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OASYS – Integrated Optimization of Landslide Alert Systems

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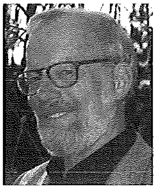

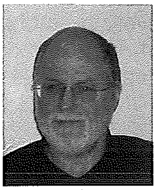

Abstract

In the past there has already been done a wide range of research work on landslides. Most of this research, however, had a bias towards one discipline, like GPS or geology. Therefore an international and interdisciplinary project was started. The proponents of the project, sponsored by the European Union, believe that a multidisciplinary integration of different methods has the greates potential for substantial progress in natural hazards management. The goal of the project is the development of methods that allow:
1. to detect potential landslides
2. an efficient and continuous observation of critical areas
3. the devivation of real time information about actual risks.

Kurzfassung

In der Vergangenheit hat es bereits viele Projekte gegeben, Hangrutschungen zu beobachten. In den meisten Fällen war dies jedoch mit dem Nachteil verknüpft, dass nur eine Disziplin beteiligt war, wie die Geodäsie mit GPS oder die Geologie. Es wurde daher ein internationales Projekt organisiert. Die Teilnehmer des Projektes, welches von der Europäischen Union finanziert wird, sind überzeugt, dass eine multidisziplinäre Integration verschiedener Methoden den größten Fortschritt für das Katastrophenmanagement bringt. Ziel des Projektes ist, Methoden zu entwickeln, die es erlauben:
1. regional Rutschungsgebiete zu detektieren
2. kritische Gebiete kontinuierlich mit hoher Genauigkeit zu beobachten
3. Echtzeitinformationen für das Abschätzen von Risiken zu gewinnen.

1. Introduction

Worldwide landslides are one of the major types of natural hazards killing or injuring a large number of individuals and creating very high costs every year.

Besides direct costs landslides are also reason for even higher indirect costs like interruption of important infrastructure facilities or losses for the tourist industry etc. In future it is very likely that the damages caused by landslides will even increase as the hilly areas, where the majority of the landslides occur, are used by a growing number of tourists and intersected by increasingly powerful transnational networks. In addition many global climate change scenarios predict an increase in the probability for heavy rain, which is a primary trigger for landslides (refer to Taiwan Sept. 2001, 128 death toll from landslides). This implies that there is urgent need for highly productive and reliable tools for landslide hazard management at an operational level.

In contrast to these prospects the national funds for hazard prevention and the number of personnel in the national authorities responsible for hazard management are stagnating or shrinking. Several natural disasters in the last years have also shown that the decision makers in hazard management are confronted with a justice and public that will evaluate their decisions in an increasingly critical manner and look very thoroughly for possible responsibilities.

There has already been done a wide range of research work on landslides [1] [2] [3]. Most of this work had a bias towards one discipline, like remote sensing or geology. The proponents of the project believe that for future work the multidisciplinary integration of different methods has the greatest potential for substantial progress in natural hazards management. The aim of the suggested research project is to set up an integrated workflow for landslide hazard management. This system should lead the practitioner from the data acquisition all the way to suggestions of risk management measures. The majority of fatalities occurs due to the fact that the affected persons are not aware of the danger and are surprised then by the actual landslide event.

The emphasis of the suggested project is the development of observation methods that allow
1. to detect potential landslides
2. an efficient and continuous observation of critical areas
3. the derivation of real time information about actual risks

2. Existing technology

Currently the investigation of landslides and unstable slopes is based on two groups of information sources:

2.1. Information sources on regional scale:

- Data on historical landslides:
  The relevant data should include information when and where landslides occurred in the critical areas.
- General conditions of the areas
  Map data of the general conditions, like digital elevation model, geology, tectonics, geomorphology, vegetation, climate, land use are indicators for active landslides [4].
- Remote sensing data
  Further sources for the potential landslide risk can be differential satellite image analysis, time series of airborne sensor data (photogrammetry, laser scanners, radar systems, geophysical measuring devices) and terrestrial mapping.

