JRC Scientific and Technical Reports

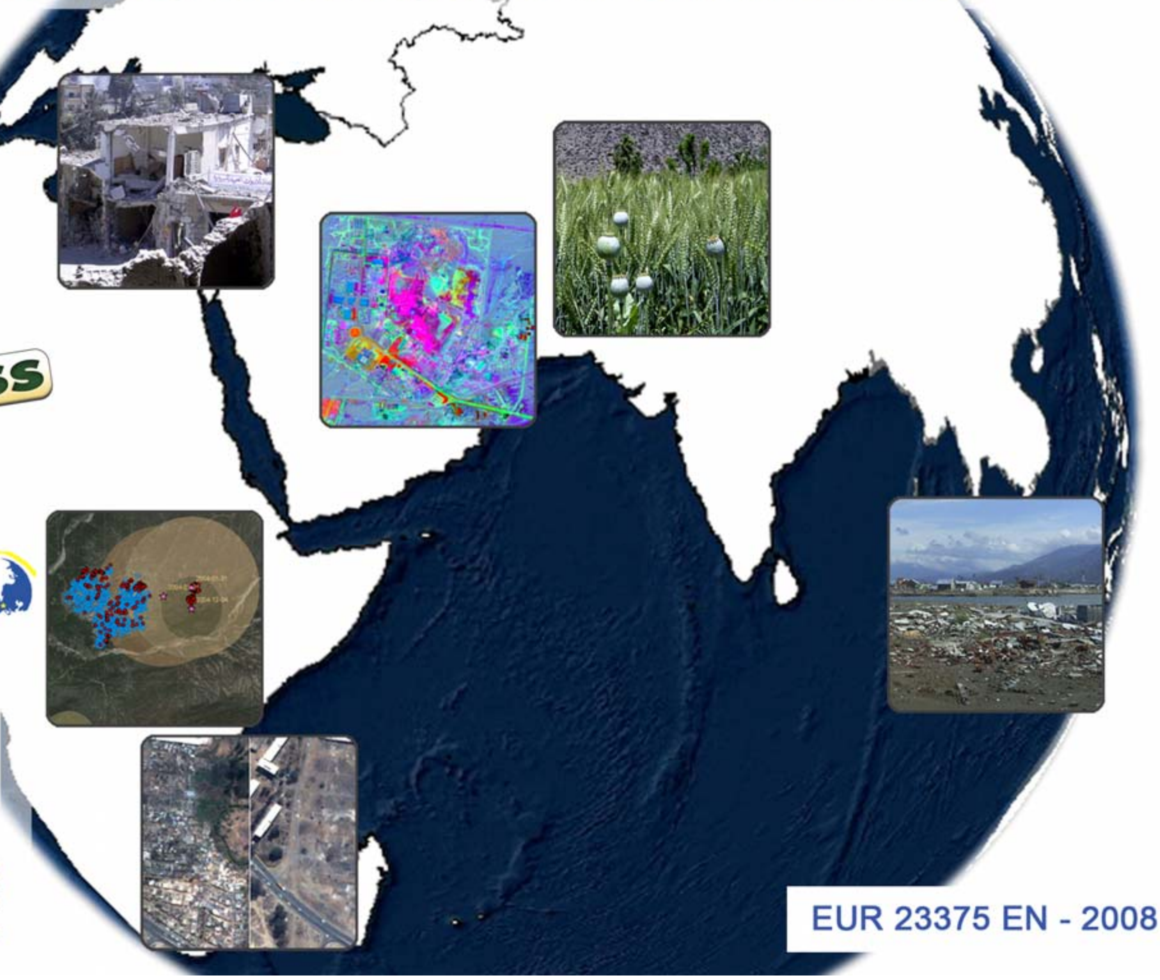
REMOTE SENSING FOR INTERNATIONAL STABILITY AND SECURITY

INTEGRATING GMOSS ACHIEVEMENTS IN GMES

JRC, Ispra, 19-20 February 2008

Book of Abstracts

Edited by
Gunter Zeug, Thomas Kemper, Alan Steel & Martino Pesaresi



GMOSS Global Monitoring for Security and Stability

ISFEREA

ipsc Institute for the Protection and Security of the Citizen

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The Institute for the Protection and Security of the Citizen provides researchbased, systems-oriented support to EU policies so as to protect the citizen against economic and technological risk. The Institute maintains and develops its expertise and networks in information, communication, space and engineering technologies in support of its mission. The strong crossfertilisation between its nuclear and non-nuclear activities strengthens the expertise it can bring to the benefit of customers in both domains.

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The cover is based on photographs taken by JRC-ISFEREA members in the field as well as on figures out of presentations given by GMOSS partners during the workshop.

