, using analog telephone lines [12].

2.2. Related work in defense

A wide variety of defense projects have been funded and developed by the Federal Government to implement and research telemedicine development. Some of them are listed in the reference section. Many small communities are also looking to developing their own telemedicine systems to cater to their immediate needs [16], [17], [19].

2.3. Laws governing telemedicine

The Center for Telemedicine Law (CTL) is a non-profit entity founded by organizations to provide high quality patient services through the use of telemedicine systems throughout the United States and the world. It gathers and analyses information related to the legal and regulatory aspects of telemedicine. Because uncertainty about legal and regulatory issues often serves as a deterrent to the use of telemedicine, CTL seeks to identify and clarify the legal and regulatory barriers and to offer solutions for overcoming these barriers [13].

3. Methodology

The Pace University Telemedicine System is a web-based portal designed to permit interaction between a nurse and a patient using remote locations at Pace University. With the Telemedicine system the patient does not need to travel to a different campus/location in order to see a nurse, instead the patient can explain his or her symptoms to a nurse over a networked computer. The web portal is built using the Apache Tomcat web-server, with ability to port to any J2EE compatible server along with a robust database to store information.

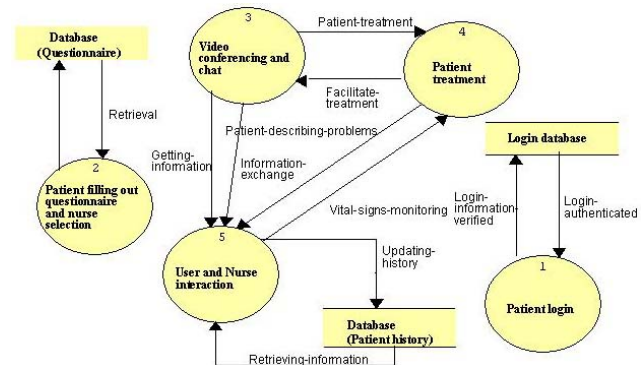


Figure 1. System architecture DFD level 1

The portal is composed of simple functionalities. The system is designed to provide video/audio conferencing

via Microsoft Windows Net Meeting between the patient and nurse. Along with the ability to communicate with each other via video conferencing, the system also enables a nurse to view a patient's record of past visits and history information. The nurse, based on her assessment suggests a referral or a course of action via email.

A new patient to our portal is required to complete personal information forms similar to those requiring completion on a visit to a doctor's office for the first time. If the patient is a recurring patient, they simply log in using a unique username and password they chose when first signing into the system.

The requirements for a nurse to use the system are a little more complicated. A nurse login must be created by a system administrator, which gives the nurse login rights to the system. By doing this, our system maintains a security framework of medical professionals allowed to use it. Once the system administrator sets up the nurse username and password they can log in to the system. The architecture of the system is depicted in the Data Flow Diagram in Figure 1.

In order to create a successful Telemedicine system we must create a user-friendly application that will be accepted by medical practitioners. The GUI design is the key to having a user accept an application. Our system is designed to give the nurse and the patient the ability to easily navigate through the website using the navigation toolbar on the left. Figure 2 shows screen shots of the User Navigation for the Telemedicine portal. As you can see in the screen shot buttons are provided for a user of the system to enter personal, emergency, login, and Insurance information. Once this information has been entered for the patient can consult with a nurse to determine what is wrong. The nurse's navigation allows them to view personal and emergency information as well as register to login. A nurse then has the ability to start viewing patients. At any point either user can log out or return to the home page by clicking the navigation buttons.

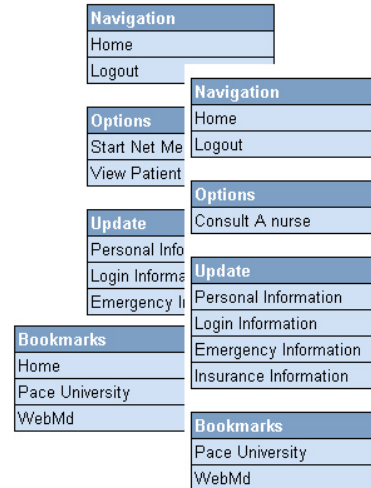


Figure 2. Website Navigation Screen Shots

The privileges include updating a changed address, password or emergency contact information. Only the patient has the ability to update insurance carrier information, which is not required for the nurse.

