floor model, RFID, Wi-Fi, path tracking, ergonomic, user interface, space & time pattern analysis, medical applications

Marina GAVRILOVA[*], Shikha NAYYAR[*]
Jonathan GILGEN[**], Ottar JOHNSON[**], Bill GHALI[*]

ERGONOMIC DESIGN OF INTERFACE FOR CONCEPTUAL FLOOR PLAN MODEL AND SPATIAL EVENT HANDLING IN RFID APPLICATION

The development of advanced spatial-positioning and monitoring systems for medical monitoring and emergency response using RFID & Wi-Fi technologies is a large-scale research project being conducted at the ward W21C of Foothills Hospital, Calgary, Canada by University of Calgary. The scope of this project is to support real-time location tracking of medical equipments and personnel in hospital settings. In this context, we developed an innovative, interactive, decision-support medical system for tracking of personnel and high value medical equipments. The goal behind development of such a system is to provide a convenient, easy to use interface using existing technologies that allows to visualize and analyse clinical pathways and health care provider's workflow pattern as well as to perform time motion studies and more advanced statistical pattern analysis. While achieving this goal, we aim to also fill the existing void of documentation and present to scientific community functional issues encountered along with their importance in success.

1. INTRODUCTION

The development of biomedical devices supporting non-invasive medical monitoring is an exciting domain of research, with significant human health implications and exceptional technology transfer potential. Novel wireless devices for the real-time monitoring of the location of patients, medical personnel, and equipment are now commercially available, proposed by some as a technology solution that can contribute to better and safer health care. Real Time Location Systems (RTLS) can be based on RFID (Radiofrequency Identification Tag) technology and Wireless Fidelity (Wi-Fi) networks. These technologies have been implemented at some of the medical centres around the world but without any notable published information not only on operational issues that arise with this implementation, but also on user friendliness and effectiveness of this technology in meeting its intended benefits.

The Medical Ward of the 21st Century (W21C) at Foothills Hospital in Calgary, AB, Canada is a setting in which these technologies can be tested to assess their usability in an applied health care settings and to explore the potential contributions of RTLS to safety and quality of care. Technology leaders IBM and AeroScout are also partners in this research.

The fully interactive path tracking system developed is based on ergonomic design principles. This Paper argues that ergonomic criteria if applied to RTLS system in medical environment can significantly improve over all system usability and will ultimately enhance patient care. Evidences are presented to corroborate this argument.

2. BACKGROUND LITERATURE

Location-based tracking is a new area of application and research in healthcare for addressing patient safety. Most location based tracking technologies to date have been cantered around RFID. However, the emergence of Wi-Fi tracking technology which uses the existing 802.11 wireless standard has been gaining more momentum recently [9]. The advantage of the Wi-Fi solution is that it uses the existing wireless infrastructure that is being implemented in healthcare environments, including our research ward W21C. Traditionally, location based tracking has been applied for the "real-time" identification of assets, such as wheelchairs or ventilator equipment [3]. However, the potential exists to apply Wi-Fi location-based tracking for improving quality and addressing patient safety [1, 4]. Since this is a new innovative technology, the application of these devices and systems in hospital environments is limited and the literature on its application remains scarce. We foresee that location-based tracking of human resources such as physicians, nurses and their interaction with patients can provide insight that could contribute to improving patient safety and quality of care. Examples of this include improving clinical pathways, provider's workflow [8], information about monitoring patient safety procedures, time motion studies and more advanced research applications [6, 7, 10].

As was recently demonstrated in [5] good knowledge management of any health care related data can be of significant benefit for overall patient care. On the other hand, well developed principles of ergonomic design [2] are always a significant input into overall knowledge management.

The rest of paper is organized as follows. Section 3: Brief overview of Research Project, Section 4: Salient features of Previous System, Section 5: Test Case Results of the previous system, Section 6 : Salient features of New System, Section 7: Model Validation and Experimentation, Section 8: Conclusions & Future Advancements in the project and Setion 9: Biblography.

[*] University of Calgary, Department of CPSC, ICT 709, 2500 University Drive NW, Calgary, AB, T2N 1N4,Canada.
[**] University of Fribourg, Avenue de l'Europe 20,CH-1700 Fribourg

3. BRIEF OVERVIEW OF THE RESEARCH PROJECT

The recently-established Wi-Fi Network on the W21C is a key infrastructure asset that now makes implementation of location tracking system readily feasible. This protocol aims at integration of such technologies (RFID & Wi-Fi) into an applied clinical care setting, and also exploration of the potential impact of this location tracking system on safety and quality of care.

