A Prototype System for Heterogeneous Data Management and Medical Devices Integration in Trauma Resuscitation

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Abstract

We propose a system for information acquisition, integration and presentation to support situation awareness during trauma resuscitation. The system consists of (a) medical devices for data acquisition, (b) a database and middleware applications for storing and processing data, and (c) a computer coupled with a large wall display for data presentation. We discuss the initial design of this system and the planned evaluation and implementation steps in the future.

Keywords: heterogeneous data, system architecture, healthcare, trauma resuscitation

Introduction

Trauma resuscitation is a safety-critical medical domain, with frequent decisions being made rapidly within a short period of time (on average 20 to 30 minutes) (Faraj & Xiao, 2006). This fast-paced and critical nature of work requires an overall situation awareness of the patient status and team activities during resuscitation. To maintain situation awareness, team members must obtain and share a large amount of diverse information in a timely fashion. Even so, information gathering and sharing are currently minimally supported by information and communication technology (ICT). Trauma teams primarily rely on verbal communication to share information and team leaders rely on short-term memory for information retention. Although introducing ICT in this domain poses many challenges—it may, for example, require changes in the current work practices—we believe that implementing ICT could facilitate information flow, improve situation awareness, and support decision making.

Our long-term research goal is to design and develop ICT solutions to improve situation awareness in high-risk and safety-critical medical settings. In this poster, we focus on designing a system to allow for acquisition and integration of heterogeneous information, and to present the integrated information to trauma teams in real time. The key contributions of this poster are: (1) system requirements for technologies to support situation awareness and decision making in an emergency medical domain. (2) Initial design of a prototype system for real-time information acquisition, integration and presentation.

Related Work

Information technology has been used for optimal data acquisition, integration and presentation in a number of medical and non-medical domains (Bardram et al., 2006; Heath & Luff, 1992; Hourizi & Johnson, 2001; Hutchins, 1995; Mumaw et al., 2000). Despite these efforts, trauma resuscitation remains one of the few information-intensive work environments with minimal ICT support. Several attempts have been made to introduce computer-based decision support systems in resuscitation areas, but they have not yet yielded optimal outcomes (Berlin et al., 2006; Fitzgerald et al., 2011). The key reasons for the lack of success include the challenges of capturing real-time data from diverse sources (Sarcevic et al., 2012), and integrating these disparate data in a dynamic environment (Barthell et al., 2004; Berlanga et al., 2008; Halevy, 2005). The increasing use of technologies, such as radio frequency identification (RFID)

(Fry & Lenert, 2005) and personal digital assistants (PDAs) (Anantharaman & Swee, 2001) in medical domains provides an opportunity for exploring automatic techniques for capturing data in real time. Large wall displays, on the other hand, allow for efficient data presentation and visualization, and the effectiveness of this approach has already been evaluated in several medical domains (Bardram et al., 2006; Bitterman, 2006; Parush et al., 2011). Coupling computerized data entry using medical devices with large wall displays offers a mechanism for providing additional teamwork support during trauma resuscitation.

System Requirements: Information Acquisition and Sharing

The initial design of our prototype system is based on in-depth field studies conducted at two Level I trauma centers over the past five years (Sarcevic & Burd, 2008; Sarcevic & Burd, 2009; Sarcevic et al., 2012). These studies revealed several challenges in information acquisition and sharing during resuscitations.

Incomplete and Missing Information

En route communication between Emergency Medical Services (EMS) paramedics transporting the patient and the emergency department (ED) receiving the patient is a critical source of information about the incoming patient. This pre-hospital information is used to formulate initial decisions about treatments, resources, and needed personnel (Sarcevic & Burd, 2009; Sarcevic et al., 2012). Our field studies have shown that only a small portion of this information reaches the trauma team leader before patient arrival; the rest is available from the EMS report upon patient arrival. The trauma leaders we interviewed expressed the need for more detailed and timely pre-hospital information to aid their initial decisions. This finding led us to consider approaches for automatic capture and display of pre-hospital information as it is being communicated en route.

Information Overload and High Mental Workload

During resuscitation, the team collects and shares a large amount of information about the patient status and team activities. We found that a team leader manages about 60 different information types in a typical event, including patient demographics, initial status, injury and medical history, vital signs, evaluation findings, and patient reactions to treatments (Sarcevic & Burd, 2008; Sarcevic et al., 2012). Interviews with team leaders also showed that managing multiple patients increases the difficulties in gathering and retaining patient information (Sarcevic et al., 2012). Because there are no mechanisms by which this information is acquired, integrated and stored, the leaders mainly rely on their working memory to process information. Sole reliance on working memory, however, increases the mental workload of team leaders, leading to diagnostic errors. This finding led us to consider mechanisms for providing external memory aids to support rapid acquisition and processing of information.

