Visualization and user interface for monitoring and interpretation of sensor data

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1. Introduction

ElderCare uses technology to address the changing needs and risks of the elderly and aging. Its goal is to help elders remain independent as long as possible by using sensors to monitor physiological signals and activity patterns, minimizing the need for elders to move to a personal care facility. My part in this project has been to develop web-based graphical visualizations of sensor data.

2. Prior Work

Pervasive computing was built into Oatfield Estates Cluster, an assisted living complex created by Elite Care, as the building was constructed [1]. The establishment follows an aging-in-place model that "avoids the traditional institutional care model used in nursing homes for the elderly who can no longer live unassisted" [1]. Sensors there include locator badges that use a combination of infrared and radio frequency transmissions, as well as embedded weight sensors that can also gauge restlessness. A personalized database documents vital signs, reducing stress on staff members. These elements combine to allow elders to receive individualized care. An interesting effect of this method of care is that staff turnover rates are dramatically reduced, an important consideration "in an industry where [turnover rates] can go over 80 percent per year" [1].

The Digital Family Portrait uses a sensor system that is less invasive, but no less pervasive, to allow an adult child or other trusted designee to monitor an elderly person in his or her own home [2]. [2] describes a trial run of this system with a healthy elderly woman and her adult son. An ambient display was placed in the son's home. The display showed a portrait of his mother, much like what one would find on a fireplace mantle, framed by 28 butterfly icons whose respective sizes indicated the activity level for the past 28 days. If the son wanted to know more detail about any of those days, he would touch the icon for that day to change to a detailed display. Both mother and son responded positively to the trial. The mother indicated that she felt less alone knowing that her son was looking out for her through the noninvasive monitoring system, and she expressed a wish that she had had such a system available when her own mother was alive. The subjects' enthusiasm for the system is demonstrated by the fact that they continued to use it at their own expense after the trial ended [2].

There are other proposed methods of monitoring the health of elderly persons. Health smart homes are "equipped with special electronics to enable the remote control of automated devices specifically designed for remote health care," and they use "automatic devices and various sensors to ensure the safety of the patient at home and the supervision of their health status" [3]. A ring sensor worn on a patient's finger can continuously monitor physiological data, specifically data related to blood flow for detection of cardiac and circulatory problems, as well as location [4].

3. ElderCare Project Description

ElderCare, also referred to as ElderTech, is a project that uses advanced technology to address the mobility and cognitive impairments of older members of the population. It specifically addresses the risks associated with living independently as these impairments progress to help elders remain independent for as long as possible [5].

We are developing “an integrated monitoring system that captures data about elder residents and their living environment in a noninvasive manner” [5]. The system will use this data to extract patterns of activity that might indicate unsafe events [5]. For example, a floor vibration sensor might detect that a resident has fallen, and the nurse on duty could be automatically paged. A temperature sensor might detect that a stove burner is on, while a motion sensor might detect that nobody has been in the kitchen for quite some time, at which point the monitoring system could ask the resident whether he or she meant to leave the stove on.

3.1 Setting

Where: University of Missouri - Columbia and TigerPlace, a senior living community that uses the aging-in-place model to minimize the need for a person to move as they age and their health care needs change [6].

When: I worked May-August 2006. The ElderCare research project is ongoing. There is a weekly meeting between researchers, nurses, and other interested parties, and once a month, a conference call is made during this meeting to the University of Virginia team.

Who – the organizations: This project is a joint endeavor by “faculty, students, and researchers at the University of Missouri - Columbia (MU) in the College of Engineering, the Sinclair School of Nursing, and the Department of Health and Medical Informatics, as well as the Medical Automation Research Center (MARC) at the University of Virginia,” along with the TigerPlace community [5].

Who – the people I worked with: My mentor during this project was Dr. Marjorie Skubic, associate professor of electrical and computer engineering at MU. She is the technical lead for the project. I also worked with Dr. James Keller, professor of electrical and computer engineering at MU. The researcher I was trained by the most was Nate Green, an MS student in computer science. I worked with three other undergraduate students: Nick Harvey, Chinonye Echebiri, and Andy Holt.

