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Science Report

Early Warning Systems in Earth Management

Kick-Off-Meeting
10 October 2007
Technical University Karlsruhe

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Dr. Ludwig Stroink

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Koordinierungsbüro GEOTECHNOLOGIEN
Heinrich-Mann-Allee 18/19
14473 Potsdam, Germany
Fon +49 (0)331-620 14 800
Fax +49 (0)331-620 14 801
www.geotechnologien.de
geotech@gfz-potsdam.de

Preface

Geological events like earthquakes, volcanic eruptions, and landslides devastate many regions of our planet time and again. Natural events increasingly create natural catastrophes – regionally due to dense concentration of people and property in threatened areas, and globally due to the unification of the world economy. An exact prognosis of where and how earthquakes occur or volcanoes erupt is therefore essential for effective protection of the population and the economy.

In the frame of the R&D-Programme GEOTECHNOLOGIEN 11 joint projects between academia and industry have been launched in 2007. The objective of this research is the development and deployment of a new generation of early warning systems against earthquakes, volcanic eruptions and landslides. All joint projects are funded by the Federal Ministry of Education and Research (BMBF) with about € 9 Million for the next three years.

Currently supported activities focus on the following key themes:

1. Development and improvement of measurement and observation systems in real time for online transmission of decisive physical-chemical danger parameters
2. Development and calibration of coupled prognosis models for quantitative determination of physical-chemical processes within and at the surface of the Earth
3. Improvement in the reliability of forecasts and prognoses for decision-making and optimization of disaster control measures
4. Implementation of mitigation measures in concrete socioeconomic damage prognoses
5. Development of information systems that ensure prompt and reliable availability of all information necessary for technical implementation of early warning and for decision-making by disaster managers

The main objective of the Kick-Off-Meeting was to bring together the scientists and investigators of the funded projects to present their ideas and proposed work plans to each other; several projects are interlinked and could therefore benefit from synergies. All who are interested in the forthcoming activities of the projects - from Germany, Europe or overseas – are welcome to share their ideas and results.

Ludwig Stroink
Max Wyss

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Integrative Landslides Early Warning Systems (ILEWS)

Glade T. (3), Becker R. (6), Bell R. (3), Burghaus S. (2), Danscheid M. (2), Dix A. (1), Greiving S. (7), Greve K. (2), Jäger S. (5), Kuhlmann H. (2), Krummel H. (4), Paulsen H. (8), Pohl J. (2), Röhrs M. (1)

(1) University of Bamberg
(2) University of Bonn
(3) University of Vienna
(4) geoFact
(5) geomer
(6) IMKO
(7) plan + risk consult
(8) terrestris

Introduction

Early warning of landslides is a challenging topic because the possibilities of prediction vary significantly. A distinction is not only limited to different types of landslides, it also comprises the differentiation between reactivated and new movements. Due to their already moved compound, reactivated landslides are relatively easy to identify and if required, appropriate monitoring instruments can be installed. The locality of new landslides is by contrast rather difficult to predict.

The aim is to design and implement an integrative early warning system for known (reactivated) and new landslides and debris flows, which provides information on future events with regard to local and regional requirements. The methodical configuration of the early warning system is developed to be transferable and modular, i.e. it can be adapted to local structures of different countries, and it can be customized to other natural processes (e.g. rockfalls). Key project targets are:

– Formulation of an integrative early warning concept for landslides
– Investigation and installation of an adapted early warning system
– Monitoring, parametrisation and modelling of local data
– Development of risk management options
– Linkage of local findings to regional modelling
– Provision of information necessary for early warning
– Integration of warning into the respective social processes of decision making. Strengthening the awareness towards underestimated risks that are associated with landslides
– Transfer of the concept to an area with many, already existent monitoring stations which are not yet networked in the above mentioned manner.

Within the scope of the submitted cooperative project, early warning systems are to be implemented in two European test areas.

1. Swabian Alb in Germany

The study area is a settlement area on a historically active complex rotational slide. Regularly recurring damage to houses and measurements of inclinometer show the reactivation of at least parts of the slide. The landslide body is already under investigation within the InterRISK research project, so that the existing infrastructure as well as valuable data can be accessed and continuative knowledge may be built.

