The Mobile Patient and the Mobile Physician Data Access and Transmission

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One of the most significant factors influencing the practice of medicine is the tremendous increase in personal mobility and the upcoming deployment of a wide array of non-invasive microsensors to monitor a person's condition, along with advances in medical imaging devices. Wireless communications, the Internet, and low-cost air travel has now created a new class of patients, the "mobile sick," and likewise the "mobile physician." This has created the need for mobile monitoring of patients as well as for mobile physician access to medical information, leading to recently developed light-weight, easy-to-wear, and affordable vests. In parallel, smaller medical imaging devices and soon capsule size video cameras for body ducts are producing increasingly large and detailed amounts of imaging data, from which to identify conditions of interest such as malignant tumors.

We present the necessary requirements that current medical information technology infrastructure needs to meet to enable monitoring of mobile patients by mobile physicians, in addition to a timeline user-interface to access patient information anywhere and anytime.

Keywords—**Mobile Patient, Mobile Physician, PDAs, Timelines, User-Interfaces**

I. INTRODUCTION

The very long-range vision into the next 10 to 20 years is that individuals, typically medical patients, will be living in a better world in which they may (A) be monitored on a real-time basis for health related information, essentially any time, any place, by light-weight non-intrusive intelligent body sensors and processors [1]; (B) be scanned for related body objects of concern (e.g., malignant tumors) by future smaller, highly mobile, low-cost image scanning (C) through the prior advances achieve more rapid diagnosis and detection of complications so that early treatment can be initiated with improved health care outcomes, and be relieved from the myriad of time lags and other inconveniences and problems in current health care.

Section II explores the necessary requirements that will need to be met to enable patients and physicians to become mobile. Section III presents a user-interface that we envision in a personal digital assistant (PDA), its capabilities and limits.

II. THE MOBILE PATIENT AND THE MOBILE PHYSICIAN DATA MANAGEMENT REQUIREMENTS

A. The Emerging Mobile Sick and the Mobile Physician

Recently, one of the most significant factors influencing the practice of medicine is the tremendous increase in personal mobility. Wireless communication devices and the relative low costs of air travel have shifted the paradigm from one of local/regional existence to that of global presence. This has affected not only patients but physicians as well. For patients, the increase in mobility manifested as an increase in both business and pleasure travel has created a whole new class of patients, the "mobile sick." Today, patients frequently travel thousands of miles with diseases that previously were thought to limit such activities. Patients now are willing to travel long distances to find the "right" physician and to obtain the

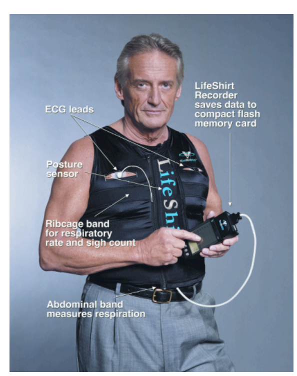

Figure 1. VivoMetrics LifeShirt (courtesy of VivoMetrics)

“best” treatment. Pleasure travel amongst the sick has also increased [2, 3]. For physicians, the increase in mobility allows doctors to travel and to practice medicine in numerous local medical centers, regional medical centers, and even clinics in remote countries. This has created a need for mobile monitoring of patients as well as a need for mobile physician access to medical information.

B. Mobile Medical Devices

The basic technology to take patient monitoring away from hospitals and into the home is commercially available and will continue to evolve. Offline monitoring systems, such as the Health Hero Network [4], CyberNet [5], LifeLink Monitoring [6], Stanford LifeGuard [7], and Vivometrics LifeShirt [8] are now available for use by physicians and patients. Offline monitoring systems are systems that a patient uses to record physiological data and other related data about themselves for a period of time, and then send the collected data to a healthcare professional for analysis. Real-time wireless monitoring is the next step of evolution, where data is gathered wirelessly and analyzed by healthcare professionals on a real-time basis. Wireless technology is now widely available, but will need to be adapted for use in medicine due to privacy, security, and reliability issues surrounding HIPAA legislature [9]. Some commercial and research systems are beginning to develop monitoring devices to support real-time monitoring, such as Lifeguard [7], Vivometrics [10], and DigitalAngel [11].