4. My Part of the Project: Visualizations

4.1 Goal

My goal this summer was to create a web-based data visualization and user interface to assist in the monitoring and interpretation of data. On this site, data would be viewable by nurses, elders’ adult relatives, or the elders themselves. The site would allow data to be displayed in an intuitive format, and it would allow rules to be set for interpretation of that data.

4.2 Where I started

When I began working on this project, a basic visualization was already in place. Catalyst, a web framework, had been installed on the server, and some test sites had been created in Catalyst. One of them would allow the user to type in the start date, select the number of weeks they wished to view, and select a user ID from a list, and a graph would be displayed with the resulting bed restlessness data (Figure 1). The data was pulled from the database using a SQL query.

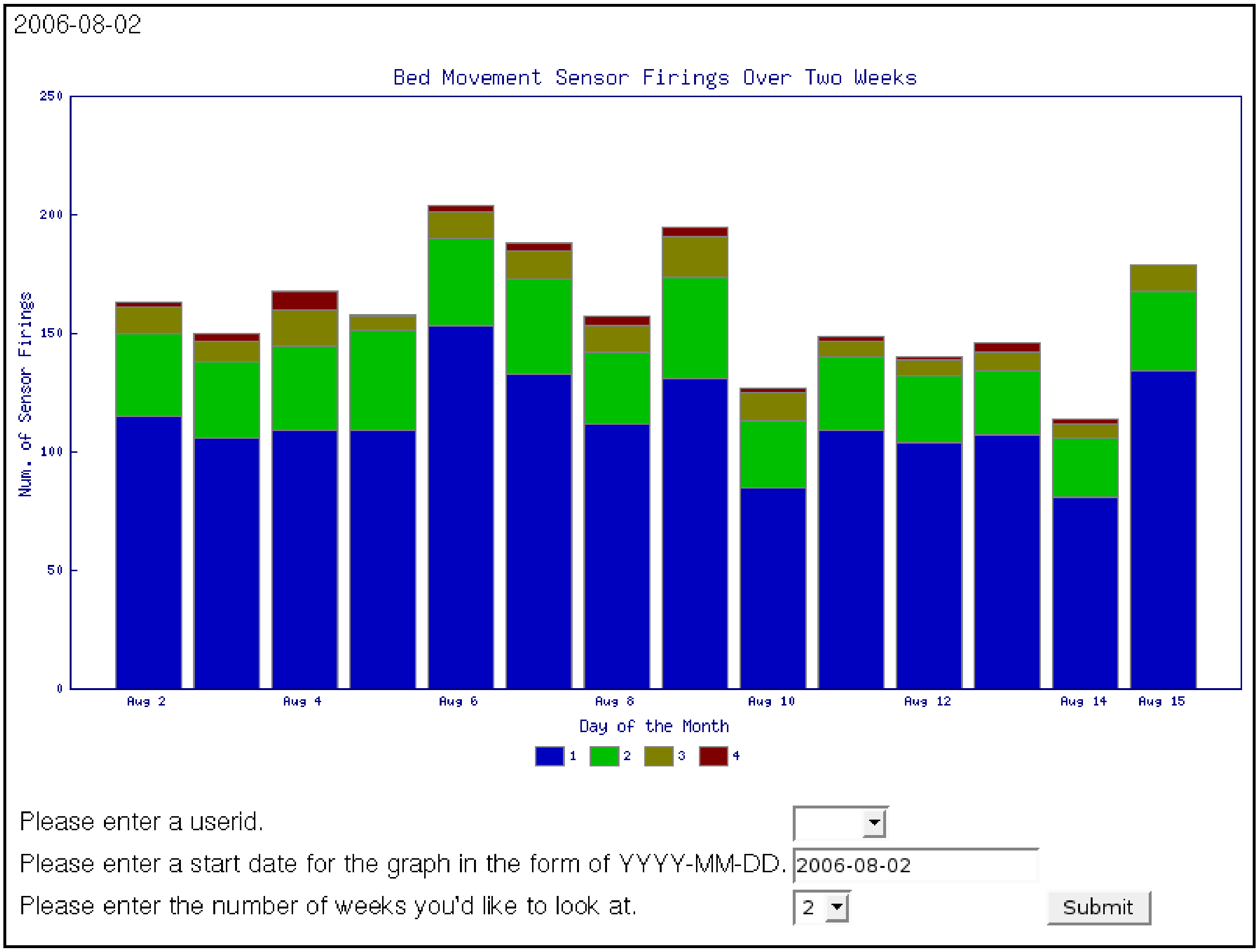

Figure 1. The original visualization and interface.