2. South Tyrol in Italy

Research focuses on a debris flow in Nals, which is already equipped with an early warning system and the Corvara Landslide, a well-investigated complex rotational slide flow which poses a threat to the village of Corvara. The monitoring infrastructure and long series of measurement of the debris flow and the Corvara Landslide are provided for the project free of charge.

In a first step it is intended to implement an ideal type of early warning system in the study site of the Swabian Alb – from sensor to recommendation of actions. In a second step it is attempted to apply findings and methods from this early warning system to the second study site in South Tyrol.

The early warning system consists of three clusters: *Monitoring*, *Modelling* and *Implementation*.

The Cluster *Monitoring* is designed to realise a robust and easy to handle online-measurement-system for comprehensive monitoring of landslides. It provides the basis for an integrative early warning system. The system consists of a new sensor-combination for the divisions meteorology, soil hydraulics and –mechanics with the corresponding innovative data transmission technologies. The broad spectrum of observed processes contributes to a better understanding of process interdependencies. Hence, the evaluation of the risk of critical landslides can be significantly be improved.

Measurement and data transmission are automated. Data is provided in a standardised form by a central measurement database for further processing (CoreSDI, Setup Monitoring, SensorGIS). Important design criteria for the survey system are the ability to operate on different scales and to be transferable. Using adjusted sensor systems for various area sizes, regions, and processes, regional conclusions must be able to be drawn.

The main aim of the Cluster *Modelling* is the conversion of all continuously and periodically gathered information into a reliable and efficient early warning. Therefore, different new models will be applied (Movement analysis Early Warning Model, Physically based Early Warning Model) and an already existing model (Real-Time Early Warning Model for Debris Flows) will be integrated.

The core of the Movement analysis Early Warning Model (Geomorphic Modelling, Geodetic Modelling) is the trend analysis of the reciprocal landslide movement rate. Linear trends give an early indication of the time for a catastrophic landslide event. This model is complemented by the integration of the continuously measured field parameters into permanent slope stability modelling. The latter results into a permanently updated safety factor (Physically based Early Warning Model). The combination of both early warning models should lead to a more reliable early warning. Regarding debris flows an existing Real Time Early Warning System will be used and optimised. The disadvantage of the existing system is the short premonition time of only some few minutes. It is intended to extend this time span by the integration of the weather forecast. Particularly important is the design of a structure, that is still fully functioning even if one or more system components fail.

The *Implementation* of an early warning system is a multistage process. It starts with the definition of protection goals – differentiated for the various subjects of protection and their respective damage potential (economic values, critical infrastructure, people, environment). The defined protection goals are then an important basis for decision-making of the Clusters *Monitoring* and *Modelling*.

The scientific analysis is an essential part of an integrated early warning system. However, the question which risks are acceptable or tolerable is a normative one, i.e. it has to be answered by the authorised players. Thus, a cooperative risk communication (Communication) is integrated into the cooperative project, identifying the configuration of the involved actors and the communication relationships between these. Within the framework of an information management, respective results will be the basis for the development of a communication network towards and between the involved actors of a early warning chain.

The described project ILEWS is divided into ten subprojects. Five of them are executed by universities, the other ones by companies. The aims of the different subprojects will be explained on the next pages.

Subproject: Monitoring of landslide movement and Early Warning Modelling

Thomas Glade & Rainer Bell,
University of Vienna

Within this subproject shallow translational slides, deep-seated rotational slides, and debris flows will be investigated. Subsurface landslide movements are monitored periodically using a mobile inclinometer device and continuously with a permanent installed inclinometer chain. Gained results complete the assessment of relevant early warning parameters for the process type »slide« within the Cluster *Monitoring*. All gathered monitoring data of the Swabian Alb and supplied data of South Tyrol are integrated for an user optimised and reliable early warning message. The early warning modelling concept uses a physically based »Near Real-Time« Early Warning Model, a Surface Movement Analysis Early Warning Model (with the subproject »Geodetic Modelling«) and Regional Early Warning Models.