Following is the 'high-level' overview of this research project. The initial phase focuses on the documentation of the organizational process of implementing RTLS technologies (RFID/Wi-Fi) in hospital setting, with emphasis on documenting the challenges & barriers encountered with their solutions. After execution of pre-created test plans to measure performance of technology, validation of time & location data produced is being carried out by a team of doctors, nurses and technology experts. The data collected is used to develop real-time observational and motional measurements of medical personnel (physicians and nurses) and equipment tracking, to create spatio-temporal data for analysis and visualization of work-flow patterns of health care service providers. In the last phase of research, observational analysis of medical personnel activities related to patient care and infection control practices will be used as a basis for the development of technology-based interventions that might contribute to safety and quality of care. For example, hand sanitization prior to patient visits will be followed by an alarm reminder for providers, if they do not visit sanitizer.

In the context of this large-scale research project, the path tracking system was developed over the existing floor plan model which allows to dynamically display movements of one or more subjects on the floor plan, represent neighbouring relationship on the model and analyze time and space dependencies between the observations. Development of User interface, underlying data model, path visualizations and analysis of resulting motion are carried out utilizing ergonomic principles of system design.

4. SALIENT FEATURES OF PREVIOUS SYSTEM

Following are the key features of the application and its user Interface.

4.1. FLOOR PLAN MODEL

Floor plan model has been developed based on physical architecture of research site W21C, Foothills hospital, Calgary. It visually shows entire ward setting comprising of various types of rooms, their purpose and allows to simultaneously track location, time and movement of subjects in the ward.

Features of previous system

- Load and display floor plan files.
- Load and display the tracking data files for a subject.
- Presentation of rooms in different colour as per there utility.
- Grid representation of the floor plan.
- Export the floor plan as an image.
- Display path and frequency of its travel.
- Hierarchical tree representation of rooms in the ward.

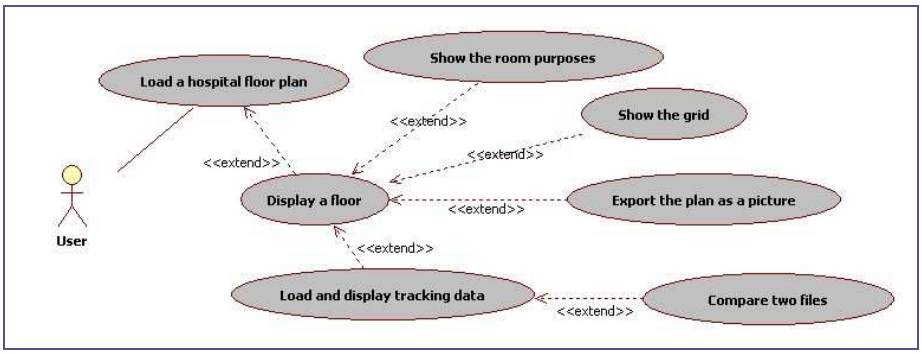

Fig. 1. User Case Diagram of the Application

4.2. USER INTERFACE OF THE APPLICATION

User interface has been divided in three parts, Main Menu at the top, Hierarchical Representation of rooms on the left, Visual Representation of floor model on right. Figure-2 below, displays the application with tracking, purpose and grid view settings.