4.3 What I accomplished

I changed the code so that instead of using SQL to pull the data, the page uses a Perl module called DBIx::Class. This module allows the programmer to treat the database like an object so that object-oriented programming techniques can be used to access the data. Later, I found another way to improve how the data was pulled from the database. Previously, I had pulled the data for one day at a time to create the graph. This led to long delays when the user requested a large date range. I changed the code to pull all the data at once instead, dividing it up into the correct days afterwards. This greatly improved the speed.

The graph shows how many times the sensors logged a certain level of restlessness while a person slept. The problem is that every time a restlessness level of 4 is logged, levels of 1, 2, and 3 are also logged immediately before. Likewise, whenever a 3 is logged, a 1 and a 2 are also logged, and whenever a 2 is logged, a 1 is also logged. In other words, the sensors register all the lower levels "on the way" to registering a higher level. This can distort the data towards the lower levels. I was able to filter these artifacts out of the data with a simple algebraic algorithm.

I also made significant changes to the user interface. I knew it was time to stop fixing the program code and start working on the interface when someone glanced at my page and said, "Boy, the University of Virginia sure has an ugly interface there," mistakenly thinking that the page had been created by that organization. To allow the user to choose the starting and ending dates, I added a calendar module. I set it up to display two months at a time in such a way that the two months would "scroll" together, in order to limit the user to selecting no more than 60 days of data (Figure 2). Since the calendar relies on JavaScript, I set up the page so that if the user did not have JavaScript enabled in his or her browser, the calendar would not be displayed and an alternate method of entering the dates would be presented.

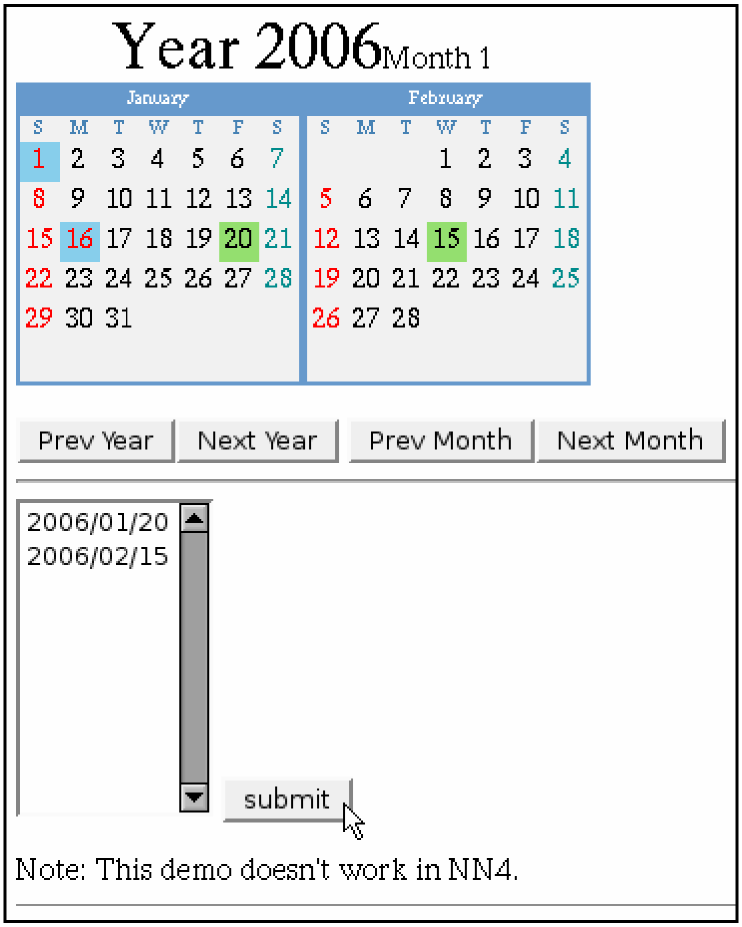

Figure 2. The 60-day range date picker. Dates highlighted in blue (January1 and 16) are holidays, and dates highlighted in green (January 20 and February 15) are user-selected starting and ending dates.