Within the physically based »Near Real-Time« Early Warning Model the continuously measured data, especially soil moisture and rainfall (provided by the subprojects »Moisture Geolelectric« and »Setup Monitoring«), will be integrated in equations to calculate slope stability. Thus, a continuous safety factor can be calculated (the respective WebGIS application will be programmed by the subproject »Info-Management«). If the safety factor gets lower than a specified threshold value, preliminary warning messages are provided in the WebGIS and SMS are sent to the scientists of the subproject (by the subproject »Sensor-GIS«) to check and validate the warning using sophisticated slope stability models as well as current subsurface movements. The slope stability software will also be applied to calculate highly likely sliding circles for rotational slides and to identify the best suited slope stability equations. The results are then again input for the physically based »Near Real-Time« Early Warning Model. At the end of the optimisation period an autarkic running early warning model will be set up, which controls to some degree itself and must only be supervised by experts.

Within the Surface Movement Analysis Early Warning Model all measured movement rates (inclinometer, inclinometer chain, tachymetry, GPS – with subproject »Geodetic Modelling«) are analysed using the approach of »progressive failures« (Petley et al. 2005). Depending on the way how the movement rates change, the catastrophic failure of a slope can be predicted. In a last step, it is investigated if both models can automatically support each other.

It is tested at the Reisenschuh landslide in South Tyrol, whether the early warning models developed for slides in the Swabian Alb can be transferred to other study areas, which are already partly equipped with measurement instruments. Regarding the already existing Debris Flow Early Warning System the scientific basis as well as the extensive measurement series will be analysed in detail to suggest possibilities to improve the system on the one hand. On the other hand important insights towards the set up of a Regional Early Warning Model (with the subproject »History«) are expected.

Local Early Warning Modelling will also provide information on the magnitude of potential events. To better define the endangered areas depending on the type and magnitude of the process empirical or physically based run out models are applied. Regional Early Warning Models for slides and debris flows are based on the regionalised critical local conditions. Regarding slides GIS-based models will be applied which calculate the threat due to translational slides on the basis of the »infinite slope model«. For debris flows an statistical model will be applied, which transfers the results based on the extensive measurement series from one debris flow track to other catchments. The integration of the official

weather forecast into local and regional early warning models will lead to an expansion of the warning time. A comparative analysis of all applied early warning models will give important information on the usage of each approach for different conditions.
Historical frequency-magnitude analyses based on the data provided by the subproject »History« will help to estimate the recurrence interval of landslides of various magnitudes more reliably and to better interpret local measurement results. The GIS-based combination of the early warning modelling and damage estimation (with the subproject »Management«) will provide very helpful information for decision makers for choosing the best-suited system for risk mitigation and reduction. In cooperation with the Cluster *Implementation* a user optimised preparation and provision of the early warning message will lead to improved reaction capabilities of the affected people.

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Petley, D.N., Higuchi, T., Petley, D.J., Bulmer, M.H. And Carey, J., 2005. Development of progressive landslide failure in cohesive materials. Geology 33(3): 201–204.

Subproject: Coordination, Integration and Optimisation of a Multi-Sensor System for Monitoring of Landslides

Rolf Becker, IMKO Micromodultechnik, Ettlingen

The most important objective of the »Setup Monitoring« project within the collaborative research project is the coordination and hardware-related integration of heterogeneous field sensors into a unified, robust and simple to use measurement system, as a standalone component of an extensive landslides early warning system.
The innovation of the monitoring system are its particular measuring procedures and integrated data recording mechanisms, which will be specifically adapted to the early warning of rotational slides. The system includes sensors for determining the load (meteorological data), the inner status of the vadose zone (water content, soil suction head, and pore water pressure) and the system response (assessed by monitoring kinematics using GPS, tilt meters, inclinometers, and extensometers) for a slipping body. Conventional sensors as well as novel measurement procedures will be used.
The time variant soil water dynamics is the key factor ruling the current geo-mechanical stability of a slipping body. Determining the soil moisture in clay or highly electrically conductive soils is a technological challenge due to energy dissipation during the measuring procedure. The measuring principle Time-Domain-Reflectometry (TDR) is less prone to these effects and thus especially suited for the particular application. TRIME-TDR sensors by IMKO supply reliable measurements even with difficult soils, and are therefore used as the solid backbone of ground water measurements related to landslides.
The novel stationary geoelectric system from the project partner geoFact is one of the first being capable of continuous monitoring and will be a key component of the integrated monitoring system. Scale transition from point to slipping body is achieved by the extended two- or three-dimensional conductivity fields resulting from geoelectricity in combination with the pointwise soil moisture measurements used for calibration. The subproject will support geoFact in developing a procedure for upscaling soil moisture.
The »Spatial TDR« method, currently being developed at several german universities and research institutes, allows the determinination of water content profiles along elongated sensor cables of several meters length. However, this procedure requires a large mathematical effort to analyse signals and locally does not achieve the same accuracy as conventional TDR sensors. As part of the project it will be tested whether a combination of Spatial TDR and standard TDR sensors provides a significant information gain concerning infiltration, purched ground water tables, and hanging slippage.