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INTRODUCTION

Gunter Zeug, Thomas Kemper, Alan Steel and Martino Pesaresi

European Commission, Joint Research Centre, Institute for the Protection and Security of the Citizen (IPSC), Support to External Security Unit, Ispra 21027 (VA), Italy

Introduction

After four years of research on numerous aspects of security and stability, the Global Monitoring for Security and Stability (GMOSS) network of excellence (NoE) came to an end in Febuary 2008. The aim of GMOSS was to integrate European civil security research and to foster scientific and technological developments in the field of remote sensing and geo-information related to (civil) security. Due to its nature as a NoE, GMOSS acted as a think tank for related projects and consequently aimed to share its knowledge with the remote sensing community. For this reason the Joint Research Centre (JRC) hosted a two-day workshop ***"Remote sensing for international stability and security: integrating GMOSS achievements in GMES"*** to disseminate the scientific and technical achievements of GMOSS to partners of ongoing and future GMES projects such as RESPOND, LIMES, RISK-EOS, PREVIEW, BOSS4GMES, SAFER, G-MOSAIC, and TANGO.

The objectives of this workshop were:

- To bring together scientific and technical people from the GMOSS NoE and from thematically related GMES projects.
- To discuss and compare alternative technical solutions (e.g. final experimental understanding from GMOSS, operational procedures applied in projects such as RESPOND, pre-operational application procedures foreseen from LIMES, etc.)
- To draft a list of technical and scientific challenges relevant in the next future.
- To open GMOSS to a wider forum in the JRC

The workshop started with a first session and introduction about the security issue in GMES. Eight projects dealing with that subject were presented. A short overview on them is given in the next chapter. In the following five technical sessions fifteen researchers presented their activities, methods and results in developing innovative techniques targeted at deriving information from satellite image data relevant to users in the (civil) security domain. Another nine posters were presented in a separate poster session. Posters and presentations addressed pre-processing, feature recognition, change detection and applications. The studies presented were conducted on different scales, from continental to local, using a variety of techniques to obtain diverse information from satellite imagery. It is important that these impressive results are followed up by further research on both generic remote sensing methodology and thematic stability and security applications. Existing algorithms and tools need to be developed further and tested to become robust enough for the successful and sustainable information extraction from satellite data. Planned and future satellite sensors with enhanced spatial, spectral and temporal coverage will require innovative methods to be developed. This provides a great opportunity for new research.

The workshop presentations demonstrated that research on remote sensing is not sufficient on its own but needs to be integrated with political and socio-economic sciences to provide relevant solutions to the information requirements of the user community. Further effort should be made on the geometric and thematic validation of products to provide reliable information for policy support. This requires also a closer link to the enduser. On the one hand, user requirements have to be obtained and understood in order to guide relevant and successful research. On the other hand end users require expert advise to help them understand the added value of earth observation-derived products and the advantages of using them in their decision making process.

The GMOSS workshop organised by JRC made clear that regular meetings and knowledge exchange between researchers are necessary. However, this is probably not enough on its own. Web-based platforms for sharing scientific knowledge and experiences are also needed to enable the GMOSS community to continue to contribute to the development of techniques to integrate information derived from remote sensing into the management of security issues in Europe after the end of the network.

The "S" in the GMES landscape

In 1998 the European Commission together with the European Space Agency initiated the Global Monitoring for Environment and Security (GMES) project. Its objective is the implementation of information services dealing with environment and security using earth observation satellite data and ground based information. The services will mainly support decision-making by both institutional and private actors.

Several GMES projects provide information needed to address security related concerns. Following the workshop subtitle of '*Integrating GMOSS achievements in GMES'* eight of those projects presented their objectives, technical procedures and solutions and main technical challenges not solved. The following pages provide short overviews of those thematically related GMES projects. They are based on information from the related project websites.

RESPOND

Presented by Alan Steel, JRC

Respond is an alliance of European and International organisations working with the humanitarian community to improve access to maps, satellite imagery and geographic information for humanitarian relief efforts and to increase the efficiency and effectiveness of the humanitarian community through the appropriate and reliable application of geographic information.

In terms of service portfolio development the ambition of Respond is to provide, by year 10, a recognised, guaranteed level of service within all the thematic types of information identified as important for humanitarian organisations. In terms of service portfolio deployment Respond should be using all major methods of delivery for geographic information, from on-line mapping to alert service and paper map delivery. Currently, the supply of geospatial information to the humanitarian community is largely project based - the production of information can only be commenced when the project plan is finalised, and funds allocated. This leads to the ´just too late´ problem once operations or projects are authorised, the customer wants the product as quickly as possible often placing very difficult time constraints on production. Respond is in a unique position to break this ´just too late´ cycle. By deploying proactive mapping of identified and likely ´hot spots´ so that the raw materials and background information is available in time to react to direct requests from users.

Further information can be obtained from the corresponding website:

http://www.respond-int.org/respondlive/

RISKEOS

Presented by Geraldine Florsch, Infoterra France

RISK-EOS is providing crisis information in the context of flood and fire for the European region. Different service chains support the management through all phases of the crisis:

prevention, early warning, crisis and post crisis. These services are primarily dedicated to the institutions at local, regional and national level:

- Land planning services,
- Civil protection and rescue services,
- Forestry management services,
- Environmental agencies,
- Local communities.

