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Design of an Earthquake Early Warning System for Railway Networks

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The project EWS Transport (Early Warning System for Transportation Lines) analyses the potential of earthquake early warning for railway systems. The study focuses on rapidly producing an alert map during an ongoing earthquake as well as providing a damage map immediately after the strong-motion phase that visualizes potential damage to the railway infrastructure. Additionally, a flexible standard-based architecture is specified in EWS Transport to ensure future reusability of the design principles. Based on these characteristics, EWS Transport is exploring early warning possibilities beyond the Japanese railway earthquake early warning system (UrEDAS), so far the only existing system with a focus on the special requirements of transport lines. In addition to the presentation of the EWS Transport design, the principle of functionality - from extracting earthquake parameters to visualising estimated infrastructure damage – will be presented at the EGU in a simple online demonstrator.

The federal state of Baden-W
ürttemberg (BW), located in the south-west of Germany, serves as test area because of the availability of GIS railway data, knowledge of the railway operational system and information on the local geology. Due to the shortage of observable data, synthetic seismograms of earthquakes in and around BW are generated, based on regional earthquake ground motion data, site amplification parameters and stochastic simulation. Ground motion records at any point in BW can be created for any given hypocenter and magnitude; therefore, different earthquake and sensor network scenarios can be tested. This enables the set-up of a simulation environment that demonstrates EWS Transportś innovative idea of implementing a large number of low-cost sensors in or near railway tracks through the use of the given infrastructure and communication options. Such a dense network would provide comprehensive information directly for and directly at the object of interest.

Earthquake parameters are extracted from the sensor network via artificial neural net technology. Estimates of magnitude, hypocenter and peak ground acceleration (PGA) are computed as soon as one station is triggered and are continuously updated using the incoming information from all triggered and not yet triggered stations. Alert maps displaying estimated PGA values are provided rapidly during the ongoing earthquake. Immediately after an event, shake maps based on the PGA values determined from the actual seismograms of each station are available for damage assessment.

The EWS Transport system is designed according to the principles of an open architecture with standard-based interfaces of system components. These interfaces ensure the flexible and easy exchange of components and are especially advantageous for the joint use of system components between cooperating institutions.

The architecture document is set-up according to the ISO “Reference Model for Open Distributed Processing´´, which uses several architectural views to characterize the system. The views defining user requirements, the information model and the service components are described on an abstract basis before the decision for specific implementation architecture is taken. The abstract parts of the architecture can be reused if new information technologies are developed or the implementation needs to be changed.

The architecture takes into account the standards of the Open Geospatial Consortium (OGC), especially those of the Sensor Web Enablement Group (Sensor Observation Service, Observation
Measurement Model).

The architecture defined in EWS Transport is realized in a simple demonstrator.

One goal is the use of artificial neural networks to demonstrate rapid and robust early warning possibilities for

railway lines. The demonstrator can simulate any one of 301 synthetic earthquakes for which ground motion records have been generated at 30 virtual stations along railway lines in the test area.

A further goal of the demonstrator is to show the interoperability between the standard-based components. Web Services were chosen for the implementation architecture because of online access to the demonstrator and the use of available open source components.

The demonstrator simulates the entire scenario: occurrence of an earthquake, triggering of the sensors, estimation of earthquake parameters, production of an alert map, estimation of hazards, train alert, production of a shake map and estimation of damages. The following OGC standard services are used in this workflow: Sensor Observation Service, Web Processing Service, Web Feature Service and Web Mapping Service. The results are visualized online in a Web mapping client where the different result layers (alert map, shake map, damage map) can be analysed together with base layers (sensor stations, railway tracks, topography).

The demonstrator reflects the EWS Transportś current status. The experience gained herewith will lead to an enhancement of the demonstrator as well as an improvement in the EWS Transport architecture.