Inefficient Information Capture Techniques

The current low-tech techniques for capturing information during trauma resuscitation cannot meet the needs of the rapidly changing environment. For example, fluid dosage administered to the patient requires constant monitoring. In the current practice, however, the nurse responsible for administering medications also monitors the progression of the fluid drip, making the information about the fluid status difficult to obtain in a timely fashion. More recently, RFID technology has been adopted for monitoring medication and fluid administration in critical care units (Ohashi et al., 2008). We believe that high-tech approaches such as RFID have the potential to increase efficiency and accuracy of information capture in trauma resuscitation.

Based on our findings, we propose a computerized decision-support system that can acquire, integrate and present critical patient information in real time to address the identified challenges and support teamwork during trauma resuscitation.
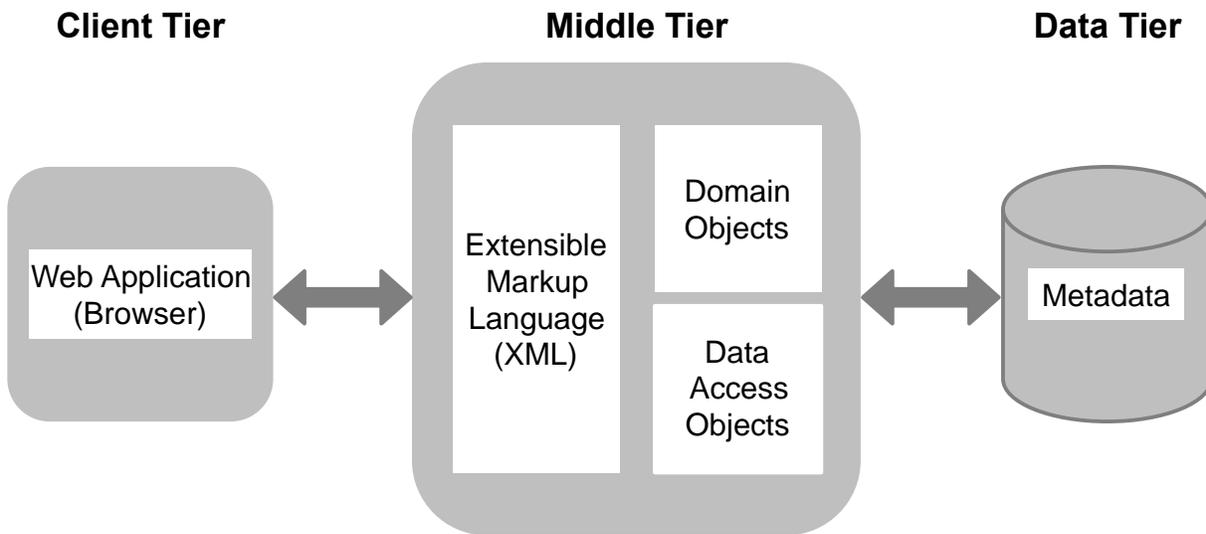
Client Tier **Middle Tier** **Data Tier**

Figure 1: The three-tier architecture of our prototype system.

A Prototype System for Managing Information during Trauma Resuscitation

The system architecture is the technological core that allows the optimal management of information (Hernando et al., 2008). The architectural design should make the system easy to deploy, scale, maintain, and enhance. The most commonly used application for developing system architecture is a component-based, three-tier model, which provides several benefits, including reusability, manageability, flexibility and scalability (Chu & Cesnik, 2000; Komatsoulis et al., 2008). This model divides a system into three subsystems or tiers: (1) the client tier provides a user with access to the system, (2) the data tier stores data in a relational database management system (RDBMS), and (3) the middle tier defines rules and algorithms for data processing.

Given the complexity of our application domain, we found the three-tier model the most appropriate for architectural design of our system (Figure 1). We selected a web-based application for the client tier because it allows portability and flexibility on the client side when accessing the system. For the middleware application, we adopted Extensible Markup Language (XML) following the Simple Object Access Protocol (SOAP) standard. By doing so, users can use a web client efficiently to communicate with the RDBMS.