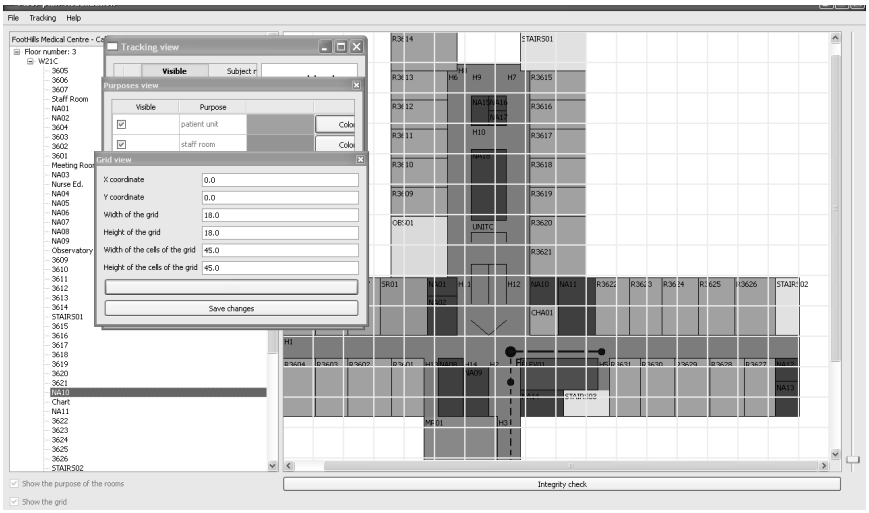

Fig. 2. User Interface of the Floor Model

5. TEST CASE RESULTS OF THE PREVIOUS SYSTEM

To discover potential area of improvement and enhance user experience test cases were executed in consultation with medical personals of Foothills hospitals. These test cases compared output of the system with user's experience and requirements

The obvious need of improvement was visible. We now report some of the errors and improvements based on both functional and ergonomic criteria.

5.1. FUNCTIONAL TEST CASE RESULTS

Functional Test Case Results	**Priority**
The system doesn't take into account the doors and hallways to compute the movement. It just looks at the XML file and checks if this is a 'neighbour' value to decide if a movement is possible or not.	High
The comparison of 2 files doesn't care about time.	*Medium*
The application displays the floor as needed but it uses an external library 'QT'. It can be useful to remove this external library to really take the control of all it is displayed.	*Medium*
The XML schema has to be more restrictive with the location.	*Low*
The application doesn't manage the floor selection	*Low*
The application has to valid the XML before loading it.	*Low*

Fig. 3. Summarizes the Functional Test Case Results

5.2. ERGONOMIC TEST CASE RESULTS

Ergonomic test case results	**Priority**
Resize the main window according to the screen size.	**High**
Change the concept of "each action, another window"	**High**
Add a Menu bar toolbar with icons to facilitate the use of function.	***Medium***
Save the users' preferences.	***Medium***
Add confirmation messages (also provide facility to disable messages)	***Medium***
Provide some tooltips for users	*Low*
Provide the user with a online help	*Low*

Fig. 4. Summarizes ergonomic test case results

6. SALIENT FEATURES OF NEW SYSTEM

Based on test cases results new system was developed and following are details.

6.1. PATH TRACKING SYSTEM USING EXISTING FLOOR MODEL REPRESENTATION.

Our goal is to enhance operational functionalities and visualization aspects of the application in consistence with ergonomic principles of system design. Ergonomic design integrates knowledge from the human and technology sciences to match systems, products and environments with the physical and mental abilities of the users. The ergonomic design principles that are were referenced in development of this path tracking system have been Compatibility, Guidance, Consistence, Adaptability and Explicit control, Workload and Error Management. Following are the key benefits achieved.

Functionality Improvements & Enhanced Visualization in the application:

- Shortest paths are computed in the application in addition to the horizontal and vertical computation of the path.
- Data Filters functionality is incorporated to put restrictions on the tracking data files.
- Analysis tools are extended to provide additional information based on acceptance or rejection of data by filter.
- New Functionality is provided to compare two or more tracking data files, i.e. comparison of paths of two subjects with subsequent comparison report.
- The software additionally provides the users with a clean visualization of the path of the subjects in more than two different ways(refer Figure. 5) other than this software also provides with a mouse over events for user convenience (refer Figure. 6)
- Statistics tool are provided in the application for analysis and decision making.
- User preferences can be stored by the application, this saved user from doing same set of actions again. Preferences such as Filter selection, Layout settings, Tool bar settings, grid settings, Colour preferences can be stored. So next time when user uses the application all of these settings are already set saving users time.
- User experience was enhanced by significant additions such as help wizard, online help for user references, Language Translation, additional menu & tool bars.