When I presented the page at our weekly meeting, one piece of feedback I received was that it would be better if the calendar popped up when the user tried to type in the date, rather than being visible on the page at all times. I customized a different version of the same calendar module to accomplish this. I was able to limit the range so that the end date could not be more than a certain number of days past the start date. I customized the colors and sizes used by the calendar to try to make it easy for elderly people to use. I especially tried to avoid low contrasts and small sizes (Figure 3).

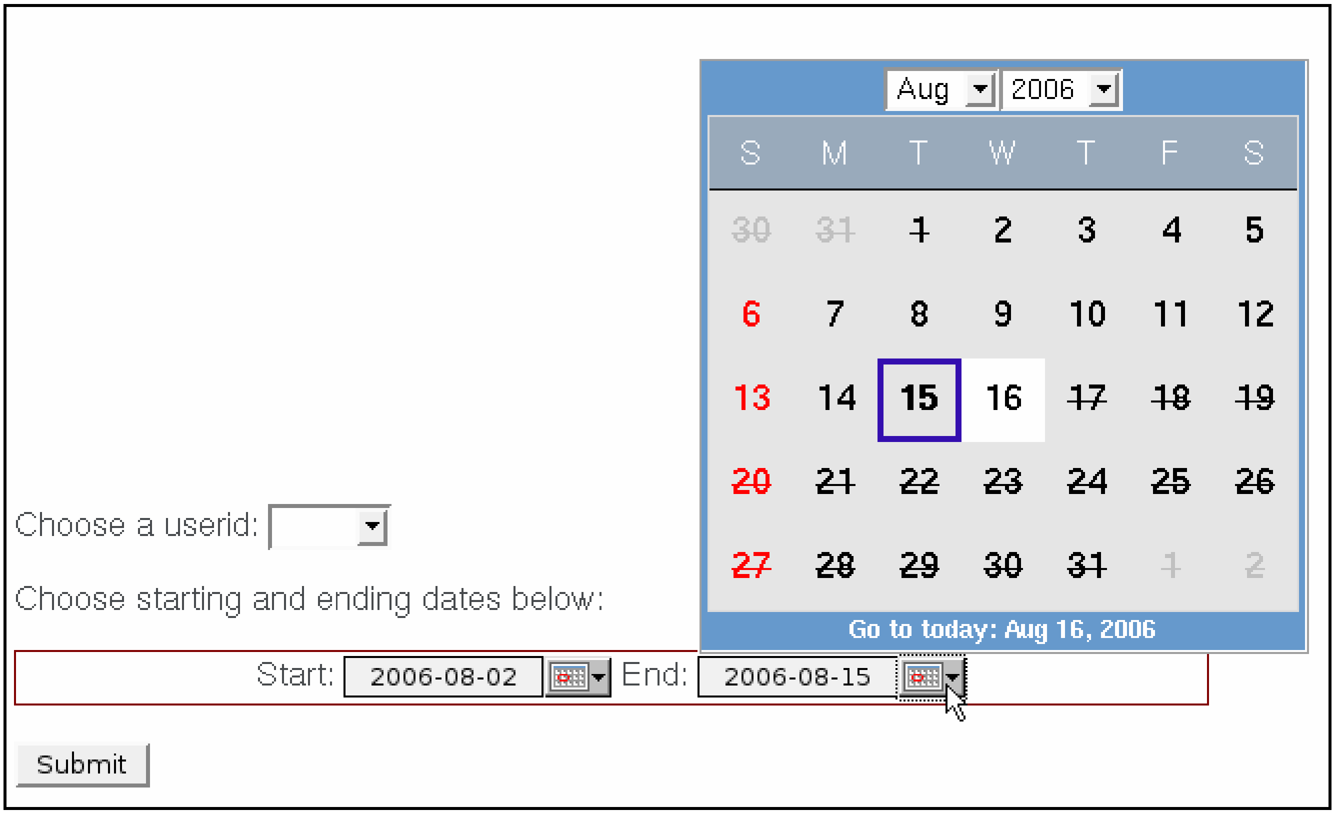

Figure 3. The pop-up date picker.

