Concept of an mobile assisting system for multi-sensor buildings-observation

Entwurf eines mobiles Assistenzssystem fr multisensorische Bauwerksberwachung

EXPOSE: Master Thesis Euteneuer

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Berlin, December 3, 2013

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1 Introduction and Motivation

This master thesis will first describe potential user needs in a graphical management and analysis tool for the structural health system and secondly develop a system which will meet the described needs. This system will help field engineers generally in:

- planning and optimising their field work,
- corresponding with the office,
- and quickly evaluate measured values.

Classical work in survey engineering consist of the measuring tasks in the field, and its evaluation, analysis and interpretation in the office. This subdivision into two spatially different, but often very cooperating tasks leads to inefficiency of work, time delay and avoidable mistakes in the work flows.

For the sake of completeness, however, it should also be pointed out that not all working tasks of field engineers can be done in the field, therewith the system is limited to this existing frame.

Nowadays a close interaction of different activities every time and everywhere is not any more a vision, it is common to our society and people get used to it. Field work today already contains usages of mobile devices which help organising the work flow.

There are three main advantages of using such a system following this approach:

- The Systems core functionality will be the assistance of the survey engineer. This means it helps to get a better 'understanding' of the measurements e.g. in comparison to former epochs. → The sharing of information between field and office leads to a better knowledge during field work. It should support the decisions in field.
- It is avoiding "mis-measurements" caused due to a incomplete knowledge of the measurement network by validation of measurement "on the fly" directly after the upload to the systems database.
- For a field exploration existing results of the former measures have not to be exported from the office infrastructure, the mobile system is linking real time data with existing results.

There is a need of such a system, the combination of used techniques like "Sensor Web Enablement", OGCs Web Services and mobile advanced IT platforms like tablet computers for a streaming of data from the field and to the field is up to now an unanswered question. This master thesis will explore possible solutions and the real need of potential users.

It will not be an alternative for engineering management systems which are already running on mobile devices, the real benefit of this system being designed with this thesis will be a direct linkage of the sensors to the systems, from data streaming up to augmented reality. The combination of classical surveying methods with new sensor observations in case of structural health monitoring will open new possibilities and new perspectives for field work of survey engineers

2 Methods

Based on existing developments like IT-Architectures and Data-formats the system will be designed by the actual need of working field engineers. Use case models and research on already existing systems will help in finding a technically optimal solution which should be also economically feasible. Main questions on the concept will be:

- Which Sensors will be linked, and what kind of data will be used (in case of e.g. interval)?
- How will the data be transferred (from the sensors to the office and to the mobile device), and where will they be stored?
- How will the graphical user interface be structured and designed?
- What kind of IT-architecture and which protocols will be used?
- Is the already existing database covering all necessary issues?

To find a working and operationally usable solution following questions, problems and concepts have to be reviewed, discussed and evaluated:

2.1 Data Insertion

When talking about a structural health monitoring system, the data of different kind of sensors are part of the evaluation calculations. Therewith the System has to deal with different ways of data input. There can be automatically harvested data from sensors like accelerometers or GPS-Stations (Global Positioning System), but also manual insertion of data from sensors like levelling instruments or additional control measurements should be possible. This is of course also a task for the database: how to deal with different kind of features.

Occurring questions like how to deal with different intervals (e.g. accelerometers are sending data each second while levelings are inserted only e.g. once a month) have to be answered.
But also the question how to insert manual changes of the data in field by the engineer (e.g. on a tablet computer) into the database has to be answered.

2.2 Complex Data

The used database then has to be able to store those different kind of data: Starting with point clouds from terrestrial laser scanners up to feature models of the observed structure. And also the raw material might be important for future scientific work, therewith maybe also pictures have to be stored. Projects like the GITEWS (German Indonesian Tsunami Early Warning System have already developed examples for databases storing complex data (Strobl et al., 2007).

2.3 Time Series

Second problem in case of the database will be the storage of time-series of the data. Monitoring means changes of values in comparison to former epochs. In our case most changing values are spatial information, and therewith the problem describes the storage of moving objects in a database. Several approaches exist dealing with this problem, first: For every change of one parameter a full snapshot of all data will be stored in the database but this would lead to a big amount of data.
Second: Only the changed parameter will be stored, but then the relationship model of the database entities and therewith the managing system will become very complex. (Erwig et al., 1999)(Koubarakis, 2003)(Yuan, 1996)

2.4 Data Streaming and Visualisation

The System then has to be able to stream and visualise the data on a certain platform. Webservices might be the actually best solution and they fit to the trend offering software as a service. The service oriented architecture paradigm described in (Papazoglou, 2008) describes the method how to serve the relevant information without having a monolithic static system. With geometric data, as for example geometric primitives, the encoding of the data in CityGML (Gröger et al., 2012)(Kolbe et al., 2009) would be the best solution. With the help of Services defined by the Open Geospatial Consortium (OGC) like for example the Web Feature Service (Vretanos, 2005) (de la Beaujardiere, 2006)(Douglas Nebert et al., 2007)(**?**)(**?**) the related data could be visualised.