2.2. Information sources on local scale :

- Geodetical:
  GPS, precise levelling, tacheometers (measurement robots), multisensoral remote sensing techniques (using optical- and radar-sensors)
- Geophysical:
  geoelectric and electromagnetic field measurements
- Geodynamical:
  borehole tiltmeters, extensometers, hydrostatic tiltmeters
- Seismological:
  sensors for microseismic activity, seismic reflexion measurements
- Hydrological:
  sensors for groundwater level variations, water level variations, groundwater stream variations
- Meteorological:
  sensors for temperature, air pressure, precipitation

The information of the first source enables to detect the site of the landslide, those of the second source are used to describe the mechanism of the processes. Normally, however, only some of the parameters (deformation vectors, water power pressure) are used for the investigations and the measurement points are widely spaced divided across the landslide domain. The deformation measurements are frequently based only

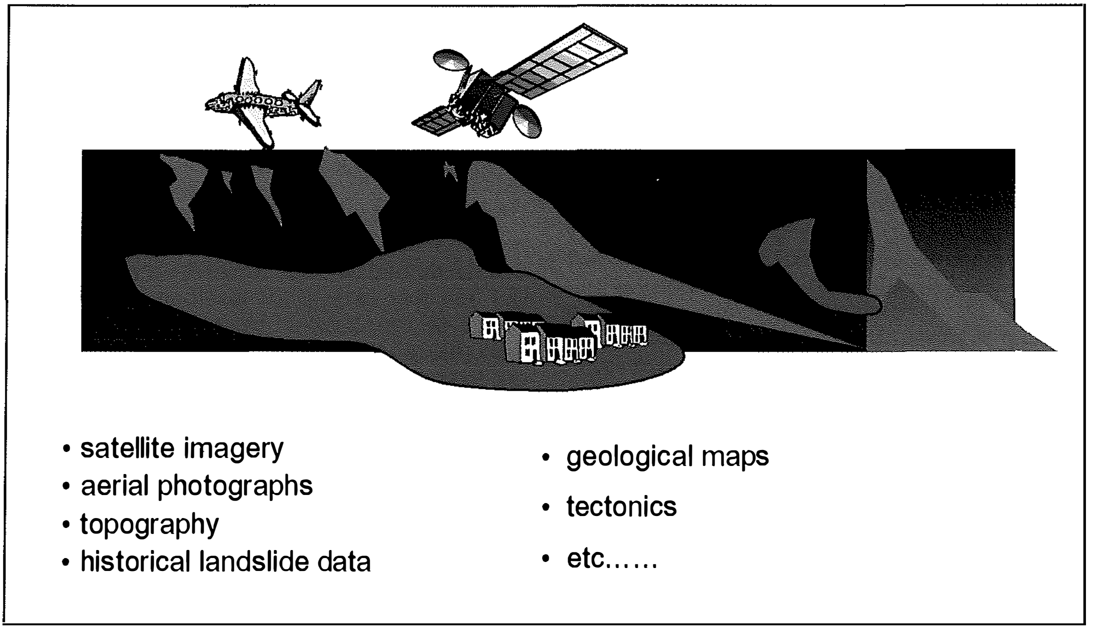

Fig 1: Large scale monitoring with airborne and satellite remote sensing

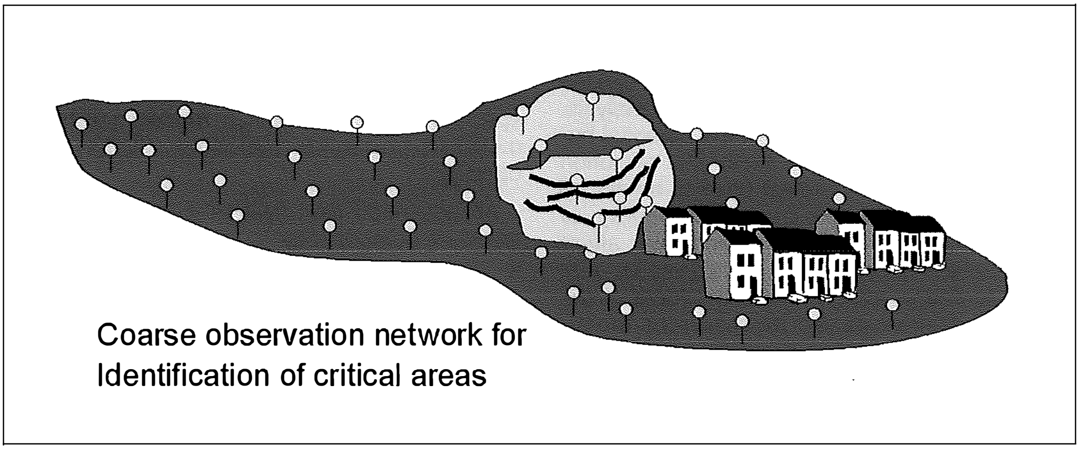

Fig 2: Large scale monitoring using GPS and total stations

on one measurement method (GPS, tacheometry). As these measurement methodes are relatively costly, normally only a limited number of observation points are used and the measurement systems are not run continuously. This methodology has made it possible to follow the evolution of the landslides precisely but yet it is difficult to predict the evolution.