They have been defined during the first stage of *Risk-EOS* (2003-2004), and selected on the basis of priorities expressed by "core users" spread throughout Europe (France, Germany, Italy, Spain, and Sweden). The objective for *Risk-EOS* stage 2 (2005-2008) is to extend this service portfolio - with additional services - to new users and European regions.

The *Risk-EOS* services are already delivered to a large number of users. At this stage 21 Service Level Agreement (SLA) have been defined with regional users organisations spread in Bulgaria, France, Germany, Italy, Spain, Slovakia and Sweden .Moreover, *Risk-EOS* also serves the full community of European Risk Management Actors via its involvment in rapid mapping operations.

Further information can be obtained from the corresponding website:

http://www.risk-eos.com/

BOSS4GMES

Presented by Geraldine Florsch, Infoterra France

The *BOSS4GMES* project aims to provide the technical, financial and contractual foundations which will enable the transition of GMES from a concept to an effective, operational programme, and, in doing so, to link GMES with key political decision makers, a broader sphere of users and the wider public.

To date, GMES has made good progress in building user communities and in developing prototype services to meet the specific needs of each community. This is particularly true for the so-called "Fast Track Services", whose definition, progress and road map have been reviewed at European level in autumn 2005. However, if GMES is to evolve into a viable and valued activity, meeting the needs of Europe's decision makers for timely, accurate and relevant information related to critical environmental and security topics, a number of key issues need to be recognised, analysed and resolved.

BOSS4GMES aims to do precisely this, and thereby play a major role in the operationalisation of GMES. The key targeted challenges are:

- To provide rationale for GMES and demonstrate reliable production capabilities for services over large areas. This will enable decision making for the implementation of GMES Fast Track Services and Pilot Services as soon as possible
- To improve integration/interoperability between GMES service structures and architectures and to optimise the operating costs
- To define appropriate contracting principles and operational structures (trusted networks of services providers and independent QA controlled services)
- To raise awareness amongst political decision makers and the general public in the nature of GMES and the benefits it will bring

To resolve these issues *BOSS4GMES* will focus upon three pillars of activity.

1. It will support the development of the three fast-track services (ocean, land and emergencies) and analyse the potential for synergies between current GMES services and will recommend the resulting optimal operational processes for and between those services, illustrating the resulting benefits through service operations of each of the EC specified "fast track" service topics.

2. It will define, study, and test options for the most appropriate funding mechanisms, business models and organisational structures, mainly for the three fast-track services, and check how these findings can be applied to other GMES services.

3. It will aim to build awareness of, and support for, the fast-track services and GMES as a whole amongst all its potential stakeholders in Europe and beyond. *BOSS4GMES* aims to leverage the knowledge and experience of many existing service providers and users, augmented by experts in the fields of financial and organisational analysis and in communications/lobbying to ensure that the project aims are met.

Further information can be obtained from the corresponding website:

http://www.boss4gmes.eu/

PREVIEW

Presented by Geraldine Florsch, Infoterra France

PREVIEW will provide new or enhanced information services for risk management in three thematic domains: atmospheric, geophysics, man-made.

Supporting European Civil Protection units – local, regional, national and European authorities – PREVIEW draws on the most advanced research and technological developments using satellite observation in combination with other data and scientific models, that will help better prevent, anticipate and/or manage different types of disasters. Examples include:

- New early warning systems to better anticipate short-term risk - for instance, floods and landslides;

- Crisis support services to allow more effective rescue operations, e.g. fire monitoring and rapid mapping;
- Building ‘risk maps’ for different types of hazards, in order to improve prevention and preparedness measures.

PREVIEW is jointly developed by a consortium of 58 partners from 15 nations, gathering a wide range of technical skills and key representatives in risk management.

Further information can be obtained from the corresponding website:

http://www.preview-risk.com/en/index.php

TANGO

Presented by Marte Indregard, JRC and Antonio de la Cruz, EUSC

Innovative satellite telecommunication solutions are crucial in several domains, such as risk and crisis management, maritime services, security and humanitarian aid. TANGO (Telecommunications Advanced Networks for GMES Operations) is a research project that focuses on the use of satellite telecommunication solutions to serve the needs of the community of the Global Monitoring for Environment and Security (GMES) initiative by developing, integrating, demonstrating and promoting new satellite telecom services dedicated to specific GMES requirements. The TANGO consortium aims at developing and providing operational telecommunication solutions to the immediate GMES services needs, and at preparing the definition of optimised satellite telecom infrastructures to expand the future GMES services.

Further information can be obtained from the corresponding website:

http://www.teladnetgo.eu/

LIMES

Presented by Luca Bocci, Telespazio

LIMES (Land/Sea Integrated Monitoring for European Security) will complete the GMES programme until 2010 by providing core competence within the field of security. The project goal is to define and develop prototype information services to support security management at EU and global level in the following thematic/policy areas of interest:

- Organization and distribution of humanitarian aid and reconstruction
- Ssurveillance of the EU borders (land and sea)
- Surveillance and protection of maritime transport for sensitive cargo
- Protection against emerging security threats (e.g. terrorism, illegal trafficking, and proliferation of weapons of mass destruction)

The services developed by LIMES support the building up of a common cooperation framework between the major EU research and operational actors on security management. The LIMES service development is focused on the use of Earth Observation technology and on its integration with satellite telecommunication and navigation capacity.

