An interactive 3D visualization system for displaying field-monitoring data

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Abstract

Wireless sensor network provides great potential in construction engineering to obtain valuable information spanning both in space and time. However, effective visualization is necessary in order to comprehend or utilize these measured data. In this work, a 3D interactive visualization system is developed and demonstrated to interact with modern monitoring information system to visualize and utilize monitoring data. The visualization system is designed with requirements to help viewers digest monitoring data efficiently, and hopefully provides insights into real system behaviours.

Keywords: visualization, human computer interaction, field monitoring, decision support

1 Background

Field monitoring systems can provide valuable information to engineers and to scientists. For engineers, site monitoring data provide indication of site conditions, including its own safety and the impact of engineering activities to surroundings. For scientists, field monitoring data can verify computer models, which can be used to gain deeper understanding to system behaviours. Furthermore, field monitoring data can also be used in forensics to identify causes of engineering disasters. In order to fulfill the later purposes, however, monitoring data need to be effectively utilized.

To effectively use monitoring data to gain insight into site behaviour, or to identify causes of engineering disasters, monitoring data alone are not enough. It is necessary to combine other information, such as site conditions and spatial location of sensors, etc. to achieve such purposes. The fusion between 1) monitoring data, 2) deployment of instrumentation devices, and 3) site conditions and the presentation of such fusion is the main theme of this work. We pursue this possibility to fuse aforementioned information to create an interactive visualization that enables viewers see monitoring data with their context (site condition and sensor deployment) in a single display to help viewers gain understandings to monitoring data and their corresponding system behaviours.

It should be noted that the current monitoring system setup for regular construction sites are rather small-scale (e.g. 10 – 20 instruments), and therefore showing monitoring data in conventional statistical charts assisted with 2D top-view map is probably sufficient. However, technology advances such as wireless sensor network and MEMS (microelectromechanical systems) are likely to lower the cost of field monitoring systems (Lynch, 2007), and therefore it is expected the scale of site monitoring may gradually increases. Presenting large-scale monitoring data with conventional charts will eventually cause confusion and reduce productivity. Can viewers really easily tell which data
point belongs to which sensor, if there are more than 20 different sets of data showing on a scatter-plot?

2 Visualization & monitoring information system

The overall visualization and monitoring information system architecture for supporting this study is shown in Figure 1, and will be discussed in the next two sub-sections.

2.1 Monitoring information system

The monitoring information system was constructed using service oriented architecture, proposed by Hsieh and Hung (2009), and constituted by data services, coordination services, and field services. This three service architecture enables the constructed information system to be scalable, reliable, and accessible. All monitoring data are collected by field services, and collected data are sent to data service for storage and further processing after consulting coordination services on which data service should handle the collected monitoring data. Communications between different services are based on standard based web service technologies, such as SOAP (simple object access protocol). The visualization system will mainly interact with data service to obtain monitoring data for visualization.

It should be noted although the monitoring information system based on Hsieh and Hung (2009) communicates using SOAP web services, the data service can be constructed to support multiple protocols in order to have wider audience or to support more consumers of obtained monitoring data.

2.2 Visualization system

The visualization system developed in this study fuses the display of monitoring data, field models, and sensor deployments. The monitoring data are obtained through the monitoring information system using REST-style web services (Fielding, 2000), and remote procedure calls are made possible by simple HTTP/GET requests and responses in XML format, as summarized in Table 1. Using HTTP/GET requests eases developing programs in C++, which does not have standard libraries to make web service calls.

The visualization system also needs field models, which is the context of monitoring data. In the developed system shown in Figure 1, field models created using Google SketchUp are imported and

Figure 1. Overall visualization and monitoring information system
displayed along with monitoring data. The importation of Google SketchUp models is made possible by 1) COLLADA (COLLAborative Design Activity) file format, which is gaining popularity in popular 3D modelling tools, and 2) COLLADA-DOM class library. Furthermore, in order to avoid problems associated with inconsistent coordinate systems, sensors are drawn in the field model and identified using special naming rules to allow the visualization system to identify which graphical elements are to be replaced by the representation of monitoring data.

Finally, in order to graphically present monitoring data and field models, VTK (visualization toolkit) is used. VTK is an established high-level class library for scientific visualization. By using VTK, creating interactive 3D graphics becomes easy, and many advanced visualization such as iso-surface extracting, march-cubes, stereo display, etc. can be easily implemented through VTK as desired.

All the technologies used in implementing the visualization system are summarized in Table 2. It should be noted all selected technologies are cross-platform, enabling the developed visualization system to run on Windows, MacOS, or Linux, three major operating systems that run most personal computers.

Table 1. Summary of Web-Service Interface.