Another forward-looking aspect of the system integration is the fusion of IMKO's well established sensor technology for recording environmental variables with novel self-organising wireless networks, which will be installed and operated by the subproject »SensorGIS«. A small number of the sensors for vadose zone monitoring will be taken out of the previously built cabled field bus system and will be integrated into the wireless network. The wireless network nodes from ScatterWeb have a variety of interfaces to connect the sensors. Here too, hard- and software adjustments will probably be required to match the different interfaces. Robustness, prevention of downtime, and energy supply for the planned sensor network are important aspects of the joint investigations. These issues are decisive criteria for future applications of wireless sensor networks for environmental monitoring.

Subproject: Cooperative Risk Communication

Marco Danscheid & Jürgen Pohl,
University of Bonn

The subproject »Communication« has two superordinate aims: One is the clarification of general local and regional needs. The other regards the cooperative implementation of early warning systems with both the affected players and the other subprojects.As a logical starting point the work is oriented on the end users needs. These shall be assessed in detail right from the beginning of the project and they shall influence the design of the Early Warning System that is to be developed. It is of decisive importance to identify the information required and how it should be presented. More pointedly, do the end users want a »flashing red light« or do they prefer more detailed information, which require them to come to a decision?
Questions are: Which protection-worthy goods exist on the localities? Which concrete need for action does that imply? Which kind of early warning information do the players need?
Where men are involved, one can speak of social systems. Every social system (e.g. companies or public authorities) has specific logics and connected languages. To investigate these is an important aim of this project.
Since there are different logics and languages in different social systems, it is important to take this into account for risk communication. It is essential to develop showcase translations to enable different social systems to communicate.
Questions are: How can be guaranteed that timely communicated early warnings will be transformed to adequate reactions? How to conceive an early warning system that is accepted by the end users?
Examining other research projects on »early warning of landslides« it becomes obvious that social scientific components are either completely neglected or only implemented as a simple communication module. These modules are often only used to communicate natural scientific results to the players. A cooperative implementation of the Early Warning System, where players – both end user and consultant – are taken seriously right from the beginning does not exist, at least not as it is specified in the plans for the subproject »Communication«.
The subproject »Communication« would like to break new ground by penetrating the complexity of social actor systems with the help of cooperative interviews and by developing sensible solutions in collaboration with the players. The aim of this approach is to make a contribution to an early warning system which even works in the ultimate consequence – and in doing so saves lifes.
The cooperative implementation of the Early Warning System stretches across the whole project time. A main focus of the subproject »Communication« is to do qualitative interviews with the involved players and to analyse the findings.
Based on the analyses showcase translation schemas are developed. They shall help to improve the communication between different actor systems or even to enable communication for the first time. The question is, how

does the communication of a player have to be formed for other players to perceive it and acknowledge it as relevant.

Subproject: Historical comparative regional analysis of frequency and magnitude of landslides

Andreas Dix & Matthias Röhrs,
University of Bamberg

The subproject's objective is to develop methods for monitoring frequency and magnitude of landslides through history. This is to be conducted based on research of the Swabian Alb region and compared with South Tyrol in two landslide-prone regions. Based on the results and experiences gained, conclusions shall be made as to how historical analysis can in the future be integrated into an early warning system which is as effective as possible.

Historical data plays a decisive role in the complex chain of early warning and risk communication in at least two system areas:

1. Current knowledge of the spatiotemporal distribution of past landslide events is very incomplete. The effectiveness of an early warning system, however, depends upon the quality of data especially of the frequency and magnitude of events. It is therefore necessary to use all existing data pools to implement an early warning system, which includes the historical information saved in the archives. Systematic research and indexing of the historical material thus helps to improve the knowledge of the total distribution of landslides. Only by establishing event series whose spatial and temporal resolution is as high as possible, can conclusions regarding risk zones and expected distributions of future events be made. Along with the measurements of current conditions, these form the basis of a significant early warning system. This data can also be used to check existing data for its representativeness and validity.
2. Apart from scientific risk analysis, an early warning system is only effective if it is based on a high public risk awareness. This knowledge, on the other hand, can essentially only be based on past events. Therefore historical knowledge seems fundamental for the successful implementation of an early warning system. This knowledge also includes handing down perception and handling of these specific natural hazards through history. The question of what and how much of this knowledge was actually handed down, can be adequately reconstructed by analysing the archives.