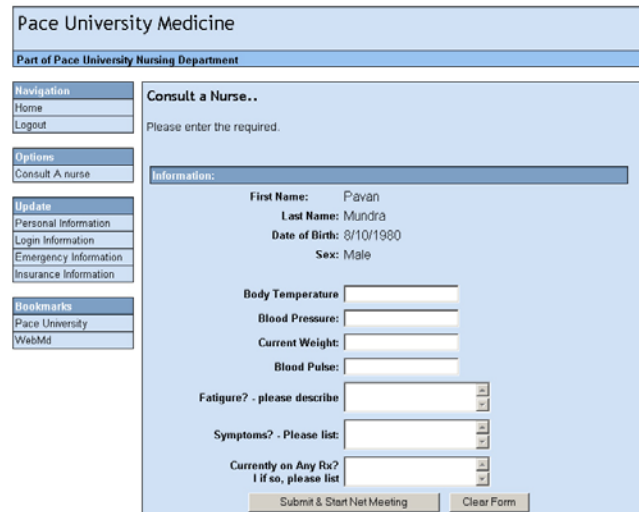


Figure 3. Patient Examination

A visit to a nurse using our system would require the patient to answer a few questions about his current state of health through our web interface as depicted in Figure 3. The patient must give vitals such as body temperature, blood pressure, current symptoms and other ailments before starting a videoconference. These questions are designed to get a general overview of a patient's health, which will help in diagnosing a patient. The answers given by the patient are entered into the database automatically which the nurse can access and review. The system aids the nurse in diagnosing the patient by giving him or her the ability to hear and see the patient as well as

review a patient's record as needed. The nurse then enters the patient's diagnosis into the system. This gives other medical professionals the ability to review the information at a later time. A Net Meeting session can begin as depicted in Figures 4 and 5 after all user information is entered. The nurse and patient can have a face-to-face conversation to determine the best course of action.

Our Telemedicine system implements a queuing system that allows nurses to attend to patients based on first come first serve. Once the nurse is ready to see patients, he/she selects a patient from a drop down list, where the earlier patient shown on the top of the list, and last patient in the bottom of the list. The nurse chooses the patient, from the dropdown and this starts a net meeting session. This process creates a call to the patient waiting for the nurse's attention. While helping the patient, the nurse may look at patient history, to get a better idea of the patient condition.

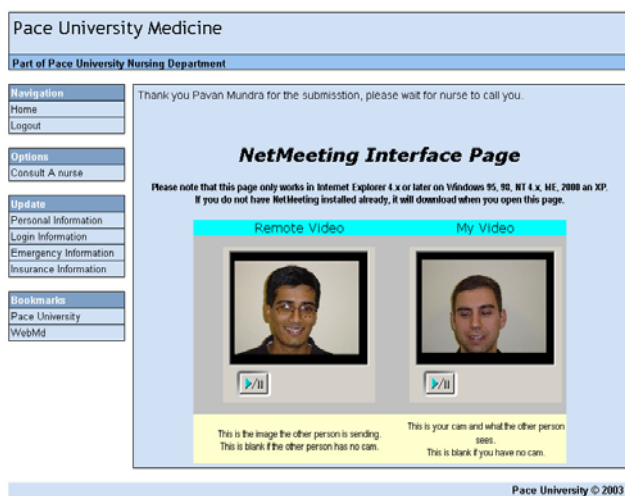


Figure 4. Patient Net Meeting Session



Figure 5. Nurse Net Meeting Session

When comparing the Pace Telemedicine system with other heavily funded systems such as Yale University Telemedicine project [4], designed to transmit X-rays to radiologist stationed in remote locations. We believe that our methodology provides a solid implementation designed without proprietary hardware that is extensible to wide areas of use of Telemedicine. Our system can be used to not only to build first contact with the nurse for general checkup, but as a means to check on outpatients and elderly patents that require guardianship. Since our system is web-based and builds on J2EE MVC architecture with an independent database in the background. It is scalable to fit the needs of the Pace University nursing department or a larger number of users.

The J2EE framework gives future developers the ability to add or change modules using any J2EE technology making the Telemedicine project a scalable enterprise level application. Using this technology also gives us the flexibility to use any database using JDBC connectivity and to also connect to any file system. More functionality like choosing a specific nurse, automatic update of teleconferencing details could be included to improve the overall performance and function of the system.