Further information can be obtained from the corresponding website:

http://www.fp6-limes.eu/

G-MOSAIC

Presented by Luca Bocci, Telespazio

G-MOSAIC aims at identifying and developing products, methodologies and pilot services for the provision of geo-spatial information in support to EU external relations policies directed to achieve a peaceful global society, and at contributing to define and demonstrate sustainability of GMES global security perspective. In particular, G-MOSAIC services will support the prevention and management of external Regional Crisis for, i.a. peace keeping, peace enforcing, crisis prevention, EU citizens rescue. Expected results are

- new GMES services for security
- new users involvement
- contribution to GMES sustainability

The proposed service cases, built together with the reference users, will be relevant to support Intelligence and Early Warning applications, and to support Crisis Management Operations. G-MOSAIC is currently in the negotiation phase.

SAFER

Presented by Guido Lemoine, JRC

SAFER aims at implementing preoperational versions of the Emergency Response Core Service. SAFER will reinforce European capacity to respond to emergency situations: fires, floods, earthquakes, volcanic eruptions, landslides, humanitarian crisis. The main goal is the upgrade of the core service and the validation of its performance with 2 priorities:

First priority is the short term improvement of response when crisis occurs, with the rapid mapping capacity after disastrous events, including the relevant preparatory services (reference maps). The second priority is the extension to core service components before and after the crisis. It targets the longer term service evolution, through the provision of thematic products, to be added in the portfolio of services. In SAFER, thematic products will cover mainly the meteorological and geophysical risks. SAFER is currently in the negotiation phase.

Information Exchange

WORLD INFORMATION FUSION MODEL: TO STRUCTURE THE INTERACTION BETWEEN DECISION MAKERS AND EARTH OBSERVATION SERVICE PROVIDERS

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Our modern (post-) industrial society is increasingly confronted with crisis situations of all kinds: wars, unstable states, terrorist attacks of unseen dimension, natural disasters, crises caused by technological or industrial malfunction, etc. All these crises have a characteristic in common. They all "seem" to be new and more complex to us than the crises of a couple of decades ago due to the complexity of our modern society, the evolution of technology, the demographical evolution etc. Some of their typical features are: they are cross-bordering, they often cause a knock-on effect and they are more and more 'out-of-the-box' (i.e. they cannot be imagined beforehand).

Since every crisis destabilizes our society in a certain way, we as a community are obliged to intervene with the necessary means to normalise the situation as soon as possible. Intervention means making decisions at very different levels of decision making: from high representatives who are generally located in remote organisations (United Nations, European Union, National governments, etc.) to local emergency workers present in the crisis zone.