Data acquisition is to be carried out comparatively in cooperation with the subprojects from the *monitoring*, *modelling* and *implementing* clusters in two sufficiently different test regions, the Swabian Alb and South Tyrol.

The first work step, the index books of central archives are to be analysed so that the following step the relevant files can be searched through thoroughly and other local archives included.This should allow long data series regarding frequency, magnitude, triggering factors and perception of landslides to be created.

To achieve results in a short period of time the snowball effect has proven successful for previous investigations. This does not only take into account all available types of source but also keeps track of any considerations as regards other subprojects, experts or the local population. Here an exchange in both directions has proven to be fruitful.

It can be assumed that based on the experiences in the Swabian Alb region systematic research not previously carried out in South Tyrol will produce similar results. The source density in South Tyrol is supported due to the fact that from the 19th century the Habsburg Monarchy conducted high-resolution cadastral mappings precise by lot which can be rated as very good in terms of quality and density. We also assume that during the Alpine war from 1915 not only measurements but also the first aerial view series and photogrammetric measurements were conducted on a large scale which had never been used for such purposes before.

Subproject: Integration of early warning into an integrated risk management

Stefan Greiving, plan + risk consult, Dortmund

An early warning system has to be developed according to the requirements of its users who have been identified in the Cluster »Implementation«. Therefore, the management of information as well as the dissemination of information (risk communication) are of particular importance. Thus, there is a strong connection to both of the other sub-projects that belong to the cluster »Implementation«.
Research objective of the part »Management«, to be awarded by contract, is to broaden the perspective and to provide the stakeholders in the case study areas with an appropriate consideration of action alternatives. An early warning system however is only one of many alternatives because the whole »disaster management cycle« of prevention, preparedness, reaction and reconstruction has to be considered. An early warning system thus may not have to be understood as a single isolated measure of which the implementation is based only on the identified hazard. Moreover, existing vulnerabilities and action alternatives have to be considered, too.
As a part of the envisaged integrated approach, different and sometimes alternative measures may compete with each other. Criteria for the assessment of measures – that have been defined in co-operation with local stakeholders – are especially the protection goals for hazard-prone areas but also aspects of efficiency and effectiveness.
Consequently, this part contributes to improve the implementation of the early warning system to be developed and tested as well as to improve the economic exploitation by the involved companies. Further, it will contribute to a secure and efficient use of public funds that are needed in order to establish early warning systems in practice.
The existing fragmentation of isolated approaches often derives from the broad distribution of responsibilities for action within the disaster management cycle among numerous persons and/or institutions in charge. According to the fact that planning and implementation competences are only bundled at the local level and taking into account that the proximity to potentially affected people promises a high level of involvement of concerned stakeholders, the focus of the work within this part will be on the local authorities of Lichtenstein-Unterhausen (Swabian Alb, Germany) and Nals/Nalles (South Tyrol, Italy). The relevant stakeholders in the Swabian Alb (association of administrations, county, Regional Association Neckar-Alb) and in South Tyrol (Autonomous Province of Bozen/Bolzano with its responsible departments) will be identified and involved in the project.

Subproject: Central Spatial Data Infrastructure, Open Web Services and Web Processing Services for the Development of an Information and Decision-Support System for Risk Management in Early Warning Systems for Landslides

Klaus Greve, University of Bonn

This subproject aims to develop the basic technological principles for an early-warning specific spatial data infrastructure. Early warning systems require very complex information and communication structures. They need to interface sensor and data management technology with database management systems, data preparation and analysis, prognosis and model calculations, computer networks, communication terminal units, result processing systems, and communication tools.
To date, major problems on syntactic and semantic levels have resulted from the connection of heterogeneous components in complex Systems. Basically, such interconnections are easily controllable by the use of classical technology. However, due to the special complexity of early warning systems, the coupling of numerous components and interfaces (syntactic problem), different requirements on the content (semantic prob-

lem), and a highly dynamic technology development, the interconnection is more difficult and potentially lossy. In these cases, infrastructure oriented technologies described by the keywords Sensor Web, Open Web Services and WPS will be used. They are based on the Web Service Paradigm and originated in context of Spatial Web approach of the OGC. This technology offers much higher interconnection and networking abilities than classical technology.