The core component for processing and managing data in our system consists of a database, a Web server, and middleware applications located on the hospital server (Figure 2). This core system component is dedicated to processing incoming data from medical devices and providing the synthesized data to trauma teams via the display. The current system integrates three medical devices—EMS terminal, RFID scanner, and Lab computer—for obtaining different data types and transmitting them to the server (Figure 2). The integration of additional devices is planned for the future. In particular, the EMS terminal allows EMS paramedics to enter pre-hospital data that can be fed directly to the system and shown on a large wall display in the emergency room. RFID scanner collects data from the environment, including objects in use and administered medications and fluids, and presents this information directly to the team via the display. The lab computer is used for entering lab results, such as those obtained from blood draw, which are then fed directly to the system and shown on the display.

Conclusion and Future Work

The proposed system has the potential to support the work of trauma teams by acquiring, synthesizing and presenting critical patient information in a timely fashion. The system can also be used as an external memory aid to help trauma teams, and leaders in particular, acquire and process information needed for decision making.
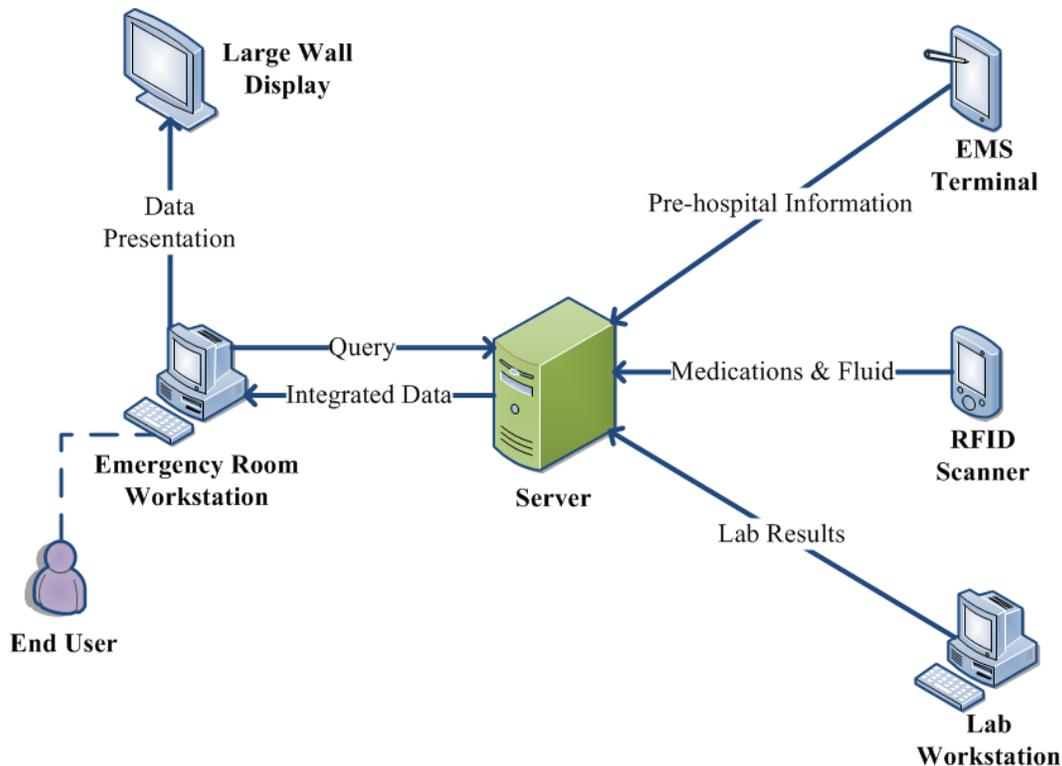
Figure 2: Proposed infrastructure for our system.

Our next step is to assess the feasibility of the proposed system using a series of focus groups with trauma team members. In doing so, we plan to gather additional design requirements and to evaluate the extent to which the system affects current work practices. In addition, we will address several technical challenges, including (1) accurately extracting useful information from unstructured or semi-structured communication data, (2) semantically integrating heterogeneous data from different devices and sources, and (3) efficienlty retrieving and presenting information queried by trauma team members.

References

Anantharaman, V. & Swee Han, L. (2001). Hospital and emergency ambulance link: using IT to enhance emergency pre-hospital care. *International Journal of Medical Informatics 61*, 2-3, 147-161.