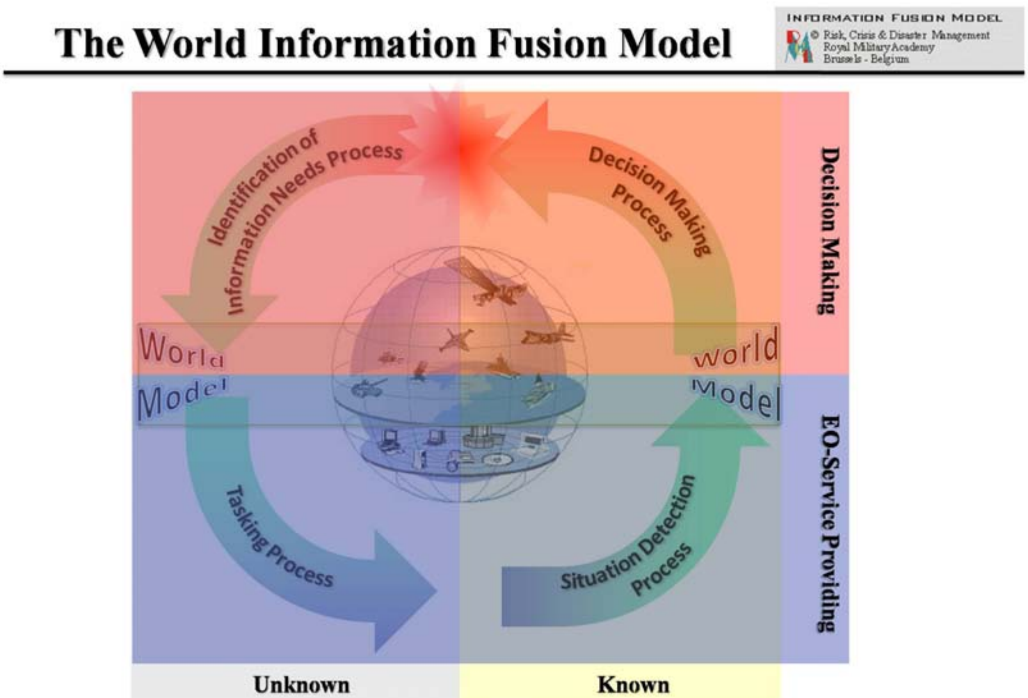

Figure 1: The World Information Fusion Model

In order to make correct decisions, Crisis Management Decision Makers (CMDM) need accurate, clear and very often specific information so they can take the necessary actions to confront the crisis situation in an efficient and effective way. Generally, the CMDM obtain their information from very different sources such as people present in the crisis zone (local people, field workers, local community representatives, etc.), informants outside the crisis zone (the media), but also from specialised and remote Earth Observation Service Providers (EO-SP) who generally will provide additional and complementary information after the crisis happened.

It has been observed during recent real crisis situations (Katrina, 2005), but also during the latest GMOSS Near-Real-Time-Exercise (GNEX-07) that the cooperation and the communication between CMDM and EO-SP is far from optimal. CMDM are often unaware about which type of information the EO-SP can deliver and in what time period. On the other hand, EO-SP often receive no specific and well-formulated demand for information from the CMDM, so they do not know exactly what kind of information they should (be able to) provide. This situation is, at least (partly), due to a lack of mutual understanding of the two main processes (decision making and providing earth observation) and to the non-existence of a common and non-ambiguous language.

Therefore, we think a World Information Fusion Model should be developed which acts as the link between the worlds of Decision Makers and Earth Observation Service Providers (each with their own specific processes) and which will allow an efficient and effective communication: identification and specification of information needs by the Decision Makers, and the provision of adequate information by the Earth Observation Service Providers. The aim of the presentation is to propose the first ideas regarding such an Information Fusion Model (*see figure 1: World Information Fusion Model*).

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COLLABORATIVE GEOSPATIAL PROCESSING AND VISUALISATION FOR SITUATION ASSESSMENT

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Extended Abstract

Collaborative mapping in emergency response contexts are typically aimed at rapidly establishing a situation assessment to support coordination and decision making. The basic technical requirements of a rapid mapping exercise include (1) establishing the reference situation from a collation of existing data sets (both raster and vector data); (2) an impact assessment with post-event imagery and context information; (3) responding to specific geospatial questions arising from the situation assessment and direct questions from emergency operators and (4) the organization of post-event peak workloads on data collection, interactive analysis, integration and distribution of actualized information, etc.

Translated into information technology challenges, the collaborative mapping requirements include the collection and distribution of heterogeneous sets of geospatial feature data, include *in-situ* observations, and large, very high resolution imagery. The architecture should preferably support value adding geospatial querying and image processing functions, some of which may be computationally intensive. Support to near real time integration of raw and interpreted information is essential. The architecture should support the tailored presentation of information to relevant roles (e.g. a digitizer, a project quality controller, a decision maker), usually on a "need to know" basis, i.e. requiring role-based access rules. Ideally, the system should support communication functionality as well, e.g. for the distribution of workloads, progress monitoring and quality assessment.

Our presentation discusses a client-server architecture developed at the JRC which is based on the use of the public Google Earth (GE) virtual globe viewer as client and a number of open source modules that constitute the server functionality. This GEOspatial Repository for Google Earth is codenamed GEORGE. The choice of GE was inspired by its widespread exposure to users (over 250 million copies downloaded) and the integration with the Google Earth image database, which is an essential background information layer in many emergency response contexts. The server side combines a PostgreSQL/Postgis spatial database backend with Java servlets to parse KML structured feature data into the database and serve database collections out as KML (optionally using Geoserver as a web map server component). The Keyhole Markup Language (KML) is GE's adoption of a simplified and extended GML format. We use a number of stand-alone toolkits to manipulate and prepare data for use in the

system, e.g. the GDAL library for format conversion and image re-projection, udig, OpenJump and gvSIG for quality control.

Image data are served from a static web server as SuperOverlays. SuperOverlays are image pyramid constructs for use in visualisation of client side imagery in the GE. SuperOverlays combine standard image formats, such as JPEG, PNG or TIFF, with geographical metadata tagging in KML files. This has the fortunate side-effect that SuperOverlays can be easily served either off-line or via standard web servers (Figure 1).