The LifeShirt System [8, 12] (see Figure 1) is an example of an innovative ambulatory multi-sensor continuous monitoring system for collecting, analyzing and reporting cardiac, pulmonary and kinetic data, capturing an ongoing "movie" of physiologic data rather than episodic "snapshots" collected during periodic office visits. The LifeShirt System is able to collect body data through various sensors, including respiratory bands, which measure pulmonary function (tidal volume, respiratory rate, etc; currently numbering about 24 parameters) as well as electrical activity of the heart (ECG). An on-board PDA (currently a modified Handspring Visor) continuously encrypts and stores the patient's physiologic data on a compact flash memory card. Posture and activity information is also tracked and recorded, and the PDA has an electronic patient diary to record subjective patient data about mood, symptoms and activity. Sensors are woven into the 8-oz shirt around the patient's chest and abdomen. We are currently using the LifeShirt in our research and development [12].

Like the Vivometrics LifeShirt, the LifeGuard system [13] is a compact, portable, and wearable device that gathers a variety of vital signs. Lifeguard is comprised of physiological sensors, a wearable device, and a base station. The wearable device acquires and logs the physiological parameters measured by the sensors. The data can be downloaded or streamed wirelessly to the base station for display purposes and further processing. LifeGuard measures 2 channels of ECG, respiration rate, heart rate, activity, skin temperature, SpO2, and blood pressure.

Research in proactive computing, such as sensor network technologies and context-aware systems, will also add to the quality of monitoring of patients outside the hospital. Intel’s Proactive Health program has focused on caring cognitively declining people with proactive computing [14]. Other projects have focused on seamlessly connecting healthcare professionals with patient data [15-17]. Wireless sensor networks [18] and wearable networks [19, 20] will provide the platform and infrastructure to collect data pervasively. Research in data stream processing will add to our ability to analyze data efficiently and ubiquitously as well [21-23].

Medical imaging has also made advances in regards to mobility. Smaller, more mobile and less expensive imaging devices [24] are beginning to be deployed in more locations. Many of these imaging scanning devices will be without physicians and highly trained health-care individuals being physically in the vicinity.

C. Summary of Requirements and Expectations

The emergence of new technologies to enable mobility for the patient and the user are now emerging and

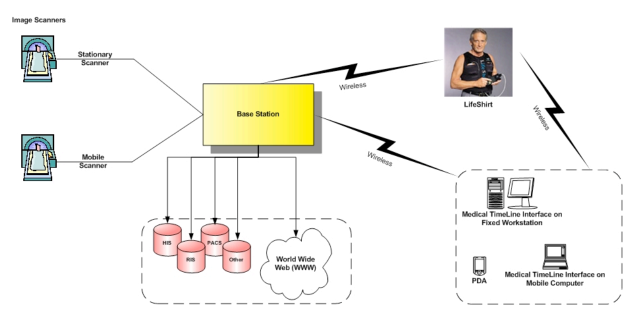

Figure 2. The requirements for the mobile patient and physician

becoming evident. Figure 2 summarizes the challenge and need for the integration of these new technologies. Stationary and mobile scanners will provide more frequent high-resolution imaging scanning. Devices like the LifeShirt will provide continuous ambulatory monitoring of mobile patients.

Remote devices and PDAs will be a major complement to a physician's available PACS [25], HIS, RIS, the Web, and imaging workstations and related tools in the office and medical center [26]. The physician and others of concern will need to have two-way wireless communication of multimedia data and voice data with the mobile patient, focusing on the body sensor data streams and medical images. Physicians should be able to command turning on/off sensors, as patients will not know what is pertinent or not at specific times. The physician should get thumbnails of whole images from on-board the patient and/or from pertinent medical sites and then indicate what regions of interest or tumors to receive in full high quality detail. As Figure 2 shows, the amount of potential data sources may be numerous (e.g., many different types of imaging scanners, medical sensor devices, existing database management systems, etc), facilitating the need to develop some type of common interface that would lie on top of these data sources, such as DICOM [27].

Figure 2 also shows that much of the communication among these devices will eventually occur wirelessly since most users of these devices will be mobile. Typical small sensors and processors such as PDAs will continue being supported into the foreseeable future by very limited low power and rather short-lived batteries, and one of the largest consumers of such power is the transmission and receipt of data [28, 29] Secondly, the commercial cost of wireless Internet access has a large premium on volumes of data beyond a few megabytes [30]. Wireless communication in such a setting will have to take into account security, latency, connection loss, handoffs, and other issues.

III. TIMELINE AND PDA USER-INTERFACES

A patient's medical record is a history of clinical events over time. We will consider the timeline paradigm, user interface, and visualization for such medical records [31, 32], and integrate textual, alphanumeric and imaging data in accordance to a database model that organizes data around a patient's medical problems [33, 34] . A basic TimeLine view previously has been developed to access medical records as if all the data were in one single location, while in reality the data is generated and stored in a variety of heterogeneous hardware and software systems and organizational units in the medical center (e.g., PACS, RIS, HIS, etc). The next challenge we are addressing is to able to adapt the TimeLine user-interface, originally developed for high-powered workstations with large displays, for handheld devices with much smaller screen-sizes and a limited user-interface, enabling the physician to become much more mobile than he is now.