By a better integration of this information sources a more reliable prediction should be possible in the future.

3. Integrated Optimization

An advanced model is now under investigation, based on large scale monitoring and a multi-component alert system. The method will consist of four different steps:

1st step:

Detection of potential landslides (Large scale monitoring)

To get information about the long-term geodynamical processes, a large scale evaluation has to be performed. This includes the historical data, all information describing the general conditions of the areas, as outlined in section 2.1, and remote sensing data, like aerial photographs, optical and radar images from satellites (Fig. 1).

More specific remote sensing techniques (InSAR), differential GPS (using phase observations) and tacheometric measurements shall be used to get additive information about the deformation process (Fig. 2). The measurements will be performed only three or four times a year and the results will be fields of vectors describing the displacements and velocities [10].

An advanced and generalised deformation analysis algorithm based as well on geometrical as on topographical, geological, hydrological and meteorological information has to be developed to improve the detection of taking-off domains, see [7] [11].

2nd step:

High precision permanent measurements in the taking off domains

High precision borehole tiltmeters, extensometers and hydrostatic levelling and further relative measurement systems shall be used in the area of the taking-off domains to get online information about the geodynamical process [6] [8].

This multi-sensor system will be running continuously and can therefore support a real time alert system, see Fig. 3 [5].

3rd step:

Impact and risk assessment / Development of stategies for alert systems

Risk assessment comprises the analysis of the empirical data and the development of an alert system deals with the management of an impending landslide hazard.

The analysis of empirical data includes the detection and interpretation of velocity fields in order to define zones of increased deformation. The final analysis will be supported by expert systems, using methods of cluster analysis, neuronal networks, fuzzy techniques and others [7].

The process of risk analysis can be divided into hazard analysis and vulnerability analysis. Hazard analysis is the review of the potential hazardous processes. Scenarios for the evolution of a landslide area of interest have to be set up including an estimation of the probability of these scenarios. Different scenarios will affect different areas and therefore a different amount of people and property. The assessment of the impact of different hazard processes on the affected population and its property is called vulnerability analysis.

The integration of hazard and vulnerability analysis will lead to an estimation of the actual risk situation of the affected population. The risk management measures will depend heavily on the specific conditions and will include landuse planning, technical measures (e.g. drainage systems), biological measures (e.g. afforestations) and temporary measures (e.g. evacuations).

The information of the public about potential hazards and the fast and effective alerting and evacuation of the people in endangered areas are vital prerequisites for a functioning natural hazard management system. One of the main sources for fatalities caused by natural hazards is the lack of awareness of a certain hazard and the lack of knowledge about appropriate behavior in an emergency case. Therefore people are often surprised then by a landslide. This work package tries to tackle this deficit by the dissemination of background information to the public and by the development of new means of alerting and evacuation by the application of new communication technologies. This has to be performed by taking into account the cultural and socioeconomic boundary conditions in each specific case. Participative models for hazard mitigation/prevention measures will be developed [9].

An advanced alert system will consist of the following components:
- communication system which transforms the informations to a control station
- communication system which informs the persons who have to make decisions
- quality criteria to support the decisions
- communication system which informs the persons who have to start actions.

4. The project OASYS

The integrated workflow for landslide hazard management, as outlined in section 3, is depicted in Fig 4. The integration of the acquired data in a multidisciplinary approach in order to detect and classify landslides will be one of the most challenging tasks of the project. Therefore a multidisciplinary working group was formed to meet this task:
- Vienna Consulting Engineers (VCE), Austria
- Institut for Geodesy and Photogrammetry, Technical University Braunschweig, Germany
- Institut for Geodesy and Geophysics, Technical University Vienna, Austria
- Geodetical and Geophysical Research Institute of the Hungarian Academy of Sciences, Hungary