4. Results and benefits

The Telemedicine project contributes significant methodology for further development and enhancements in telemedicine particularly in the conversion and adaptation of electronic patient records and history. This conversion of records and history will help in expediting emergency situations that require fast accurate information on a patient. The technology can significantly reduce the risk of medical errors due to lack of information or communication. The system can also be expanded to more geographic locations at Pace University and the local community around Pace and can provide local residents with access to specialists that would otherwise not be accessible or would be too expensive. It could reduce the cost of commuting for the patient between campuses or local health care facilities, especially during adverse weather conditions or holidays when the facilities are closed. Telemedicine also provides a way for medical professionals to speed up medical research and innovations by allowing them to share their findings from any location. This could allow doctors from different countries to coordinate research and participate in specialized treatments. It could also reduce the number of nurses on duty in person all the time in all campuses. Finally it could scale down a huge amount of medical expenditure to Pace and the local community.

The project if implemented professionally with the help

of interested telecommunication organizations could provide healthcare benefits to rural areas throughout New York, Westchester and other counties in and around Pace University like most other universities listed above.

The telemedicine system developed by us serves as a starting point upon which Pace University can demonstrate its value to broad constituencies as a clinical research center, a tertiary care facility, and as an educational institution.

5. Conclusions

Telemedicine is undoubtedly the way of the future. Due to rising health care costs and shortages of medical professionals, a need is arising for cheap, efficient medical services. Many universities have taken the opportunity to establish multi-million dollar organizations to meet this need. Pace University should be among those institutions.

In order to continue, we must reiterate what telemedicine should mean to Pace. As stated before, the Pace telemedicine project is to provide health care mainly via video services. This structure is not a simple one but it is the most prevalent and cost effective one to date. Most organizations utilize the video conferencing aspect as their key tool in the telemedicine architecture.

It is important not to underestimate the complexities of a successful telemedicine project. Telemedicine is an attempt to mix human nature with machine. In the majority of these cases, the relationship between patient and computer has been outstanding, but the relationship between administration and those who create the systems have been one of contention. Administrators are quick to lose focus on the goal of telemedicine and in doing so, create discord between the technical and administrative aspects of their systems.

5.1. How to make a telemedicine project work

As with any endeavor, the key to success lies in meeting the objective and hard work. If one group can accomplish a task, there is no reason why another group should fail. There are numerous successful multi-million dollar telemedicine projects. One such institution is the Canadian Telehealth Society, which is a product of the University of Calgary in Canada [22]. The organization defines itself as a "national non-profit organization of individuals and corporations committed to the promotion, education, research and development and diffusion of telehealth." In less than one year, Canadian Telehealth has attracted more than 170 organizations. Each organization pays a small fee for membership (corporate members pay \$200 per year). Canadian Telehealth is also federally incorporated, has an 18-member board, standing committees, a web site with logo plus a newsletter. The

company has sent its members to conferences all around the world and has hosted numerous world conferences in the science of telemedicine.

Canadian Telehealth is not alone. The University Of Arizona College Of Medicine has provided telemedicine services since 1979. The university created the Arizona Health Sciences Center Physician's Resource Service in 1990, which provided over 11,000 consultations last year. In 1996, the Arizona state legislature budgeted \$1.2M to fund the first year of operations for the Arizona Rural Telemedicine Network [8].

Another remarkable institution is the University of Texas at Lubbock, which has been recognized as one of the top 12-telemedicine facilities in the world since 1990 [3].

The preceding information illustrates that telemedicine is not a small time endeavor. Careful planning and consideration must be taken into account to succeed in the telemedicine world. The EHealth Center at KFSH&RC states that telemedicine projects do not happen by accident and need the following [23]:

- Careful planning
- Sound management
- Dedicated health care professionals and support staff
- Commitment to appropriate funding to support capital purchases and on-going operations.
- Management to be dedicated to successful implementation of the program.
- A program director to manage the resources required by the project.

Ehealth states that management is the key to success. The manager must be dedicated to the successful implementation and operation of the program with clear accountability for its operation. The manager has a stake in the project and if it fails, so does the manager.

The telemedicine project should be treated as an organization. Ehealth states that telemedicine organizations should have a program director, a clinical director, an originating site manager and a multi-disciplinary team. The program director is the manager described above. The clinical director should establish a physician liaison in each department or medical specialty, which participates in the telemedicine program. This person is also responsible to train those who use the system. An originating site manager is the person responsible for management of an individual telemedicine site and the multi-disciplinary team is composed of subject matter experts in the realms of technology, akin to the Pace University graduate team assigned to this project.