Figure 3 shows screenshots of the current implementation of the Pocket TimeLine, which is a Java servlet-based application. A demo is available at [35]. This interface allows users to view selected portions of the patient medical record across time, including previously stored data streams from the LifeShirt and other streaming data sensors. It also enables users to view low-resolution images of an entire medical image as well as graphs of LifeShirt data. Future implementations will enable users to zoom in on selected areas and view higher resolution images of that area. Information that will be available to the mobile physician in future implementations includes the more traditional medical histories, reports, and laboratory test results.

A desktop version of the TimeLine interface was already developed on the Java platform [36]. We considered implementing the handheld version of the TimeLine interface by simply porting the desktop Java implementation to a Java virtual machine on the PocketPC platform. However, it was deemed infeasible due to the lack of user-interface technology, such as Swing [37], on the J2ME platform (the mobile device version of Java) [38]. Thus, we decided to implement the handheld TimeLine using dynamically generated HTML pages from a Java servlet, leveraging the existing Java infrastructure we developed for the original TimeLine application.

The design tradeoffs when developing a web-based handheld timeline revolves mainly on the limited screen space available on the device and the functionality that webpages provide for. On the desktop TimeLine, users are able to view large spans of time and all the events that occur in that time interval simultaneously, due to the larger screen space. However, on a handheld device, we have to accommodate large spans of time on a small screen while maintaining readability. Thus, simply shrinking a timeline (including fonts and icons) is not an acceptable solution. Alternatively, a time span can be partitioned into several HTML pages, where only one page for a sub-interval of the entire time span is viewed at a time. However, if there are large gaps in between events, many pages will simply be blank and yield no useful information. Furthermore, the visual temporal relationships among events that appear on different pages are lost to the user. Another possible solution is to maintain items that require readability (e.g., text and icons) at readable levels while scaling everything else (e.g., resolution of a time span) down. As a result, the size of the font and the icons within the timeline would be exaggerated compared to the time span scale, yielding only relative temporal visual relationships (e.g., event A takes longer than or occurs before event B), which is the approach we have taken with the current implementation. The drawback is that users can no longer estimate absolute distances in time visually (e.g., event A is 20 minutes long). Furthermore, text and icons may become too cluttered with one another if many events occur close together in time. In future implementations, we can alleviate this problem by replacing clustered icons with a single summary icon that if the user clicks on, a new timeline with an expanded timescale is shown with only the originally clustered icons.

The second design tradeoff that will need to be resolved in future implementations is the user-interface capabilities of HTML. On the desktop version, real-time data can be displayed as quickly as data arrives to the desktop TimeLine application. However, since we are taking a web-based approach for the handheld platform, the data would arrive on a Java servlet [39] and a new HTML would have to be generated and sent to the handheld device. Because of the overhead involved, we envision that the user-interface on a handheld device cannot be updated in real-time but rather at fixed time intervals determined by the user or the system.

IV. Conclusion

We have presented several advances to answer some of the problems presented by the advent of the mobile patient and the mobile physician. We are pursuing an intuitive user-interface based on the timeline paradigm for the handheld device. With these enabling technologies, patients and physicians can become mobile.