Bardram, J.E., Hansen, T.R., & Soegaard, M. (2006). AwareMedia: A shared interactive display supporting social, temporal, and spatial awareness in surgery. *Proceedings of ACM CSCW 2006*, 109-118.

Barthell, E. N., Coonan, K., Finnell, J., Pollock, D., & Cochrane, D. (2004). Disparate systems, disparate data: integration, interfaces, and standards in emergency medicine information technology. Academic Emergency Medicine 11, 11, 1142-1148.

Berlanga, R., Jimenez-Ruiz, E., Nebot, V., Manset, D., Branson, A., Hauer, T., et al. (2008). Medical data integration and the semantic annotation of medical protocols. 21st IEEE International Symposium on Computer-Based Medical Systems, 644-649.

Berlin, A., Sorani, M., & Sim, I. (2006). A taxonomic description of computer-based clinical decision support systems. Journal of Biomedical Informatics 39, 6, 656–667.

Bitterman, N. (2006). Technologies and solutions for data display in the operating room. Journal of Clinical Monitoring and Computing 20, 3, 165-173.

Chu, S., & Cesnik, B. (2000). A three-tier clinical information systems design model. International Journal of Medical Informatics 57, 2–3, 91-107.

Faraj, S. & Xiao, Y. (2006). Coordination in fast-response organizations. Management Science 52, 8, 1155-69.

Fry, E. A. & Lenert, L. A. (2005). MASCAL: RFID tracking of patients, staff and equipment to enhance hospital response to mass casualty events. Proceedings of AMIA Annual Symposium, 261-265.

Fitzgerald, M., Cameron, P., Mackenzie, C., Farrow, N., Scicluna, P., Gocentas, R., et al. (2011). Trauma resuscitation errors and computer-assisted decision support. Archives of Surgery 146, 2, 218-225.

Halevy, A. (2005). Why your data won't mix. Queue 3, 8, 50-58.

Heath C. & Luff, P. (1992). Collaboration and control: Crisis management and multimedia technology in London underground line control rooms. Computer Supported Cooperative Work 11, 1-2, 69-95.

Hernando, M. E., Pascual, M., Salvador, C. H., Garcia-Saez, G., Rodriguez-Herrero, A., Martinez-Sarriegui, I., & Gomez, E. J. (2008). Definition of information technology architectures for continuous data management and medical device integration in diabetes. Journal of Diabetes Science and Technology 2, 5, 899-905.

Hourizi, R. & Johnson, R. (2001). Unmasking mode errors: A new application of task knowledge principles to the knowledge gaps in cockpit design. Proceedings of INTERACT 2001, 255-262.

Hutchins, E. (1995). How a cockpit remembers its speeds. Cognitive Science 19, 3, 265-288.

Komatsoulis, G. A., Warzel, D. B., Hartel, F. W., Shanbhag, K., Chilukuri, R., Fragoso, G., et al. (2008). caCORE version 3: Implementation of a model driven, service-oriented architecture for semantic interoperability. Journal of Biomedical Informatics 41, 1, 106-123

Mumaw, R.J., Roth, E.M., Vicente, K.J., & Burns, C.M. (2000). There is more to monitoring a nuclear power plant than meets the eye. Human Factors 42, 1, 36-55.

Ohashi, K., Ota, S., Ohno-Machado, L., & Tanaka, H. (2008). Comparison of RFID systems for tracking clinical interventions at the bedside. Proceedings of AMIA Annual Symposium, 525–529.

Parush, A., Kramer, C., Foster-Hunt, T., Momtahan, K., Hunter, A., & Sohmer, B. (2011). Communication and team situation awareness in the OR: Implications for augmentative information display. Journal of Biomedical Informatics 44, 3, 477-485.

Sarcevic, A. & Burd, R. S. (2008). What's the story? Information needs of trauma teams. Proceedings of AMIA Annual Symposium, 641-645.

Sarcevic, A. & Burd, R. S. (2009). Information handover in time-critical work. Proceedings of ACM GROUP 2009, 301-310.

Sarcevic, A., Zhang, Z., & Kusunoki, D. (2012). Decision making tasks in time-critical medical settings. Proceedings of the ACM GROUP 2012, in press.

Sarcevic, A., Weibel, N., Hollan, J., & Burd, R.S. (2012). A paper-digital interface for information capture and display in time-critical medical work. Proceedings of the 6th International Conference on Pervasive Computing Technologies for Healthcare - Pervasive Health, 17-24.