Simulation for a volcano monitoring network

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This paper investigates the capability of GNSS aided smart sensor network positioning based on Wireless Local Area Network (WLAN) signals incorporating access points, to monitor 3D deformation associated with volcanic activity and other comparable hazardous events. Many of the world's volcanoes that erupt, experience significant pre-eruption surface deformation. Internal magma pressure makes the surface bulge upwards and outwards. Thus, precise monitoring of surface deformation has the potential to contribute significantly to the realisation of a predictive capability of volcanic eruption. In particular, eruption source depth and evolution time can be estimated from surface deformation. The scale of this deformation is typically centimetric to decimetric over tens of square kilometres and over periods of weeks to years. Horizontal displacements show a radial pattern of movement of up to 10 cm with the displacement of the vertical components typically in the range of 4 to 6 cm per year.

In addition to the use of precise positioning information to facilitate deformation monitoring, the positioning function is vital for spatio-temporal referencing of the relevant multiple and complementary data types for volcano monitoring (e.g., seismicity, ground surface deformation, geothermal, gravity, and geomagnetic).

In architectural terms the monitoring network should consist of an array of distributed intelligent nodes (sensor motes), consisting of low-cost, commercially available, and off-the-shelf components (as far as possible) with built-in local memory and intelligence, with self-configuration, communication, interaction and cooperative networking capabilities. The nodes should be able to identify the type, intensity, and location of the parameters being measured, and collaborate in an inter-nodal manner with each other to perform distributed sensing for event confirmation and significance.

Because of the requirement for high accuracy positioning and the need to keep costs down (both in terms of technical complexity and power consumption), building carrier phase GNSS chips into all WLAN should be avoided. A compromise scenario is to have both types of nodes, some equipped with WLAN as well as carrier phase chips that are used for absolute coordinate referencing but with the majority of nodes with only WLAN communication and ranging capabilities. The limited GNSS aiding proposed should enable WLAN positioning to deliver centimetre level positioning. The sensors equipped with GNSS chips calculate their positions in a higher reference frame with high accuracy, and serve as anchor (= control or reference) points for the monitoring network. The communication function of the network should enable the exchange of the data required for positioning within the monitoring network. This should enable the WLAN nodes to position themselves exploiting inter-node distance measurements.

Such a monitoring system requires multiple key features including construction of the hardware that fulfil the requirements in terms of size, battery life and robustness, the extraction of ranges (distances) between sensor nodes, appropriate supporting network communications, protocol development, optimal routing and positioning. This paper addresses specifically the position function and characterises the performance of a novel high positioning algorithm using simulated range measurements. The 3D positioning algorithm uses the range observations for multilateration, clusterisation and geodetic network adjustment.

The novel algorithm is used to investigate various simulated positioning scenarios. The challenges associated with the use of wireless sensor networks are that ideally, the sensors (nodes) should have reliable positioning data, even in the presence of measurement noise, low inter-node connectivity and badly constrained geometry. This paper presents a strategy to enable high integrity positioning and assesses its performance based on various parameters such as the node density, maximal signal range, required fraction of anchor nodes (which have GNSS positioning capability), range measurement errors, and locations of the nodes.

Presented are results from large simulated networks (i.e. 400 nodes) and the optimal network parameters are quantified. The requirement to have direct line of sights between stations can be solved by locating the nodes for a maximum number of directs sights. The number of required nodes depends on the transmission range. The required fraction of GNSS enabled reference nodes will be around 10%, depending on the network density.

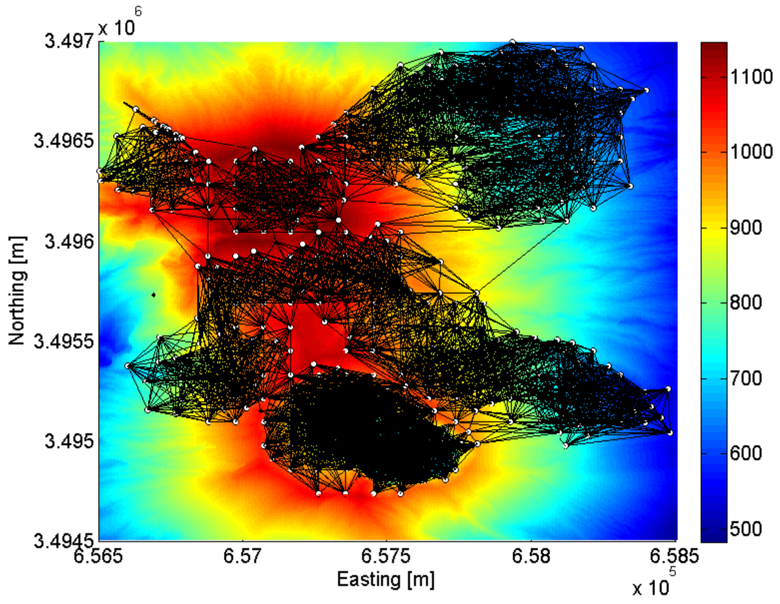

Figure 1. Optimised positions of 400 sensor nodes at volcano Sakurajima.

REFERENCES

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