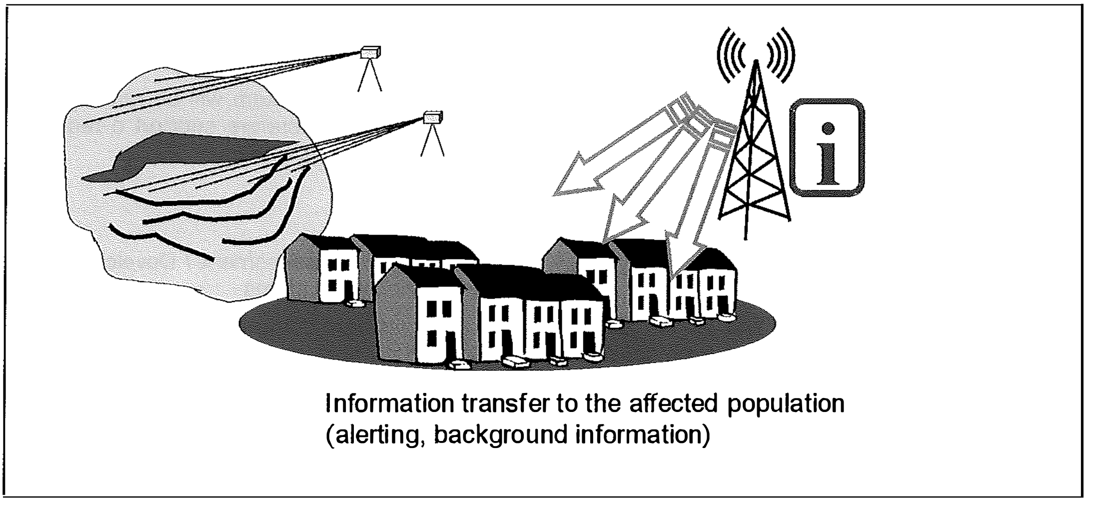

Fig. 3: Continuous local scale measurements and the information transfer

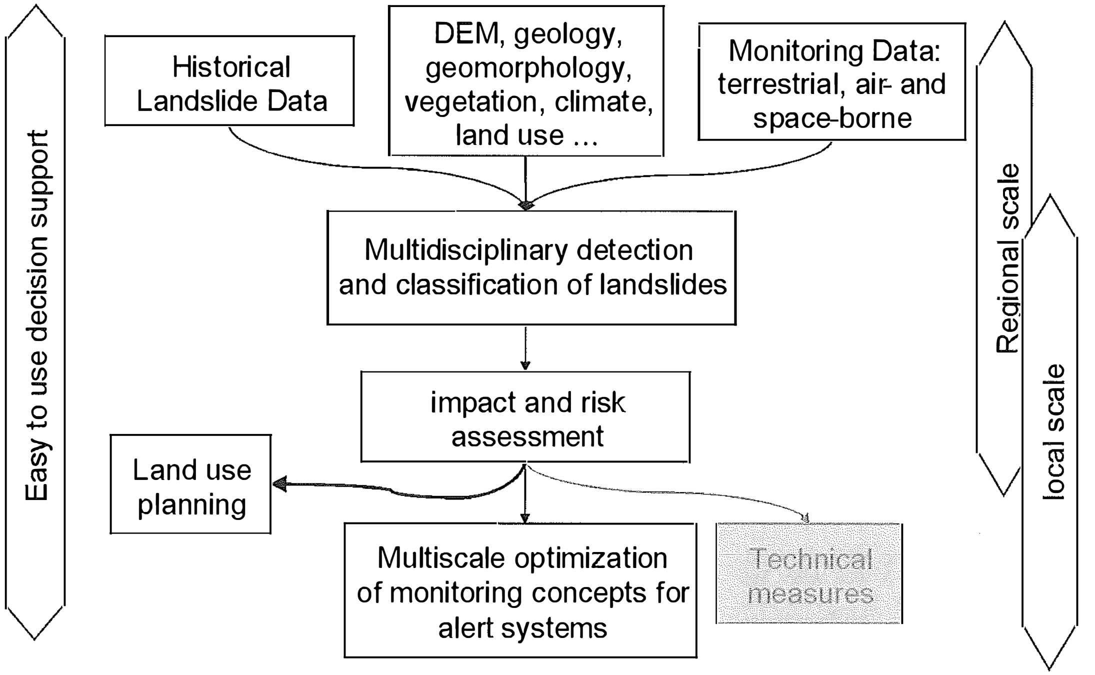

Fig. 4: Integrated work flow for integrated landslide hazard management

- Bureau for Applied Scientific Remote Sensing, Germany
- Geodata, Engineering Company, Austria
- Bureau of Investigations and Survey, China
- Hungarian Ministry of Interior, National Directorate General for Desaster Management, Hungary
- Egnatia Odos S.A., ConstructionCompany, Greece
- University of Modena, Italy
- School of Geodesy and Geomatics, Wuhan University, China
- Laboratory of Geodesy, Uni versity of Thessaloniki, Greece

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