Central questions will be what will be visualised how and with which technology. What makes sense and helps the engineer in field with his work. Which kind of data representation and which dimension makes sense in order to symbolise erroneous measurements and or changes in the results.

2.5 Data Analysis

Not as a central part of this master thesis but at least partially the analysis of the used data should be described. The development of appropriate algorithms might not be a task, but the way how to integrate them into the structure.

The Finite Element Method (FEM see e.g. (Zienkiewicz and Taylor, 1977)) should be mentioned here as an example relevant analysis tool.

2.6 Feature Extraction

The System has to be able to access the Sensors and to translate the data in to machine readable and understandable information. In a very complex case the data of e.g. a Terrestrial Laser Scanner is a point cloud which is unique in each epoch. Therewith the relevant absolute information have to be extracted, mostly in this case geometrical features. The RANSAC (RANdom SAmple Consensus) approach has been turned out as one feasible solution for the extraction of geometric Features (Schnabel et al., 2007). And for the recognition of semantic features there are existing different approaches e.g. (Schnabel, 2010)(Gumhold et al., 2001).

But also the more simple sensor types are providing data which have to be translated into machine understandable information. E.g. the accelerometer is producing numerical values without any relation to geographic position or sensor orientation. Here the system has to find a way how to harmonise all the different data inputs.

2.7 Testside

In cooperation with a students project at the Institute of Geodesy and Geoinformation Science running in parallel during the winter term 2013/14 a bridge model as a test side for structural health monitoring and Sensor Web Enablement can be used also for testings of the system being developed within this master thesis.

It has to be discovered how to access the sensors and whether it is covering all planned features of the system.

3 Expected Results

As an overall output a demonstrating prototype of the system will be developed based on one concrete example. Most open questions will in the end be answered and evaluated, based on the developed prototype.
The demonstrating example will contain data from different sensors like levelling instruments, total stations and possibly also data from accelerometers and other permanent observation sensors or terrestrial laser scanners.
The data will be transferred to a central database in such a quality and short interval that a direct and continuous observation of changes in the measurements on a mobile device can be done.
On the structural health monitoring test side for this prototype, experiments should be part of the evaluation of the developed system. Such experiments like observation of loading test on the monitored construction (e.g. a bridge).
Changes in the measured data should be illustrated in a practicable way. An interpretation of numeric results by the user is not an option. Better would be a graphical symbolisation of changes and it pre-evaluation. What kind and which statistical interpretation of the measurements will be part of the algorithms will not be part of the development of this prototype and should be offered by the partnered scientists or parallel master thesis.
This master thesis will simply develop the technological structure as a basis for any implementation of adjustment and statistical evaluation algorithms.

4 Expected Problems

With the implementation but also with the theoretical questions several problems could occur.
First of all the biggest problem would be if there are no data for any testing available. Either due to the fact that there is not an appropriate project taking place or because of data-rights problems.
The possibility of a cooperation with the 'IGG Students Project' of the winter term 2013/14 might be a proper data source.
If there is a fitting project willing to provide its data, the used sensors might not be able to connect

to the Web, and therewith one important part of the developed System cannot be tested of even worse not been developed.

For the streaming aspect of the System it is important that the used data are small enough for a time efficient sending via the web. In case of e.g. raw-data from TLS this would not be the case. The usage of preprocessing the data in the field and sending only intermediate results (in form of e.g. gml-geometries) might solving this problem, but errors in the necessary algorithms are invoking new problems.

Since the full system is depending on a database which should be given by previous work, one big problem could occur when the design of the database is inefficient for the planned tasks, or when the design is covering the full bandwidth of data the System is going to handle.

In the end the system will run on mobile devices. Up to now there have been three platforms established on the Smartphone and Tablet-PC marked: Googles Android, Apples iOS and Microsofts Windows. The development in context of this master thesis will at the most consider only on of these operating systems as a testing platform. The problem here would be a incompatibility to some existing platforms.

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