In addition to the structure of the telemedicine organization, the presentation of the organization is important to its success. According to Dr. Peter

Yellowlees, the Department Head of Psychiatry at the University of Queensland, technical demonstrations are not really the most suitable method to promote the actual use of telemedicine. Only what is shown in the real world would have any real value to companies wishing to participate in telemedicine [24].

Bureaucracy has a role to play in success. Dr. Yellowlees goes on to state, "groups get too over concerned with respect to ethical, legal and confidentiality issues in relation to innovative applications". The telemedicine administrators should concentrate more on promoting the technology than on any other issue.

5.2. How has the Pace University system fared?

In order to take advantage of the opportunities presented by telemedicine, Pace University should consider changing its approach toward the Pace telemedicine project. The key aspects of the project that should be reviewed are the stakeholders of the project, the objective of the project and the presentation of the project.

What the Pace telemedicine group lacked the most was a definable stakeholder to the project. The telemedicine team developed its own requirements due to lack of any outside influence. This fact leaves the project to be biased toward the development team with no input from medical staff. As stated before, telemedicine is a construct of different disciplines. Each discipline must have a representative who is a part stakeholder for the project. In the current scenario, the development and technology stakeholders were present while the medical was absent handicapping the project.

There seemed to be a miscommunication in the objective of the Pace project. The development team had a consensus on what the project should do but the medical side seemed to want different things at different times. This contention could have been resolved with defining an objective acceptable by both parties.

Pace had the opportunity to present the project to the private sector but had to use a technical demonstration for presentation. As stated before, this action is not the best action to take. For the technological industry to get involved, a more realistic approach must be taken. The presentation should not lie in what the project can do but more on what the project can offer as a return for an investment. This fact supports the need to present the telemedicine project in a real life setting instead of an idealistic one. Here is where outside intervention is needed. Graduate students can only present what they have worked on. To have a successful presentation, other members of the project, such as the medical team should also present their needs and how the project satisfies those needs.

5.3. Further scope of the project

Pace is on its way to creating a successful telemedicine endeavor. It is learning from past mistakes and that will help the university to create an excellent project. The telemedicine students offer the following recommendations for future success:

- There must be a board or a committee to regulate the project. With a board, opinions will be unbiased. Also, telemedicine projects utilize a lot of resources from private and government grants. A board will let these resources be distributed evenly.
- In accordance with Ehealth, the project must define an operating director, elected by the board. The director will be held accountable for all aspects of the project, holding total responsibility. The director must also not be a graduate student. He or she must be on the project on a continuous basis with no reward of a grade. The project's success must be the director's only reward.
- There needs to be a clinical stakeholder in the project. The board should elect this director. The stakeholder should also present status reports and reviews to the board. This project should not be considered a part time project.
- The only piece of the telemedicine project to be handled by students will be the multi-disciplinary team. This team consists of the developers and architects. The team will also consider new technologies. Graduate students will fit into this model because the teams can be transient. What is being developed here is that Pace University will become the users of a system that can be continually supported by graduate students.
- Once the organizational aspects are finalized, Pace should consider promoting investors into the project. Again, real life data needs to be displayed. To accomplish this task, Pace must put together a real life system. This system does exist in what already has been done by the current telemedicine students. The only missing part is to apply the current structure to a real life setting.

The good news on this system is that the work has already been started. The current telemedicine team has set up the interactive video, online questionnaire and queuing. The basic structure now exists. What is left now is collaboration with the nursing and technological staff of the University. After this task is accomplished, computers will have to be configured to handle the traffic and the medical equipment. Once the rooms are set up, real life operations can commence and real time presentations can be formulated for potential investors into the project.

Our main recommendation here is not to look at the telemedicine opportunity as a small one. To limit the project will a small scope will no doubt waste time. The project must be considered a full time endeavor with a mix of graduate students, alumni and the medical stakeholders. In this way, Pace University can join the other universities in promoting telemedicine as the wave of the future.

6. Future work

Additional functionalities like transmission and recording vital data including blood pressure, vital signs, ECG using USB portable devices can be embedded directly with the system

A hand-held telemedicine facility could also be explored. The tremendous research and progress of telemedicine in the defense sector using handhelds has even resulted in software giant Microsoft taking interest to develop a new handheld to use in the battlefields specifically for telemedicine. The solution developed by Microsoft allows medical personnel—deployed, on military bases, or at military medical centers—with diagnosis and treatment. Medical personnel also use the solution to record patient clinical encounters and transmit those records to a central repository [18]. Numerous sensors are being developed everyday to deploy various devices into soldiers at a remote location and to sense vital signs and other measurements [16] [18] [19].

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