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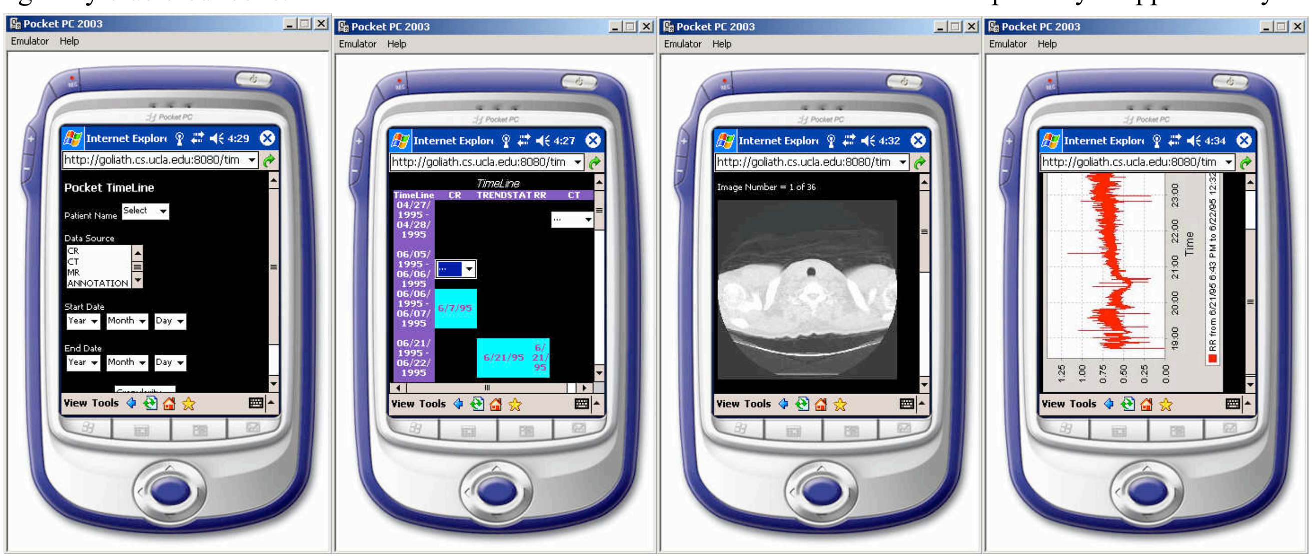

(a) (b) (c) (d)

Figure 3. (a) The mobile physician selects the patient, the data sources, and the time span of interest from the main menu. (b) Given the inputs provided in the main menu, the system creates a vertical timeline of patient records (e.g., CR, trend statistics, RR intervals, and CT records). One of the capabilities of the Pocket TimeLine is to be able to view images, shown in (c), and to view graphs of data generated by the LifeShirt, shown in (d) by selecting the appropriate records from the timeline.

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REFERENCES

[1] Siemens, "Why Health Care is Coming Home," [Online] Available: http://w4.siemens.de/FuI/en/archiv/zeitschrift/heft2_98/artikel04/, 1998.

[2] E. A. Weiss, "Medical considerations for wilderness and adventure travelers," *Med Clin North Am*, vol. 83, no. 4, pp. 885-902, 1999.

[3] R. L. Bratton, "Advising patients about international travel. What they can do to protect their health and safety," *Postgrad Med*, vol. 106, no. 1, pp. 57-64, quiz 143, 1999.

[4] Health Hero Network Inc, "Health Hero Network," [Online] Available: http://www.healthhero.com, 2004.

[5] L. Versweyveld, "Cybernet Medical awarded patent for in-home patient monitoring technology and equipment," *Virtual Medical Worlds*, 2002.

[6] LifeLink Monitoring, "Lifelink Telemonitoring," 2004.

[7] Stanford University, "LifeGuard: Wireless Personal Physiological Monitor," [Online] Available: http://lifeguard.stanford.edu/, 2004.

[8] Vivometrics Inc, "Vivometrics Continuous Ambulatory Monitoring," [Online] Available: http://www.vivometrics.com/site/index.html, 2004.

[9] T. D. Moore and R. P. Wesson, "Issues regarding wireless patient monitoring within and outside the hospital," presented at International Conference on the Management of Heatlhcare Medical Technology, Chicago, Illinois, 2002.

[10] R. Ekhtiar and C. DiRamio, "Vivometrics and Siemens Team Up to Protect First Responders By Monitoring Physiology and Environment During Shadow Bowl," [Online] Available: http://www.vivometrics.com/site/press_pr20030123.html, 2003.

[11] Digital Angel Corporation, "DigitalAngel.net," [Online] Available: http://www.digitalangel.net/, 2004.

[12] Vivometrics Inc, "Three More Studies Use LifeShirt System to Assess Treatment Protocols," *Ambulatory Intelligence - The Journal of Ambulatory Monitoring*, vol. 1, no. 1, 2002.

[13] NASA Astrobionics, "LifeGuard Vital Signs Monitoring System," [Online] Available: http://lifeguard.stanford.edu/lifeguard_flyer.pdf, 2004.

[14] Intel, "Proactive Health," [Online] Available: http://www.intel.com/research/prohealth/, 2004.

[15] M. Ancona, G. Dodero, F. Minuto, M. Guida, and V. Gianuzzi, "Mobile computing in a hospital: the WARD-IN-HAND project," presented at ACM symposium on Applied computing, Como, Italy, 2000.

[16] M. Bang, A. Larsson, and Eriksson, "NOSTOS: A Paper-Based Ubiquitous Computing Healthcare Environment to Support Data Capture and Collaboration," presented at AMIA Symposium, 2003.