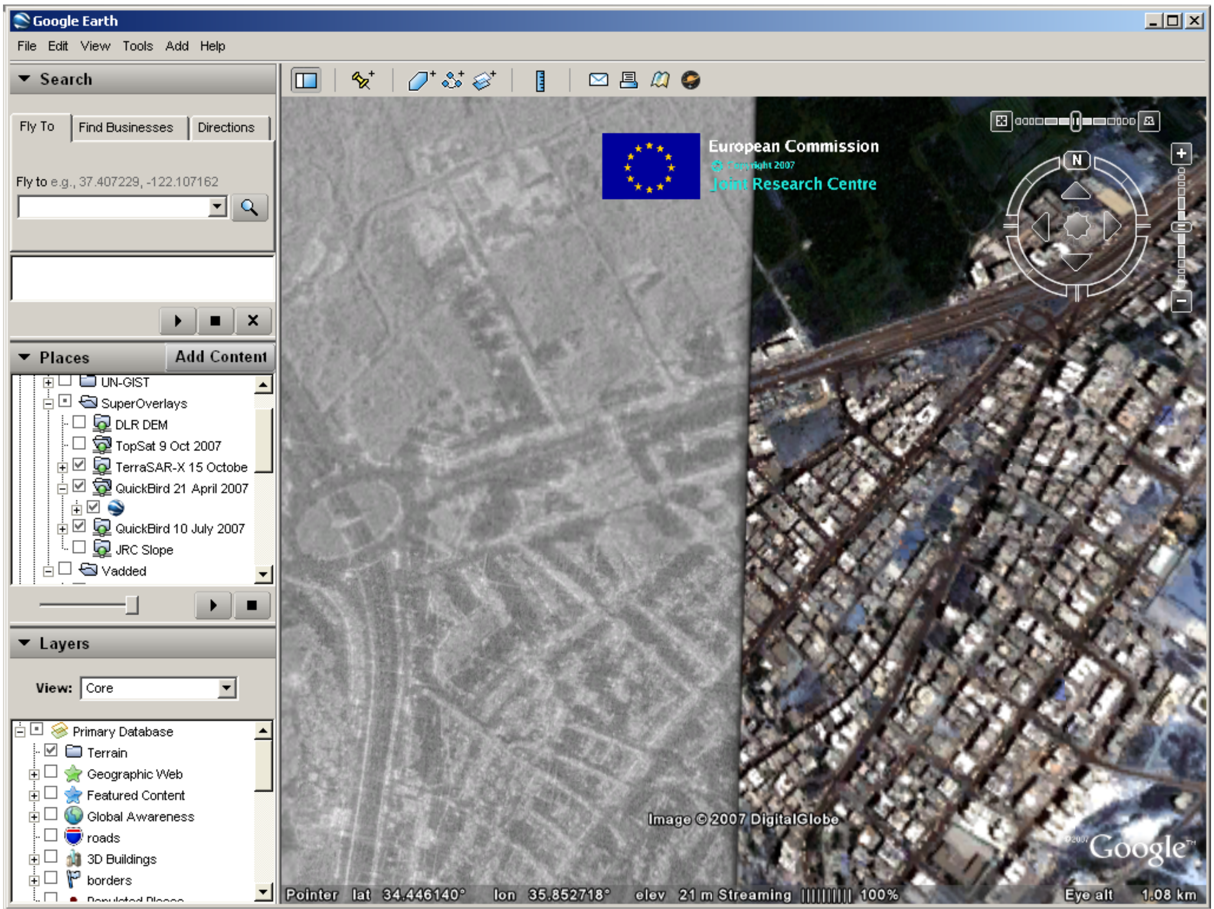

Figure 1. An example of SuperOverlay integration demonstrated in the GNEX07 experiment. The screenshot shows full resolution 1-m TerraSAR-X data on the left and pan-sharpened QuickBird data on the right. TerraSAR-X data is © Infoterra GmbH, 2007 and processred by DLR, QuickBird data is © Digital Globe, 2007 and distributed by Eurimage Spa.

We have demonstrated the use of SuperOverlays for web-enabled image data visualization of typical very high resolution satellite coverages (e.g. for QuickBird, IKONOS and SPOT-5 sensors) in [1]. Given their simple format and web-portability, it is relatively easy to integrate access to SuperOverlay in image processing algorithms [2]. Visualization in GE requires the image pyramid tiles to be available in single or 3 band byte data type. For image processing algorithms that require access to higher precision data (e.g. integer or float data for VHR optical or SAR imagery) we demonstrate that SuperOverlays can be easily reconfigured to give distributed access to other than byte data type imagery (e.g. integer or float data), using the TIFF format, and adding some meta-data to the KML structures, for instance using the SensorML standard [3].

Feature capturing [2] is achieved in our system by leveraging the standard function in GE to HTTP POST or E-mail digitized information to a server. Both mechanisms feed into application logic that parses the received features in the geo-spatial back-end supporting feature creation, updating and deletion. Features can be submitted either as digitized contribution, using GE functions, or KML formatted feature sets from existing archives. We impose a class hierarchy that can be specific to a project. User control is handled in the database and through user/password authentication. All features are accessible via URL that point to a WFS server that produces KML (geoserver) or a dedicated collection of JSP pages. The refresh mechanism in GE support synchronized views of the relevant data sets. The database supports feature styling.

We have demonstrated GEORGE in the GMOSS GNEX07 experiment and in several internal mapping applications. We are now setting up collaborations with our partners to test performance of GEORGE in near real time scenarios (e.g. in the LIMES project). As part of our research activities we are developing geospatial querying and image processing functionality that can be triggered via the GE interface. For more details the reader is referred to [2].