<table>
<thead>
<tr>
<th>Get monitoring data within a time period</th>
<th>Get latest monitoring data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response: &lt;?xml version=&quot;1.0&quot; encoding=&quot;UTF-8&quot;?&gt;</td>
<td>Response: &lt;?xml version=&quot;1.0&quot; encoding=&quot;UTF-8&quot;?&gt;</td>
</tr>
<tr>
<td>&lt;Sensors&gt;</td>
<td>&lt;Sensors&gt;</td>
</tr>
<tr>
<td>&lt;SensorData SensorID=&quot;1&quot;&gt;</td>
<td>&lt;SensorData SensorID=&quot;50&quot;&gt;</td>
</tr>
<tr>
<td>&lt;Data Date=&quot;1998-05-14&quot; Time=&quot;12:00:00&quot;&gt;-1</td>
<td>&lt;Data Date=&quot;1999-06-10&quot; Time=&quot;12:00:00&quot;&gt;-53</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>&lt;Data Date=&quot;1998-05-22&quot; Time=&quot;12:00:00&quot;&gt;-5</td>
<td>&lt;Data Date=&quot;1999-06-10&quot; Time=&quot;12:00:00&quot;&gt;-52</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
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<tr>
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<tr>
<td>&lt;/Sensors&gt;</td>
<td>&lt;/Sensors&gt;</td>
</tr>
</tbody>
</table>

Table 2. Summary of technologies used toward implementing the visualization system.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Toolkit used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parsing XML files</td>
<td>XERCES</td>
</tr>
<tr>
<td>Importing digital field model built by Google SketchUp</td>
<td>COLLADA-DOM</td>
</tr>
<tr>
<td>Interactive visualization</td>
<td>VTK</td>
</tr>
</tbody>
</table>

3 Requirements of visualization of monitoring data with context

There are four basic requirements that were set for the proposed visualization: 1) three-dimensional visualization, 2) interactivity, 3) intuitive and graphical display for monitoring data, and 4) data-filtering. These four basic requirements are discussed in the remaining text of this section.

The purpose of the developing the proposed visualization system is to put visualization of monitoring with its context: the environment and sensor deployment. This fusion between data and its context allows viewers to gain insight into the monitoring system behavior. The monitored
environment and sensor deployments are intrinsically three-dimensional, and therefore need to be displayed accordingly without losing information. Therefore, three-dimensional (3D) visualization is the fundamental requirement set for the project.

Interactivity means the presented visualization should change according to commands from user inputs. These commands may include: change of viewing positions and viewing angles, change of visualization style, change presentation of monitoring data, among many others. This is necessary for basic two reasons: 1) 3D visualization needs interactively change viewing positions and viewing angles in order to find the best perspective for a particular purpose; 2) smooth interaction between viewer and visualization system means uninterrupted thinking process, and allows viewers to focus their energy on problem-solving.

Intuitive and graphical display of monitoring data is a requirement imposed to allow viewers easily understand the spatial distribution of monitoring information. Although showing monitoring data with text is always an option, but text representation is rather abstract and does not allow direct visual comparisons between different monitoring data.

Finally, once monitoring data get abundant, gaining understanding to system or finding interesting become difficult. Therefore, providing mechanisms to filter out unwanted data or to help focus on interested data is important.

All the above mentioned four requirements are met by the proposed visualization system, and will be demonstrated in the next section.

4 System demonstration

Figure 2 shows a display showing surface settlement measured for an underground tunneling project. Using Google SketchUp to model the buildings on ground surfaces was very easy with the aids of satellite imagery available from Google Earth, which can be directly imported into SketchUp seamlessly to aid modeling. The monitoring data shown in Figure 2 are presented using 3D bars using their height to present the magnitude of surface settlement. The location of instrumentations is shown in the visualization by the bottom of the 3D bars; the presentation of magnitudes of monitoring data is further enhanced by colors. By using 3D bar chart, combined with field model, one can visually identify in the visualization: 1. the location of max surface settlement measured (by looking for the tallest bar), 2. buildings affected by surface settlements (by looking at buildings around the tallest bar), 3. buildings affected by excessive settlements, and 4) buildings suffering from excessive differential settlements. It should be noted the visualization can be easily controlled by computer mice to pan/rotate/translate viewing points.

Using a single display such as in Figure 2 to visualize monitoring data allows users to focus on reading monitoring data and site conditions at the same time. Conventionally, monitoring data are plotted using conventional x-y scatter plots assisted with a 2D top view to link between monitoring data and spatial information. The linking between two distinctly different drawings is done by using some arbitrary coding system, such as BM-12 (benchmark-12). Viewer need to reads the x-y plot first, remember the interested instrumentation has a code BM-12, and then change his/her view field onto another graph showing 2D top-view, searching for BM-12 in order to identify its location. This proposed visualization shown in Figure 2 require no remembering and no searching for BM-12, and makes the task of identifying locations of instrumentations much easier.

Figure 3 shows another requirement of filtering data using two different techniques. Figure 3a helps the filtering task by adding an icon to the data representation that satisfies user-defined criteria. Such technique is useful when there are not too many monitoring data, and showing data not satisfying user-defined criteria can help users know about data distribution better. Figure 3b shows filtering by removing data representations for data that fails to satisfy user-defined criteria. Hiding
unsatisfactory data tends to be a better choice when abundant monitoring are available, and showing them all can make the display area clutter and can make viewers confused.

Figure 2. Visualization surface settlement using 3D bar chart with its context.

Figure 3a. Data-filtering by add icons to data satisfying user-defined criteria


5 Summary

An interactive visualization system is introduced in this work to visualize monitoring data fused with the site and the sensor deployment information. The fusion of the three pieces of information enhances viewer’s understanding the monitored system behavior, helps users to focus on reading monitoring data with their context, and helps collaborating people to communicate by providing a single view monitoring data with their environment. The system is still under development, and will be further enhanced by 1) user-friendly graphical user interface (GUI) developed using Qt, 2) online collaboration by synchronizing views on different computers through Internet, and 3) more data representation techniques.

Acknowledgements

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References