Best Practice Examples for Innovative Geospatial Methods in Exploration and Monitoring of Mining Areas

by

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INITIAL SITUATION

Life cycle of mining – Main Phases

Prospection and Exploration

Planning, Development and Commissioning

Operation

Closure and Reclamation
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MINING & ENVIRONMENT

Mining activities

Impact to the environment, e.g. surface movements

Changes (e.g. surface level, water balance)

Damages (e.g. buildings, infrastructures)

Any mining activity needs legal permission

**Monitoring** is mandatory part of this permission

Detection of hazards

Prevention of hazards

Documentation

Selection of best practice monitoring method(s)
EXAMPLES FOR MINING RELATED HAZARDS
Subsidence and disruptions from underground coal mining
EXAMPLES FOR MINING RELATED HAZARDS
Subsidence and disruptions from underground coal mining
EXAMPLES FOR MINING RELATED HAZARDS
Development of wetlands by changes in ground water table
EXAMPLES FOR MINING RELATED HAZARDS
Sinkhole from solution salt mining
EXAMPLES FOR MINING RELATED HAZARDS
Sinkhole from collapsed abandoned mine shaft
EXAMPLES FOR MINING RELATED HAZARDS

Collapse of a slope of an abandoned lignite open pit while flooding
MONITORING & SPATIAL INFORMATION

- Manifold spatial information is requested for documentation and monitoring of mining activities.
- State-of-the-art methods are:
  - several ground-based methods, e.g. geophysics, geology and engineering surveying
  - some operational remote sensing techniques, e.g. airborne geophysics, airborne laser scanning, photogrammetry and multi-spectral satellites
- New technologies have achieved a promising stage of development:
  - ground-based methods, e.g. high precision permanent GNSS-monitoring or ground-based radar interferometry
  - satellite-based sensors, e.g. hyperspectral mission EnMAP or radar missions like TerraSAR-X or CosmoSkyMed
EXAMPLES FOR MONITORING METHODS

Hyperspectral satellite data

- Identify specific chemical and geometric patterns
- Map and identify mineralogy and chemistry of rocks and soils
- Detect deposits of minerals, hydrocarbons, alteration zones or petroleum

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EXAMPLES FOR MONITORING METHODS

Hyperspectral satellite data

- Environmental monitoring during and after the operational open pit mining
- Monitoring of the decommissioning process and renaturation
- The evaluation of vegetation density, vegetation health
- The announcement of vegetation stress e.g. sudden oak death, caused by contamination of the soil
EXAMPLES FOR MONITORING METHODS

Continuous Online-Monitoring

- Combination of Robotic Total Station and GNSS-Positioning with Alert function
- Integration of all components
  - Total station and targets are located in the potentially moving area
  - Absolute positioning by remote GPS-reference station
EXAMPLES FOR MONITORING METHODS
Continuous Online-Monitoring for small area monitoring

- Total station with Automatic Target Recognition and METEO sensor system
- Targets with prism heaters to avoid snow and condensed water
- GNSS processing with data from every 30 min and from every 24 h
EXAMPLES FOR MONITORING METHODS

Satellite-based Radarinterferometry for large area monitoring

Advanced radar satellite systems (e.g. TerraSAR-X, CosmoSkyMed, future Sentinel) will have several advantages:

- Very high spatial resolution (up to 1 m)
  - mapping of small scale movement phenomena
  - high density of reliable points (persistent scatterers)
  - increased opportunities for detection of large movement rates

Source: by courtesy of Gamma remote Sensing AG, Switzerland
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Examples for Monitoring Methods

Satellite-based Radar Interferometry for large area monitoring

- Very high repetition rate (approx. weekly)
- Very fast availability of data stackings for quick response to user requirements
- Increased opportunities for detection of changes in movement velocity or size
- Increased opportunities for detection of large movement rates

Source: by courtesy of Gamma remote Sensing AG, Switzerland
EXAMPLES FOR MONITORING METHODS
Ground-based Radar Interferometry for slope monitoring

- Permanent monitoring of slopes with real-time data registration and alert function
  - to provide early warnings for potential slope failures
  - to provide long-term monitoring of mining walls
  - to improve geotechnical knowledge of the slope behaviour
  - to support the forecast of slope failures
  - to improve the risk management connected to slope instability
  - to increase safety levels inside the mine

