Web-based visualisation of live streaming sensor data

This project will be an investigation into a general-purpose framework for web-based visualisation of live streaming sensor data. It will involve looking into many different techniques in which to visualise data. This proposal explains my reasoning behind choosing this assignment and the methodology I will use to achieve my aims.

Motivation and rationale

Sensors are regularly used in everyday life, and as a result there is an abundance of recorded data that people wish to see visualised for various purposes. A sensor is a converter that measures a physical quantity and converts it into a signal that can be read by an observer or instrument. Typically, sensors measure physical attributes such as acoustic data that is recorded by a microphone or the temperature that is collected by a thermometer. Another type of sensing is "virtual" in that it doesn't directly measure a physical quantity, for this could be how happy people are in the surrounding environment. This could be a model of the present humidity and as a result peoples comfort would be different.

Data is most easily displayed to people as some form of visualisation, and it makes sense to support visualisation of as many types of sensor, perhaps concurrently, as possible. According to Friedman, "…the main goal of data visualisation is to communicate clearly and effectively through graphical means." [1] The purpose of data visualisation is to use this visual representation to explore, make sense of, and communicate data patterns clearly and effectively. The specific purposes of data visualisation are out of scope for this project, however, the types of purposes are not.

At the moment, there is a lack of existing technology that can make viewing sensor data easily accessible to everyone. This is due to the fact that most data is published on stand alone PCs, meaning that the data cannot be accessed from a different location. This makes the visualisation very platform specific and problems arise when there is an attempt to decouple this data from the present software. At this present time there is a big move for an effective way of viewing this data visualisation. This led me to investigate further. When I considered that sensors are in a lot of objects these days and partnered this with the lack of accessing this visualisation, it became clear that this needed to be addressed. It is because of this that I believe my project is worth carrying out.

In my project I have chosen to visualise this sensor data over the Internet on a web page. The reason for this being the convenience and ease of accessibility that publishing the visualisation over a web page brings. There would be no need for any installation of specialised software, just access to a web browser. This would mean that my implementation would be cross-platform. It is because of this cross-platform idea which means that different people can benefit from it. Due to the different types of sensors and its data collected, people who wish to see what sort of trends that data is following can benefit. For example, the data published could show a building's energy use. This could result in the building's occupants identifying where the most energy is being used and take steps to cut down on their usage.

Aim and objectives

My overall aim is to create a general-purpose framework for web-based visualisation of live streaming sensor data. I will measure the effectiveness of my implementation by comparing what I have created to what already exists. This will be tested on a selection of domain experts that already use the existing technology and can therefore evaluate the performance of my implementation. My objectives to achieve my aim are as follows.

1) Define three use cases and how the success/effectiveness for each can be defined

These use cases will be how I will test my overall aim of a general-purpose framework. The three cases I will use will be, the TEDDI building sensor data from the Kings Gate building, the WAX kitchen tools that are part of the ambient kitchen project that is being developed in the culture lab and

a site that publishes many different streams of raw sensor data such as Cosm. [2] When I have three different case studies I will have achieved this objective.

2) Review the state of the art in terms of web-based visualisation tools that are used to create existing

This will involve me investigating into different design guidelines and tool recommendations. This involves Websockets and HTML5 canvas. Before getting started with data visualisation I need to understand the tools available, from simple charts to complex graphs. When I am familiar with many different visualisation tools and feel comfortable using them, I will have succeeded in achieving this objective.

3) Iteratively develop a visualiser starting from a minimal version, and iterate based on feedback from users and experts

The minimal version of my program will be a basic template that fetches the raw sensor data and outputs it to a webpage. I can then use this as a starting version and get users and experts to evaluate this so I can improve this initial version. The number of iterations I use will depend on how well I implement my minimal version and the quality of the feedback I receive. The features that will be tested include the ease that the raw data can be fetched, processed and visualised. Success for this objective will be achieving a general-purpose prototype that can be easily implemented for each of the three case studies.

4) Evaluate a sequence of prototypes to generate feedback on them

This sequence of prototypes will involve one for each of my three case studies. The feedback that I receive will be formative in that it will help inform instruction. This evaluation of the prototypes will be achieved through the use of focus groups and expert evaluators. These will be interaction designers and visualisation experts, who will analyse my prototypes against my success criteria. Achieving three final prototypes that are fit for purpose will be how I will measure the success of this objective.

5) Summative evaluation

The final objective will be to judge the success of my general-purpose framework implementation at the end of the project. Summative evaluation provides a means to find out whether my project has achieved my overall goal.