GEORGE is composed of open source modules and the public Google Earth virtual globe client software. We intend to integrate with the upcoming Java based WorldWind client 1.0 (foreseen to be released in early May 2008) to complete the concept as a fully open source solution (which would probably require a different name as well). We are pursuing EUPL licensing (the European open source software license, [4]) for our modules inside our organization, so that we will be able to share our solutions with the Open Source and targeted user communities, to better guarantee user uptake and continued development.

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Preprocessing

GEOMETRIC PRE-PROCESSING FOR SECURITY AND STABILITY APPLICATIONS

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Reviewing user requirements for security and stability applications with respect to performance requirements of EO remote sensing techniques the following issues can be summarized:

1. High temporal resolution to ensure fast response and rapid mapping,
2. (Very) High spatial resolution to allow detailed analyses,
3. Worldwide coverage,
4. Fast, flexible and robust processing algorithms using the above mentioned satellite data

Geometric processing, which includes e.g. rectification, image-to-image registration or 3D information extraction, forms the basis of all ongoing processing and thus, is a first crucial prerequisite for the quality of the final results (Fig. 1).

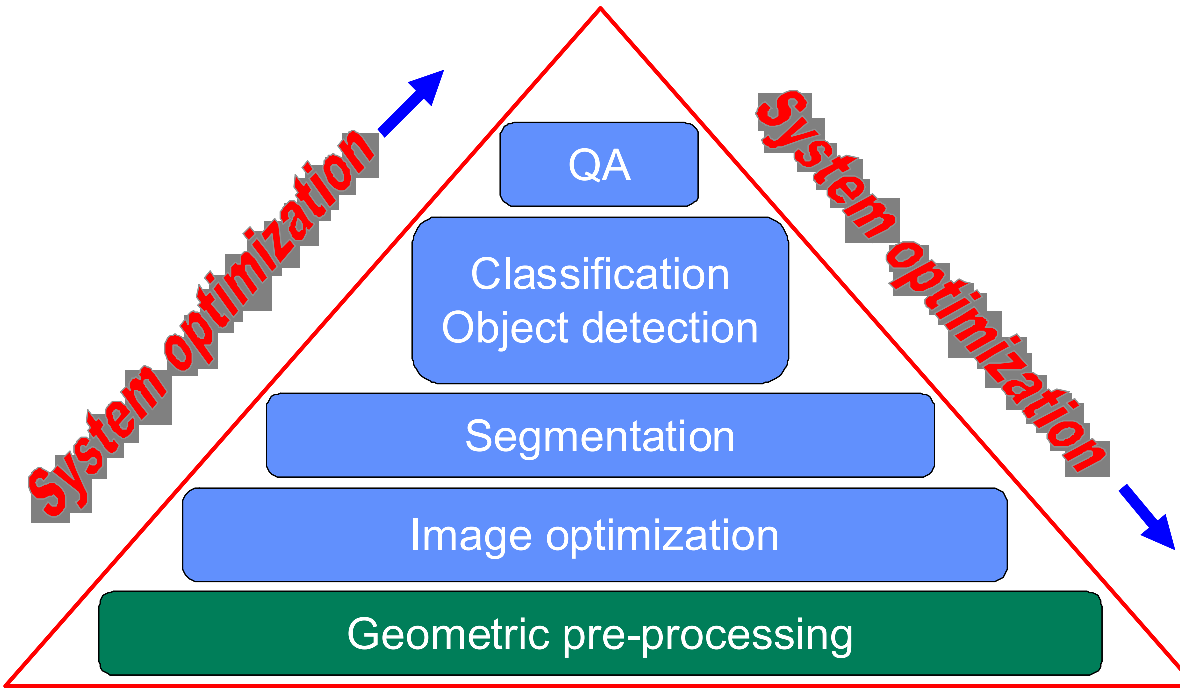
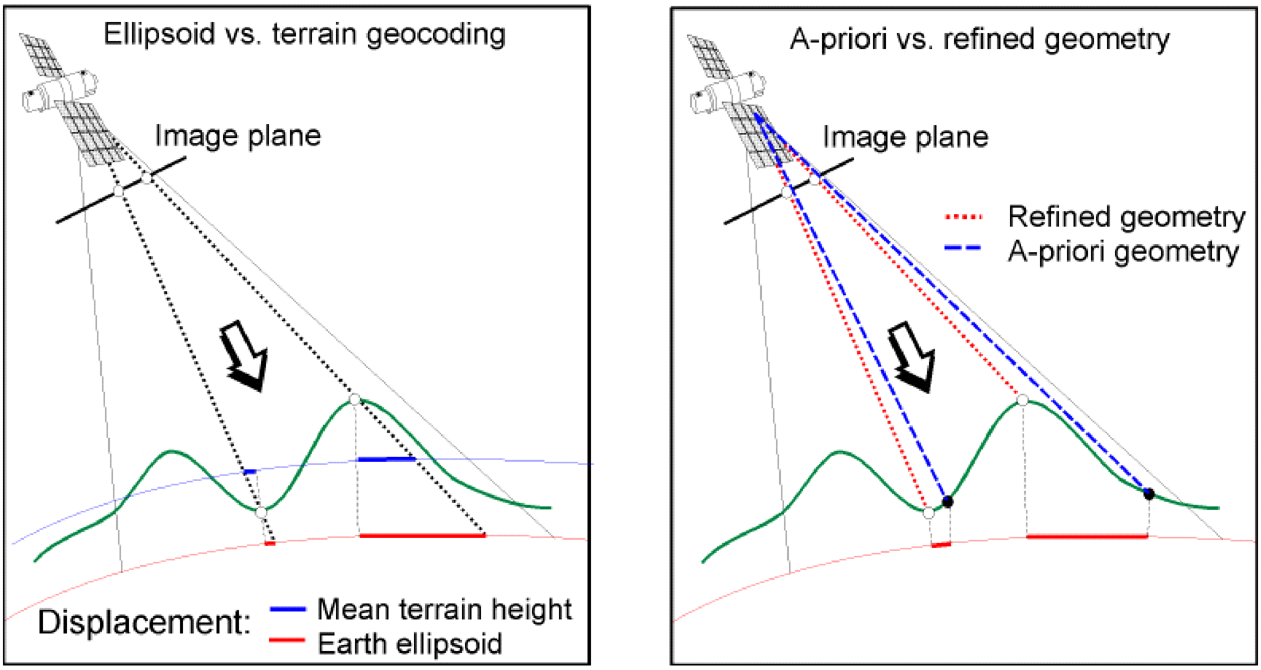