Source: by courtesy of IDS, Italy
NEW TECHNOLOGIES & MINING OPERATIONS

- The missing link on the way from research to mining operation is mainly the deficiency in integrative conceptions for utilization and analysis of different technologies
- Therefore the development of innovative multi-sensorial methods is on focus within the project GMES4Mining
  - R&D project GMES4Mining is a joint project with four partners from industries and universities
  - GMES4Mining is supported by the European Union and funds of North Rhine-Westphalia among the FKZ (support codes) 30 02 531 02, 30 02 553 02, 30 02 532 02 and 30 02 543 02
  - The project has started in August 2011 and is planned for a three-years-period
This project is supported with funds from the EU and North Rhine-Westphalia.

www.gmes4mining.info
GMES4MINING

The main work packages are:
WP 1000: Project Management
WP 2000: User Requirement Analysis
WP 3000: Development of Methods
WP 4000: Development of Integration Technologies & Quality Control
WP 5000: Practical Tests

Source: by courtesy of RWE Power AG, Germany
WP 2000:
IDENTIFICATION OF USER REQUIREMENTS

User Survey

- to gather the geo-information needs associated with any mining activities
- to understand the prospecting/exploration targets as well as monitoring targets
- to achieve optimal adaptation of the GMES4Mining technologies and procedures, regarding both, technical and economic aspects of mining
WP 2000:
IDENTIFICATION OF USER REQUIREMENTS

Questionnaire

- related to surface mining, underground mining, well mining and storage mining
- with general questions about
  - company’s mining activities
  - remote sensing within mining projects
  - data processing within mining projects
- with specific questions about
  - requirements for prospecting and exploration of mineral deposits
  - requirements for ecological monitoring
  - requirements for monitoring of ground movements
WP 2000: IDENTIFICATION OF USER REQUIREMENTS

Questionnaire Results will enable GMES4Mining project partners

- to develop
  - customized and innovative multi-sensorial methods
  - geographic information technologies
- to support
  - mineral deposit prospecting and exploration
  - ecological monitoring
  - ground movement monitoring

The partners would be very pleased if mining companies worldwide would answer the GMES4Mining questionnaire. Please request the questionnaire from the following e-mail address: kateloe@ifm.rwth-aachen.de
WP 2000: METHOD DEVELOPMENT – OPTICAL SENSORS

Targets

- State of the art analysis of current and future hyperspectral sensors regarding sensor integration with multi-temporal and multi-spectral data
- Integration of user requirements from WP 2000
- Data acquisition
- Development of a methodology for a common usage of hyperspectral data together with multi-temporal/multi-spectral data
- Assessment of the methodology and a suggestion for a concept to do the practical test in WP 5000 and coordination with the results of WP 3200
- Optimization of the methodology by integration of the practical test results
WP 3000: METHOD DEVELOPMENT – MONITORING OF GROUND MOVEMENTS

Targets (1)

- State of the art analysis of current and future satellite based radar sensors and processing methods together with innovative ground-based methods
  - ground-based radar interferometry
  - new GNSS methods
  - robotic total station systems
- Selection of most appropriate sensors for data integration
- Analysis of selected monitoring methods and their combination concerning their applicability for mining related tasks, both in operational and post-operational phases of mining
- Development of methods for semi-automated data analysis and data integration
WP 3000: METHOD DEVELOPMENT – MONITORING OF GROUND MOVEMENTS

Targets (2)

- Improvement of the quality of integrated data analysis through use of new modeling and prediction methods
- Interaction with the WP 3100 and the additional use of hyperspectral data for ground movement monitoring promises a further improved quality
WP 4000: INTEGRATION TECHNOLOGIES (GDI) AND QUALITY ASSURANCE PROCEDURES

Targets

- Establishment of prototypical geo services (e.g. WMS, WCS) which provide the user with information from all available data sources
- Consideration of user demands as determined during the requirement analysis (see WP 2000)
- Automatic combination and visualisation of preselected datasets according to given analysis tasks like mineral exploration or subsidence monitoring.
WP 5100: IMPLEMENTATION INTO PRACTISE - EXPLORATION