Background

"An Approach to Data Visualization and Interpretation for Sensor Networks." Fengxian Fan, Edoardo S. Biagioni. [3]	This paper is about colour coding visualization. It discusses how to successfully convey information gathered by the wireless sensors. The end results should be to make the sensor networks friendlier to users and more flexible to meet the requirements of different applications. As my project is helping users understand what is going on in the local environment through the visualisation of data that is sent from the sensors, this research paper urges me to keep testing my visualisation on test users to make sure that the final result is fit for purpose.
"Visualization of Hand Gestures for Pervasive Computing Environments." Sanno Kallio, Juha Kela, Johan Plomp. [4]	This paper describes basic concepts of the gesture visualization and studies how well the developed visualization method can animate hand movement performed during the gesture control. The results indicate that visualization clearly provides information about the performed gesture, and it could be utilized in providing essential feedback and guidance to the user in future gesture control applications. This paper relates to my project, as some issues that are outlined will be encountered in the kitchen tools in the culture lab kitchen. Receiving the data from the sensors is one thing, but this paper has helped me understand what problems can be faced in the collection of this data.
"Visualizing Sensor Data".	This paper tries to find a matching between sensor data and visualisations. It looks at how to

Christian Richter. [5]	implement visualization to different types of sensor data received continuously. It discusses how sensor data will change in the future and how we can adapt our visualization to match this ever-changing visualisation. This is important in my project as I am working on a general-purpose framework that could be used by many different people for many different roles. Therefore, the paper has enlightened me to design a visualisation that can resort to typical every day life and widely used visualisations, which an ordinary user can easily understand.
"Visualizing Sensor Data". Stefan Zankl. [6]	In this there is an example of an existing visualization of a sensor network. There is a user interface of the web based live streaming of the sensor pods in the Huntington Botanical Garden. The webpage offers three different views on the sensor data. In my project I will be offering the user different views of the data as well. The paper has helped me understand how to publish different views of data effectively.
"Accelerometer-based gesture control for a design environment." Juha Kela, Luca Jozzo, Sergio Di Marca. [7]	Accelerometer-based gesture recognition was studied as an emerging interaction modality, providing new possibilities to interact with mobile devices and consumer electronics. The results indicate that different people usually prefer different gestures for the same task, and hence it should be possible to personalise them. In my project I will be using TEDDI occupancy & environmental sensors to record the data from Kings Gate and also the ambient kitchen. The paper used studies to analyse accelerometer-based gesture recognition for controlling selected home appliances. This relates to my project as accelerometers are used in the ambient kitchen project.

Diagrammatic work plan

To best manage the available time for this project I created a work plan after my initial meeting with my supervisor. Figure 1 below is the Gantt chart I created using gantto. [8]

There is only one real major risk with regards to my project. This is that I do not manage to get even one use case to test my general-purpose framework on. I have chosen to have three use cases, which minimises this risk to me. The iterative nature of this project reduces the overall risk factor allocated to implementing this framework. Whereas, if I were to follow the waterfall model design process the risks would be bigger, this is because users don't really know what they want up-front. What they want emerges out of repeated two-way interactions over the course of the project. The waterfall model, with its emphasis on up-front requirements and design, is somewhat unrealistic and unsuitable to be used on this project.

In the plan I have allocated more than enough time to do each of the steps. This is my contingency plan. I know that I will definitely be able to construct the web page and get the data streaming correctly. However, if a problem arises with either the access to any of the data or the access to users and experts I will be able to use the excess time that I have set aside to come up with a solution. If the sensor data from one of the case studies used goes down, I have 2 other case studies that I can work on. This is also the case if I am not able to interact with the domain experts in the culture lab, or the people that work in the Kings Gate building. Using three different case studies means that if one of them happens to lead to a dead end, I can work on the others and still make progress on my overall aim.

So far in this project I have worked on bettering my understanding of how I will achieve my aim and objectives. I have had meetings to discuss the scope of my project, and in turn now have a clear idea of the steps required to achieve my goal. Throughout this period of continuing research I have searched and read many literature papers that discuss many different ideas. These include visualisation of sensor data and the use of sensors in controlled environments. These papers have allowed me to gain an insight into different ways to present the data as well as various ways to construct the framework. To implement this program I will have to use tools that I have not used before. Part of this research I have carried out has seen me look at the initial capabilities of Websockets and HTML5 canvas. Websockets are used in 80% of top browsers; they push data from a server to a client. HTML5 canvas is used to draw graphics on to a webpage. As well as this, I have refreshed my JavaScript and HTML writing skills, as these languages will be used to create the web page.