The nurses said they wanted to be able to view 90 days' worth of data at a time, since often they would want to evaluate data over an entire quarter. This would have crowded the bar graphs, so I set the graphs to change width based on the number of days selected. I set up the maximum y-value to be calculated by the program, rather than leaving it to be automatically calculated by the graph module as before, because the graph module sometimes set the value nearly twice as high as appropriate. Also, I added bar graphs of pulse and breathing data underneath the restlessness graph, allowing easy comparison of the data (Figure 4).

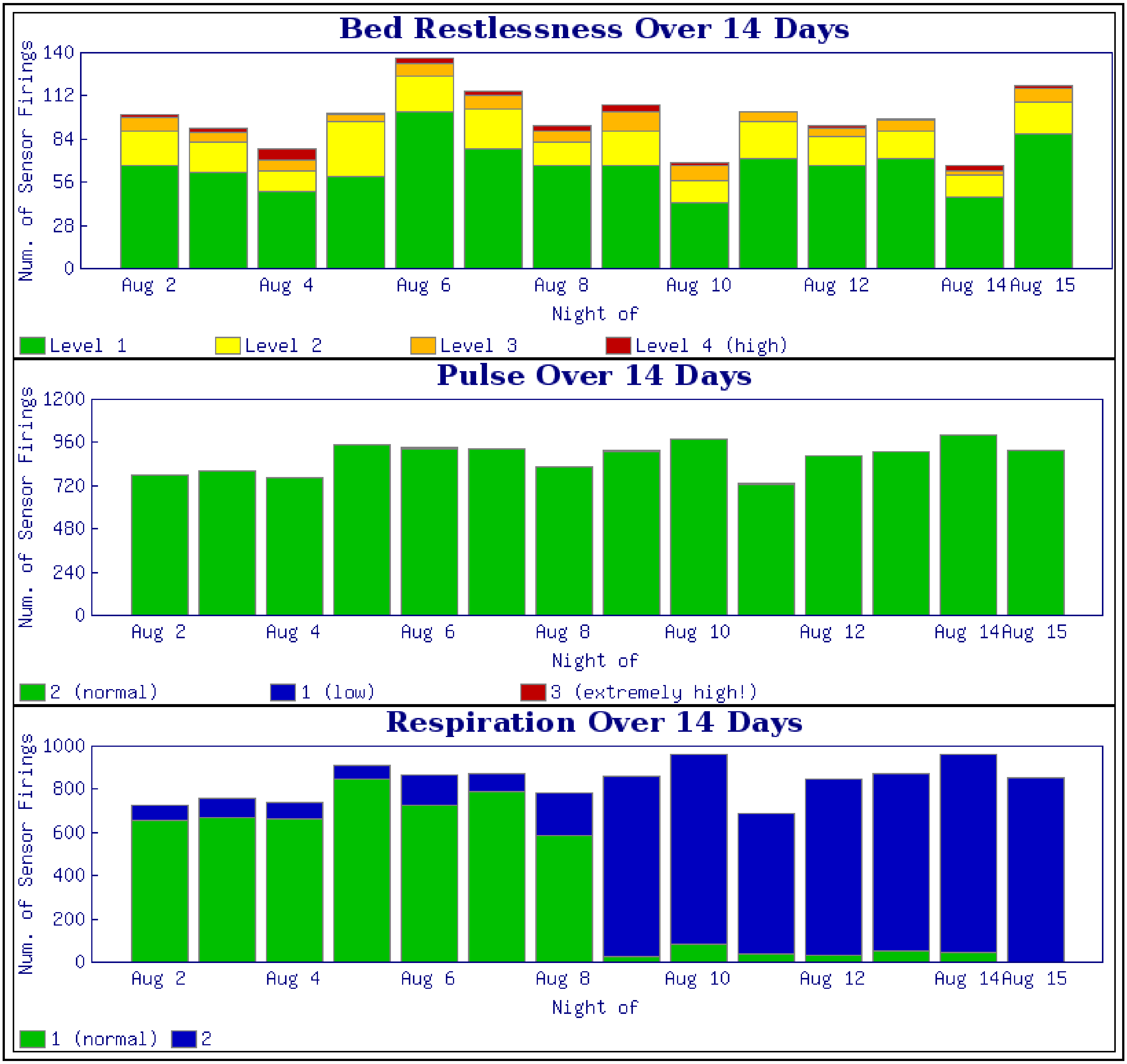

Figure 4. The new page allows for comparison of three graphs simultaneously.

Smaller changes included: changing the list of user IDs from a static list to one based on the database contents, so that if a new user shows up in the sensor logs, no changes have to be made to the program; setting up the pages to use TTSite, a module that allows for modularization of pages so that the programmer doesn't have to set up the HTML framework for each page, only the content itself; and setting the graph labels to change based on the number of bars on the graph in order to avoid label overlapping when a graph has large amounts of data.

I made mockups of other possible ways to display the data graphically, and I began implementation of some of them, but my main focus was on this bar graph page.

4.4 Future work

Currently, the page is only online when someone starts the server script, and then it can only be accessed on campus or via a combination of SSH and port forwarding. There is no login required to access the page. The user's input is not checked by the program, so malformed or even malicious data could be entered. These are issues that will have to be addressed before the page will be ready for use.

5. Conclusion

5.1 Impact on project

Since the page is not yet fully implemented, it not yet had a significant impact on the project. However, once the issues in ***4.4 Future work*** are resolved, this visualization could be a vital tool. In fact, it may be the first time the nurses will have easy access to the sensor data in a useful form. Since three different physiological measurements are displayed, nurses and researchers will be able to begin looking for patterns and discovering whether there are correlations between the signals.

We found a case where the knowledge provided by this visualization could have had assisted with decisions on a patient's health care. The patient had a heart attack around December 20. For a few days, no bed restlessness data was recorded because he was in the hospital (Figure 5). After he returned, significantly higher restlessness levels were recorded. As it later turned out, he was still having health issues. Once these issues were addressed, restlessness levels returned almost to where they were before the heart attack. If the visualization had been available at that time, the health problems persisting after the heart attack could have been detected almost immediately.