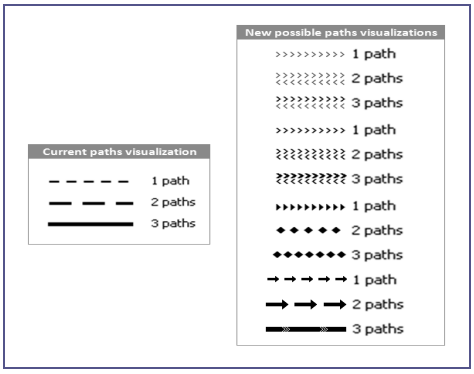

Fig. 5. Symbols for displaying different paths in application

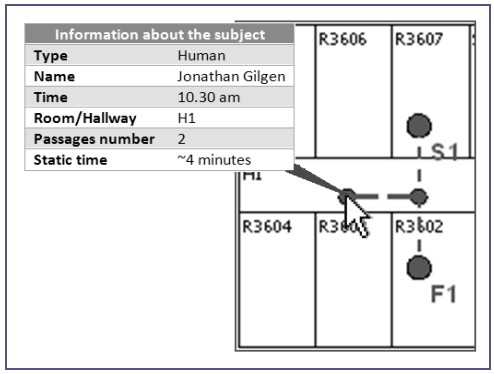

Fig. 6. “Mouse Over Event” facility

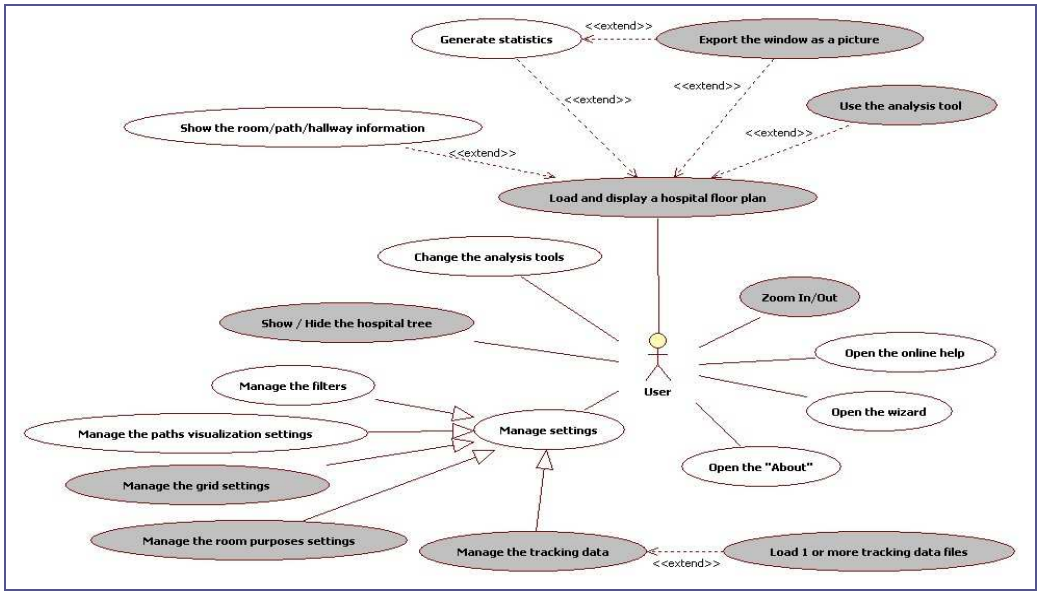

Fig. 7. User case diagram on the application

6.2. USER INTERFACE OF THE APPLICATION

User interface of new application is shown in Figure 8. System displays floor model visualization at centre. Menu bar and two more tool bars on top and other on the left of the screen, hierarchical representation of floor plan at extreme right, status bar and zoom (+/-) at bottom of the user interface.