Targets

- Testing the developed methodology for usage of optical data in the exploration phase focused on the common usability of hyperspectral and multispectral data
- As currently planned the pilot area will be an open pit mining area in Turkey which is in the phase of prospection.
- The following sub-goals have to be reached:
  - Description of the pilot project
  - Planning of the pilot project procedure
  - Execution of pilot project
  - Evaluation of the recorded data
  - Suggestion for practical implementation
WP 5200: IMPLEMENTATION INTO PRACTISE - MONITORING

Targets (1)

- Test of methods of ground movement monitoring during mining operation and abandonment phases
  - focussed on a combined, integrative use of different methods, particularly satellite and ground-based radar interferometry, GNSS, robotic total station systems and prediction models
- Additional test of applicability of optical data from WP 3100 for monitoring tasks during
  - operational phases of mining (e.g. to monitor the environmental impacts of groundwater drawdown)
  - post-operational phases (e.g. identification of old mine sites on the basis of vegetation changes)
WP 5200: IMPLEMENTATION INTO PRACTISE - MONITORING

Targets (2)

- Pilot areas are
  - an abandoned and inactive mining site in the Southern Ruhr area
  - an active lignite mine in the Lower Rhine region.

- The following sub-goals are envisaged in this WP:
  - Description of the pilot project
  - Planning of operations and measurements in the pilot project
  - Execution of the pilot project
  - Analysis of the measurement data
  - Proposal for practical system implementation
OUTLOOK - POSSIBLE APPLICATIONS (1)

Prospection – search for mineral resources and deposits
- Exploration of geological and hydrogeological structures with the aim of geological mapping
- Assessment of the deposit reserve
- Determination of the presence of individual chemical components at the ground surface using the spectral signature of rocks and vegetation (search for indicators)
OUTLOOK - POSSIBLE APPLICATIONS (2)

Exploration – detailed examination on the workability of deposits

- Assessment of the spatial extent of the mining area
- Analysis and evaluation of existing infrastructure in the exploration area
- Determination of the first drilling locations
- Analysis of the prospective minerals in the rocks or the percentage distribution of minerals in the deposit
- Exploration of the topography and relief in order to determine the appropriate mining method and appropriate mining technology
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This project is supported with funds from the EU and North Rhine-Westphalia.

www.gmes4mining.info

OUTLOOK - POSSIBLE APPLICATIONS (3)

Mineral extraction – development and mining of mineral resources

• Detection of ground movements (subsidence and uplift) within the influence range of mining
• Analysis of ecological impacts of mining (e.g. vegetation changes, water logging)
• Analysis of the changing land use during mining operations
• Monitoring of the stability of opencast mine slopes and dump slopes
• Determination of potential sites for spoil or overburden dumps
• Analysis of bulk material in opencast mining for targeted operations control in order to guarantee constant composition of main and country rock
OUTLOOK - POSSIBLE APPLICATIONS (4)

Monitoring during the extraction and closure phase

- Monitoring of geo risks, detection of ground movements or subsidence, uplift and landslides as well as resulting subsidence damages
- Monitoring of shallow ground water before, during and after mining operations
- Analysis of the overburden material in relation to chemical composition
- Monitoring of the land surface in areas of abandoned mining with regard to sinkholes or other subsidence damages
OUTLOOK - POSSIBLE APPLICATIONS (5)

Abandoned mines / Land reclamation

- Monitoring of reclamation measures
- Vegetation analysis by recording the spectral signature of vegetation (determination of chlorophyll content)
- Investigation on the distribution of soil moisture (directly by image spectra or indirectly by plant indicators)
- Site analysis for individual groups of vegetation
- Monitoring of ground movements after cessation of mining operations (settlements, slope monitoring, uplifts due to re-rise of groundwater)
OUTLOOK - SUMMARY

- The R&D project GMES4Mining has started in summer 2011
- The paper has presented the planned working schedule for the three years up to mid of 2014
- Within this time period several developments on innovative monitoring methods will be realized
- To achieve the operational utilization of these innovations the implementation to practice will be a very important part of the project
- Some mining companies have already signed an agreement to become associated project partner
- With these mining companies individual pilot measurements are already agreed or will be agreed shortly
- However, if any other mining company is interested in a participation in GMES4Mining, this company is kindly invited to contact the project team for more details (www.gmes4mining.info)
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Our Team thanks for your attention! Glückauf