[17] M. A. Munoz, M. Rodriguez, J. Favela, A. I. Martinez-Garcia, and V. M. Gonzalez, "Context-Aware Mobile Communication in Hospitals," *IEEE Computer*, vol. 36, no. 9, pp. 38-46, 2003.

[18] Center for Embedded Network Sensing, "Research and Technology," [Online] Available: http://www.cens.ucla.edu/Research/index.html, 2004.

[19] Georgia Tech, "Georgia Tech Wearable Motherboard," 2004.

[20] R. L. Ashok and D. P. Agrawal, "Next-Generation Wearable Networks," *IEEE Computer*, vol. 36, no. 11, pp. 31-39, 2003.

[21] J. E. Gehrke, "Towards Sensor Database Systems," presented at NSF IDM, Seattle, Washington, 2003.

[22] J. M. Hellerstein, "Adaptive Dataflow: Eddies, SteMs and FLuX," presented at NSF IDM, Seattle, Washington, 2003.

[23] R. Motwani, J. Widom, A. Arasu, B. Babcock, S. Babu, M. Datar, G. Manku, C. Olston, J. Rosenstein, and R. Varma, "Query Processing, Resource Management, and Approximation in a Data Stream Management System,"

presented at Conference on Innovative Data Systems Research, 2003.

[24] Siemens, "Somatom SMILE," [Online] Available: http://www.siemens-ct.com/products/somatom_smile., 2003.

[25] O. Ratib, "PACS @ UCLA History and Current Status," [Online] Available: http://www.radsci.ucla.edu:8000/academic/IHE_workshop_WebPages/UCLAPACS_History_IHE_files/tsld001.htm, 2003.

[26] O. Ratib, J. M. McCoy, D. R. McGill, M. Li, and M. A. Brown, "Use of personal digital assistants for retrieval of medical images and data on high-resoultion flat panel displays," *Radiographics*, vol. 23, pp. 267-272, 2003.

[27] NEMA, "DICOM," [Online] Available: http://medical.nema.org/, 2004.

[28] Dell, "Dell Handhelds," [Online] Available: http://www1.us.dell.com/content/products/compare.aspx/handhelds?c=us&cs=04&l=en&s=bsd, 2004.

[29] R. Kravets and P. Krishnan, "Power management techniques for mobile communcation," presented at ACM/IEEE International Conference on Mobile Computing and Networking, Dallas, Texas, 1998.

[30] T-Mobile, "T-Mobile Internet Plans," [Online] Available: http://www.t-mobile.com/plans/internet/?blnOverride=False, 2004.

[31] D. Aberle, A. Bui, E. Kleerup, J. Goldin, M. McNitt-Gray, M. S. Brown, and A. F. Cardenas, "TimeLine: A Multimedia Problem-Centered Interface for Healthcare," presented at Computer Aided Radiology Symposium, Paris, France, 1999.

[32] C. Plaisant, R. Mushlin, A. Syder, J. Li, D. Heller, and B. Shneiderman, "LifeLines: Using Visualization to Enhance Navigation and Analysis of Patient Records," presented at American Medical Informatics Association Annual Fall Symposium, Orlando, Florida, 1998.

[33] A. Bui, D. Aberle, J. Goldin, M. McNitt-Gray, A. F. Cardenas, E. Kleerup, and O. Ratib, "TimeLine: A Multimedia, Problem-centric Visualization of Patient records," *Journal of American Medical Informatics Association*, 1999.

[34] A. Bui, D. Aberle, M. McNitt-Gray, A. F. Cardenas, and J. Goldin, "The Evolution of an Integrated Timeline for Oncology Patient Care," presented at American Medical Informatics Association Annual Meeting, Orlando, Florida, 1998.

[35] Multimedia Stream System, "Pocket TimeLine," [Online] Available: http://goliath.cs.ucla.edu:8080/timeline/servlet/servlet.TimeLineServlet, 2004.

[36] Multimedia Stream System, "Medical TimeLine Demo," [Online] Available: http://goliath.cs.ucla.edu/MedicalTimeLine/, 2004.

[37] Sun Microsystems, "Java Foundation Classes (JFC/Swing)," [Online] Available: http://java.sun.com/products/jfc/index.jsp, 2004.

[38] Sun Microsystems, "Java 2 Platform, Micro Edition (J2ME)," [Online] Available: http://www.java.sun.com/j2me/index.jsp, 2004.

[39] Sun Microsystems, "Java Servlet Technology," [Online] Available: http://java.sun.com/products/servlet/, 2004.