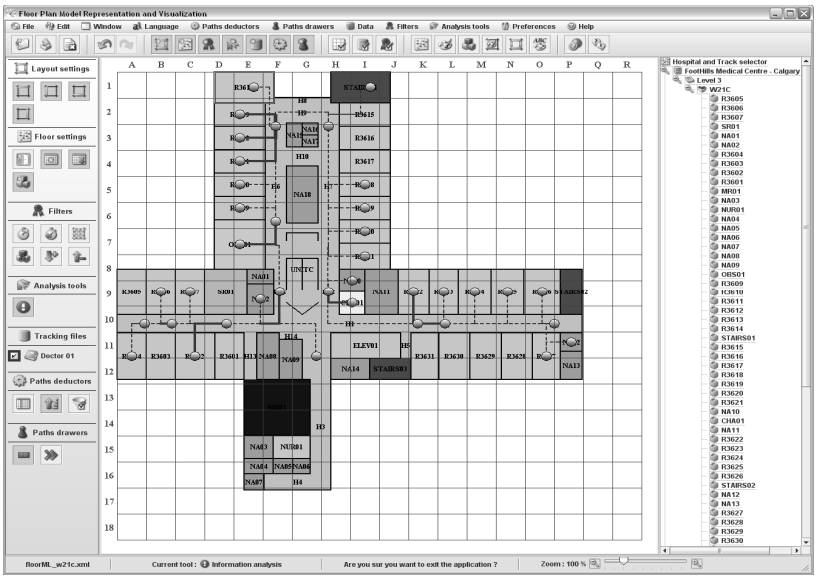

Fig. 8. Application Interface

– Figure 9 displays more features of developed application, such as manage (time/space/purpose) filters, path setting (path detectors/analysis tools/path drawers), layout settings and room purpose window. The red arrows on the floor model are the subject's movement in that ward and any mouse click on the subject informs about it's details. Each colour resemble a specific room type.

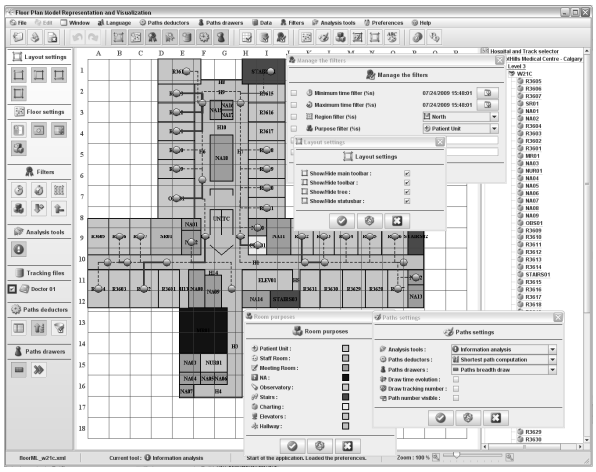

Fig. 9. Application Interface

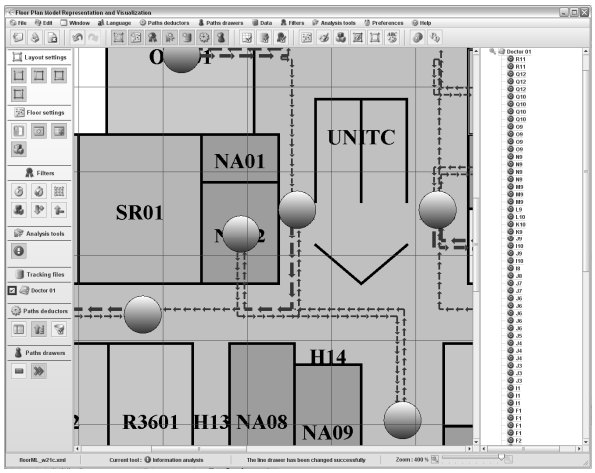

Fig. 10. Application Interface

– In new application, subject movement on the floor plan model are displayed using arrow head symbols for better understanding. There is also an added ability to zoom to focus on movements in any particular area as shown in Figure 10.

7. MODEL VALIDATION AND EXPERIMENTATION

In order to validate the interface, it is necessary to go through functional and ergonomic criteria evaluation and to analyse if all the weaknesses of the previous project are corrected. This phase would be useful for the future enhancements of the application.

The testing of the application was done by team of health care providers who will be using this application on daily basis. Figure 11 and Figure 12 very clearly show the significant improvements in the application's functionality and ergonomic design. Figure 11 shows that the new application is not only very easy to use and compatible with user needs but also very

robust to deal with high volume and significantly complex data including hospital floor plans, purpose of rooms and intricate paths. Display of tracking data in new system is as comprehensive and user friendly as loading of data. In addition to features shown in the chart, there were also many other features added to the application (refer section 6).