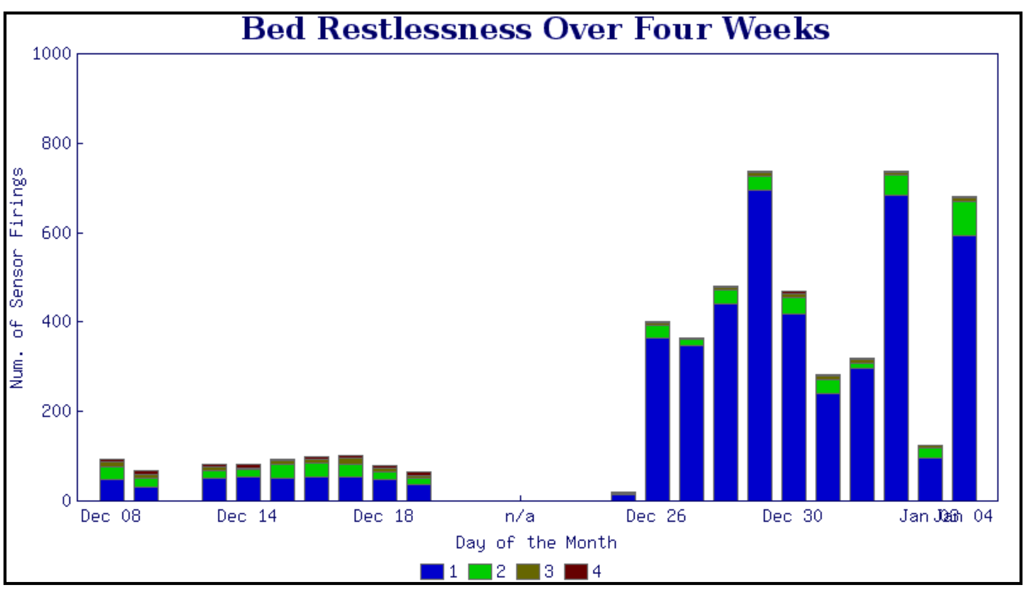

Figure 5. Elevated bed restlessness levels following a heart attack.

6. Acknowledgments

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7. References

[1] Vince Stanford, "Using pervasive computing to deliver elder care," *Pervasive Computing, IEEE*, vol. 1, pp. 10-13.

[2] Jim; Mynatt Rowan, Elizabeth D., "Digital Family Portrait Field Trial: Support for Aging in Place," presented at 2005 ACM Conference on Human Factors in Computing Systems (CHI 2005). Portland, Oregon, USA, 2005.

[3] Vincent; Duchene Rialle, Florence; Noury, Norbert; Bajolle, Lionel; Demongeot, Jacques, "Health "Smart" Home: Information Technology for Patients at Home," *Telemedicine journal and e-health: the official journal of the American Telemedicine Association*, vol. 8, pp. 395-409.

[4] Boo-Ho; Rhee Yang, Sokwoo; Asada, Haruhiko H., "A twenty-four hour tele-nursing system using a ring sensor," presented at 1998 IEEE International Converance on Robotics & Automation, Leuven, Belgium, 1998.

[5] "Technology for Eldercare Research Group - Overview." Internet: http://eldertech.missouri.edu/overview.htm, July 29, 2005 [August 15, 2006].

[6] "About TigerPlace." Internet: http://www.tigerplace.net/html/about_tigerplace.html, [August 15, 2006].

[7] "Home - Computational Intelligence Research Lab." Internet: http://cirl.missouri.edu/wiki/Home, July 20, 2006 [August 15, 2006].

[8] "CRA-W." Internet: http://www.cra.org/Activities/craw/projects/index.php#research%20mentoring, [August 15, 2006].

[9] "CRA-W." Internet: http://www.cra.org/Activities/craw/aboutCraw.php, [August 15, 2006].

[10] Idemfactor Solutions Inc. "The dreamland of javascript calendar and popup date picker controls with XML and database support!" Internet: http://calendarxp.net/, 2003-2006

[11] Marjorie Skubic George Demiris, James Keller, Marilyn J. Rantz, Debra Parker Oliver, Myra A. Aud, Jia Lee, Katrhyn Burks, Nate Green, "Nurse Participation in the Design of User Interfaces for a Smart Home System," presented at ICOST.

[12] Sarah Berry. "Smooth Coding - Home." Internet: http://www.smoothcoding.com/joomla/, August 15, 2006 [August 15, 2006].

[13] "Eldercare Technology Displays to Support Aging in Place (original project proposal)."

[14] "Technology for Eldercare Research Group - People." Internet: http://eldertech.missouri.edu/people.php, July 29, 2005 [August 16, 2006].

[15] "Nurse Participation in the Design of User Interfaces for a Smart Home System - Computational Intelligence Research Lab." Internet: http://cirl.missouri.edu/wiki/Nurse_Participation_in_the_Design_of_User_Interfaces_for_a_Smart_Home_System, July 19, 2006 [August 16, 2006].

[16] "Catalyst - Web Framework." Internet: http://www.catalystframework.org/, [August 15, 2006].
[17] "object-relational mapping: Information From Answers.com." Internet: http://www.answers.com/topic/object-relational-mapping, [August 16, 2006].
[18] "Object-relational mapping - Wikipedia, the free encyclopedia." Internet: http://en.wikipedia.org/wiki/Object-relational_mapping, August 10, 2006 [August 16, 2006].