Web Services isolate different ›jobs‹ of spatial information processing and implement them in the architecture of different modules. Theses modules can be implemented as stand alone services and communicated via standardized interfaces. Open Web Services (OWS) are the basis of spatial data infrastructure projects on international (GSDI) and national levels (GDI.de), and in nearly all of the German federal states (GDI NRW, GDI BB, GDI NI etc.).

Initial pilot tests have indicated that the concept has reached a level of possible ›real world‹ implementation. Part of the information provided by these services includes assessments about the service's own ability to provide information. Interlinking is not only possible along linear structures, but also within complex and partly self-organizing networks. These services thus already anticipate structural elements of the Semantic Web, the successor to the WWW.

In this subproject, the spatial information technology basis of early warning systems will be explored by first implementing current concepts of geoinformatics into the service architecture and processing modules. The strengths and weaknesses of the solutions will then be evaluated within the application. In order to do this, the central components of an early warning specific spatial data infrastructure will be implemented.

The basic concept and all essential modules of this subproject will be developed and implemented as WebServices, and therefore useful in other Spatial Data Infrastructures.

The concept is considered to be innovative, and real-world efficiency can be supposed.

In this project, a high complex Spatial Data Infrastructure with very heterogeneous information sources and information will be created, as defined by the involved organisations.

Subproject: Development of an adequate data model schema for an information and decision support system for risk management in landslides early warning systems

Stefan Jäger, geomer, Heidelberg

A standardized early warning process for mass movements requires a well structured information management for all relevant information and processes. This sub-project is a cross cutting issue for the project's framework outline. The temporal and spatial uncertainties on one hand as well as the great variety in quality, amount and availability of relevant data to be expected on the other hand, require complex database schemas. These must have the ability to completely represent the early warning chain and thus the activities of the *monitoring* and the *modeling* clusters of ILEWS. The information and decision support system must have the ability to help decision makers as well as disaster management with qualified decision support. This includes also information concerning the triggering mechanisms of landslide processes and their temporal and spatial quality, which is dealt with in the modeling cluster. That means, information must be covered and conveyed ranging from dense, site-specific monitoring systems on single landslide bodies, to simple landslide susceptibility maps and statistically poorly sustained rainfall intensity/duration triggering indices. The often uncertain information situation also requires the possibility to represent conclusions based on probabilities. In addition, a landslide early warning system must be able to provide estimates of the potentially associated risks for the affected population and the economic activities. Information about critical infrastructure locations and their importance are therefore an essential part of the information process.

– Definition of a geodata model for the relevant information components. The geodata model consists of basic geodata as well as of monitoring data from sensor webs, socio demographic data and critical infrastructure information, with respect to OGC-conformal data formats and description (metadata standards).
– Definition of interfaces to already existing data infrastructures of the national and municipal civil defense authorities, under consideration of interoperability standards of the OGC. Here, the task is to develop web-based services for the dissemination of the data the data and information sampled and compiled by the sub-projects to the users (civil protection, decision makers etc.).
– Development of an AJAX based visualizing component for various user groups and devices on the basis of the before mentioned web services. This is of concern primarily for the monitoring and measuring of data, which serve as input for models and for the model results themselves. These data should be visualized preferably in real time and for various time steps for visual control. The visualization component mainly will be developed based on standardized OGC compatible mapping services as far as geodata are concerned. Additional development demand is given in the field of visualization of the historical data as well as for the socio-demographic and economic data in the context of early warning.
– Implemantion and tests of the systems components will finalize the development process.

Subproject: Geodetic Monitoring and Modelling

Heiner Kuhlmann & Stephan Burghaus, University of Bonn

The task of geodetic monitoring measurements is to get a confirmation of predictable changes (e.g. subsidence behaviour of buildings) or the proof for a non-expected or non-predictable change of an object (e.g. landslide). Information is generally being supplied through selected measuring points. The behaviour of the object can be quantified by analysing the movements over time. Closely related with the determination of movements is also the question of reasons in order to derive a causal connection.