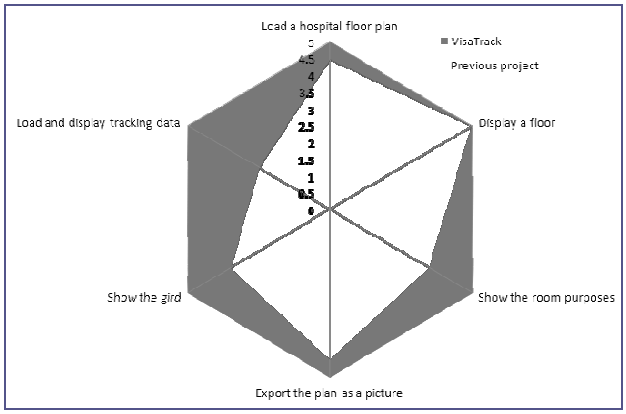

Fig. 11. Functional comparison score

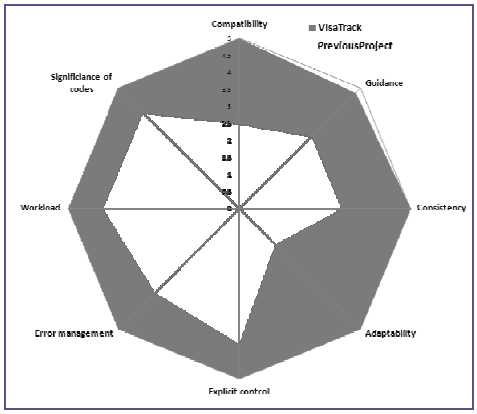

Fig. 12. Ergonomic comparison score

New application (VisaTrack-gray) and Previous project (white) in the radar charts above.

8. CONCLUSIONS & FUTURE ADVANCEMENTS IN THE PROJECT

The Path Tracking System developed on existing floor model, using ergonomic design technique has been very effective in satisfying user requirements. The analysis, statistical and Filter tools along with path detectors make this application very efficient in tracking personals and resources in clinical care settings. User friendliness of this location tracking system, plays a vital role in the success of this application. These improvements boost user confidence and hence make it possible to take this research project to next level.

Next level in this research project will be development of Spatio-temporal data analysis and visualization of work-flow patterns of health care service providers. This will be followed by performing observational analysis of medical personnel activities related to patient care and infection control practices.

The outcomes of this research will lead to policy-setting knowledge directed on improvements of complex processes (infection control, work flow, critical and lifesaving equipment sharing, etc.) in the hospital environment. This process enrichment, in turn could produce improvements in clinical outcomes, provider well-being, patient satisfaction, cost and time saving, and overall safety and quality of care.

BIBLIOGRAPHY

[1] CAVALLERI, M. MORSTABILINI, R. RENI, G., A wearable device for a fully automated in-hospital staff and patient identification, Conf Proc IEEE Eng Med Biol Soc. 5:3278-81, 2004.

[2] CHRISTIAN B., Ergonomic criteria and the ISO/DIS 9241 dialogue principles: a pilot comparison in an evaluation task, Dominique Scapin, 299-322, 1999.

[3] GUERRA A., Location, location, location. Denver Health decided to get a better handle on its clinical equipment with location tracking software., Healthc Inform. 23(6):95, 2006 Jun.

[4] KROHN R., RFID: it's about more than asset tracking, J Healthc Inf Manag. 19(3):20-3, 2005.

[5] LANE V., SNAITH J., Knowledge Management:A fad or serious instrument for sustaining and improving quality healthcare, MIT , U of Silesia, UK, 233-240, 2008.

[6] LENERT, LESLIE. CHAN, THEODORE C. GRISWOLD, WILLIAM. KILLEEN, JAMES. PALMER, DOUGLAS. KIRSH, DAVID. MISHRA, RAJESH. RAO, RAMESH., Wireless Internet Information System for Medical Response in Disasters (WIISARD)., AMIA Annu Symp Proc.:1192, 2006.

[7] MASSEY, TAMMARA. GAO, TIA. WELSH, MATT. SHARP, JONATHAN H. SARRAFZADEH, MAJID., The design of a decentralized electronic triage system, AMIA Annu Symp Proc.:544-8, 2006.

[8] MEYER, MARK. FAIRBROTHER, PAMELA. EGAN, MARIE. CHUEH, HENRY. SANDBERG, WARREN S., Using location tracking data to assess efficiency in established clinical workflows, AMIA,: 1031, 2006.

[9] SCHUERENBERG, BECKIE KELLY., RFID and Wi-Fi square off, Health Data Manag. 15(5):45-6, 2007

[10] SUTHERLAND, JEFFREY V. VAN DEN HEUVEL, WILLEM-JAN. GANOUS, TIM. BURTON, MATTHEW M. KUMAR, ANIMESH., Towards an intelligent hospital environment of the future, Stud Health Technol Inform. 118:278-312, 2005.