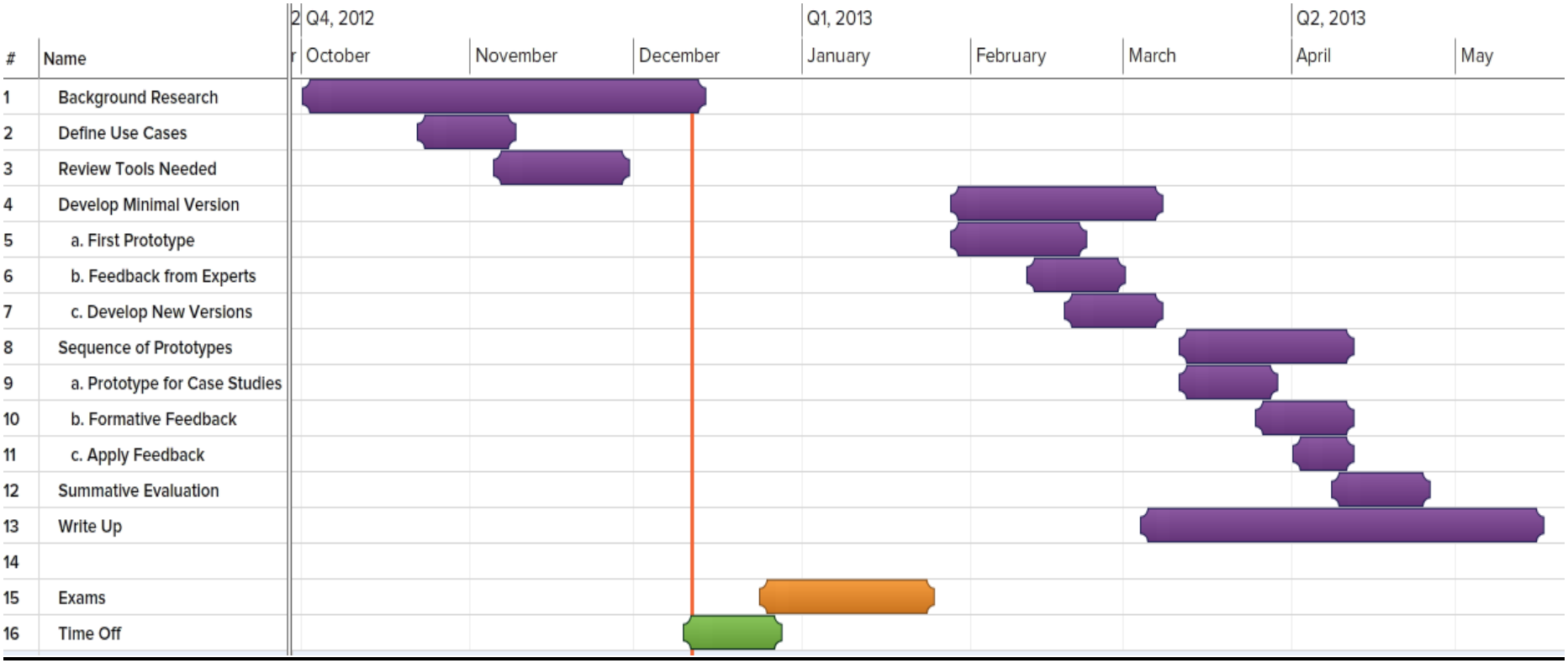

Figure 1: Gantt chart

References

[1] Friedman, Vitaly. *Data Visualisation and Infographics*. January 14th, 2008.

[2] Cosm - Internet of Things Platform. www.cosm.com
Last accessed – 11/12/2012

[3] Fan, F and Biagioni, F. *An Approach to Data Visualization and Interpretation for Sensor Networks*. University of Hawaii at Manoa. 2004. HICSS '04 Proceedings of the Proceedings of the 37th Annual Hawaii International Conference on System Sciences (HICSS'04) - Track 3 - Volume 3.

[4] Kallio, S, Kela, J and Plomp, J. *Visualization of Hand Gestures for Pervasive Computing Environments*. VTT Technical Research Centre of Finland. Finland. Proceedings of the working conference on advanced visual interfaces. Pages 480-483.
http://delivery.acm.org/10.1145/1140000/1133363/p480-kallio.pdf

[5] Richter, C. *Visualizing Sensor Data.*
http://www.medien.ifi.lmu.de/lehre/ws0809/hs/docs/richter.pdf

[6] Zankl, S. *Visualizing Sensor Data.*
http://www.medien.ifi.lmu.de/lehre/ws0809/hs/docs/zankl.pdf

[7] Kela, J, Jozzo, L and Di Marca, S. *Accelerometer-based gesture control for a design environment*. VTT Electronics, Finland. 2005. Personal and Ubiquitous Computing. Volume 10, Issue 5, July 2006. Pages 285-299.
http://delivery.acm.org/10.1145/1150000/1149819/779_2005_Article_33.pdf

[8] Gantt chart software.
http://gantto.com/
Last accessed – 11/12/2012