By means of a specially created geodetic point network that spreads over stable as well as critical slope areas those areas should be identified whose movement intervals differ significantly from other areas due to certain other effects (e.g. increase of humidity, change of pore water pressure, etc.). Absolute movements of ground points in slope areas are being recorded and compared to reference points via measuring methods such as GPS and electronic precision tacheometry. Apart from those (geodetic) network points further measuring stations are being created which are equipped with sensors for relative measurements (e.g. chain inclination measuring systems in the subproject »Geomorphic Modelling«). They must be linked with the geodetic measuring points in order to get best redundant but assignable measuring information on movements.

It is the intention to use both geodetic measuring methods one after another. If we assume that the movement intervals are about 0.3 mm/month, the measuring resolution of the precision tacheometer of about 0,2–0,3 mm will be sufficient if you carry out episodic measurements and repeated measurements about every 2–3 months. They do not only cover the monitoring of the geodetic point network but also the respective integration of all measuring stations for relative measurements. This does not only deliver redundant information on areas close to each other but the automatic relative measurements can serve as indicators for beginning movements in order to possibly initiate monitoring measurements outside the scheduled measuring epochs.

As already indicated GPS measurements shall be carried out with the same measuring epoch. They do advantages with continuous monitoring methods over several weeks provided they are being carried out as static measurements. The data achieved in the local network come together in a central control and evaluation unit, by that it is possible to calculate the basic lines between the network points automatically and continuously in order to derive station movements from that.

The observation deviations with the GPS method show a certain auto-correlation in the range of a few minutes up to a few hours. Reasons for this are e.g. multipath and extension effects of the electromagnetic waves. The dimension of the deviations lies above the point movements to be expected. A reduction of those observation deviations can be achieved during long observation periods and an analysis using the post-processing method. Due to the planned early warning system a real-time process is wanted here which arranges the analysis in such a way that a separation of measurement deviations and point movements will be done in a filter approach.

To get a relative precision of tacheometric measurement clearly less than 1 ppm a regular examination of the measuring instrument will be necessary. It is also not sufficient to introduce the gained meteorological parameters of the endpoint as representative factors for the entire measuring distance. Hence the determination of the refractive index plays an important role and finally is the precision limiting factor for the distance measuring especially in mountained areas.

A successful way for high-precision distance measuring was taken in the 1990s. Based upon the light dispersion in a turbulent medium, the fluctuations due to atmospheric exchange processes are described in a model by means of statistic factors. Suitable commercial systems to measure these atmospheric fluctuations have been developed by Scintec/Tübingen in form of the scintillometer measuring systems. Regarding the chosen study areas a scintillometer will be used, which can do measurements up to 4–5 km. Its usage will lead to a significant improvement with the modelling of the refractive index and can therefore cover huge parts of the refractive components which have previously been difficult to determine.

In the chosen study areas changes are being expected that have an explicit time connection. The movements to be achieved can be modelled together as a function of rainfall, pore water pressure, slope inclination and ground parameters, etc. This will then be the basis for an Early Warning System via which an according measure and emergency concept should be initiated in order to best handle the current situation.

Subproject: Spatial Monitoring of soil parameters with geophysical survey methods

Heinrich Krummel, geoFact, Bonn

Primary objective

– The aim of the project is the development of an innovative monitoring system for soil parameters and flow potential based on geophysical survey arrays.

The intention is to permanently install sturdy 2D/3D geoelectrical survey systems in potentially endangered landslide areas. An automatic procedure will be developed for data collection and for transferring the data via modem to a central processing unit. The calibration of the geoelectrical data is done by singular in situ soil moisture measurements (co-operator: IMKO, Karlsruhe). The processed results of the survey will be implemented into a central database for the mutual use of all cooperators involved in the main project and can be evaluated and interpreted with respect to the common goal of the development of an early warning system for landslides.

Within this sub project it is intended to permanently install a geoelectrical survey array at a known landslide endangered location in Lichtenstein-Unterhausen (Schwaebische Alb, Germany). The landslide body will be examined with geophysical methods (e.g. seismic, geoelectric) prior to the installation to determine the geometry of the body and to determine critical »hot spots« for the setup of the

permanent array. The survey system will automatically perform several surveys each day.
Special (TDR-)probes of partner IMKO GmbH will be installed within the array at different positions in different depths to measure soil moisture. The geoelectrical results will be calibrated using the probes to gain areas of different soil moisture out of the geoelectrical resistivity data.
Automatically procedures for data collection, data transfer and analysis will be developed within the sub project.

Scientific and technical objectives

Optimisation of 2D/3D-geoelectrical survey arrays (e.g. linear, star shaped or quadratic arrays, electrode separation) for continuous surveying of soil moisture/flow potential at »hot spots«, e.g. sliding surface of a potential landslide.

– Development of an automatic procedure for periodic data collection and data transfer
– Development of an automatic procedure for analysis of geoelctrical data for interpretation of soil moisture conditions, therefore:
– Development of an automatic inversion procedure for creating to create geoelectrical resistivity models from apparent resistivity data.
– Scale transformation for soil moisture from singular in situ measurement to spatial information by using 2D/3D-geoelectrical survey systems.
– Development of a prototype of an automated 2D/3D-geoelectrical survey system for monitoring the soil moisture/flow potential at potential landslide locations

Subproject: Standardised, wireless sensor networks for the efficient acquisition, transmission, storage and visualisation of geodata

Hinrich Paulsen, terrestris, Bonn

Warnings about imminent events in the realm of mass movements require timely information about certain parameters. Amongst these are changes in slope angles, pore water pressure, precipitation intensities, soil moisture contents to name but a few. The aim of terrestris is to employ wireless sensor networks (WSN) to efficiently acquire, transmit, store and visualise relevant geo-data.
Data will be visualised in a web based geographical information system (WebGIS). In every phase of the project the use of a WebGIS has the added advantage of being able to immediately evaluate and quality check incoming data with ensuing modifications to the system gradually optimising the sensors. Following this procedure it is possible to evaluate the robustness and functionality of the system – on the one hand with regard to the data and on the other hand with regard to the hardware. Failed sensors due to lacking energy, frost or mechanical damage, etc. will immediately show up in the WebGIS.
Apart from the above mentioned advantages the WebGIS can also function as a communication platform which is particularly useful when dealing with spatial data since it also facilitates the coordination of and discussion amongst spatially distributed project participants. Other players like communities, scientists working on the same test site, or even the general public can easily be granted access to the system.
Wireless sensor networks are a new type of geographical information system for in-depth and continuous monitoring of the environment. Technically termed »embedded systems« these mini computers were only possible through the progress in semi-conductor technology of recent years. They consist of a central processing unit (CPU = microcontroller), memory and radio technology. This basic hardware can be equipped with sensors of any kind like those measuring temperature, vibration, movement, humidity, etc. On principle all sensors can be attached that provide an electronic signal.
Due to the fact that sensors are distributed in space they can be assigned a coordinate which turns the measured data into geodata. This geodata is then routed to a special node with access to the internet by means of the Global System for Mobile Communications (GSM),

General Paket Radio Service (GPRS) or radio and is directly written to a database. These databases are deemed to be object-relational with some of them (PostgreSQL, Oracle) being able to directly store geographical features through the use of a spatial extension.

Collaborative geographical information systems are dependent on standards to function efficiently. The Open Geospatial Consortium, Inc. (OGC) works with government, private industry, and academia to create open and extensible software application programming interfaces for geographic information systems (GIS) and other mainstream technologies. One of its initiatives is the Sensor Web Enablement (SWE) activity which is establishing interfaces and protocols that will enable sensors of all types to be accessed over the Web.

Early Warning Systems in Earth Management

In addition to currently implemented measures for establishing an early tsunami warning system in the Indian Ocean, the German Federal Ministry of Education and Research (BMBF) has launched a portfolio of 11 research projects for developing and testing early warning systems for other natural geological catastrophes. The projects are carried out under the umbrella of the national R&D-Programme GEOTECHNOLOGIEN.

The overall aim of the integrated projects is the development and deployment of integral systems in which terrestrial observation and measurement networks are coupled with satellite remote sensing techniques and interoperable information systems. All projects are carried out in strong collaboration between universities, research institutes and small/medium sized enterprises on a national and international level.

The abstract volume contains the presentations given at the "Kick-Off-Meeting" held in Karlsruhe, Germany, in October, 2007. The presentations reflect the multidisciplinary approach of the programme and offer a comprehensive insight into the wide range of research opportunities and applications.

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