Figure 1: Image analysis workflow

Obvious examples for the propagation of errors are false alarms in change detection techniques due to geometric registration inaccuracies. Often these problems are getting worse because of missing or very coarse ground and/or reference information.

The discussion of error sources within the geometric pre-processing focus on:

1. Inaccuracies of the sensor model (also known as pointing error)
2. Inaccuracies of reference data (mainly 3D information)



Both effects are depicted in Fig 2.

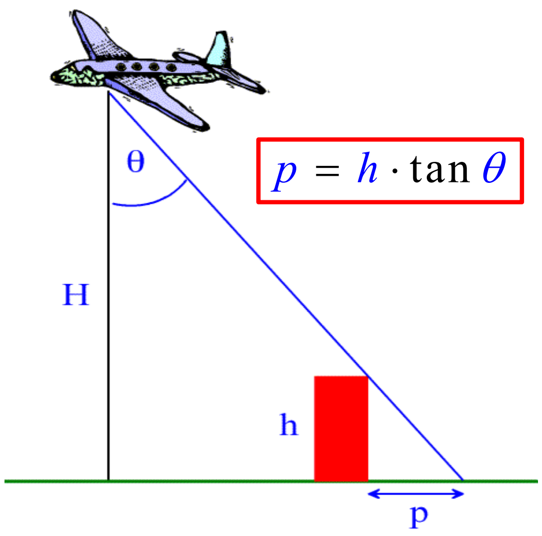
Figure 2: Displacement errors due to height inaccuracies (left) and due to sensor model inaccuracies (right)

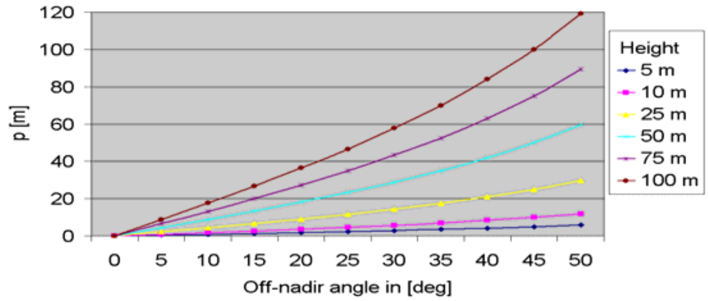
The development especially of very high resolution (VHR) optical sensors (like e.g. Ikonos, Quickbird, Worldview) and currently of VHR SAR sensors (like e.g. TerraSAR-X, CosmoSkymed) stresses the need to handle these error sources. Moreover the pointing accuracy of the sensors is somehow limited and the worldwide availability of detailed 3D information can not be expected in the near future.

Fig. 3 show the displacement error (p) as a function of ground sampling distance (GSD) and height (h) for optical sensors at different off-nadir angles (θ). Obviously, e.g. a building height of 25 m caused no problem for high resolution sensors like e.g. SPOT 5 (5 m GSD) at steep looking angles (near nadir) because the displacement error is below one pixel and therefore mix up with several other effects. On the contrary, for very high resolution sensors like the recent Worldview (GSD 0.5 m) the displacement is approximately 9 pixel which cannot be ignored anymore (Gutjahr et Raggam, 2003).

Analogous formulation can be obtained for SAR sensors. To overcome these topographic effects digital surface models (DSMs) are required which can be obtained from VHR stereo optical data, interferometric SAR data or laser scanner data.

The second error source i.e. inaccuracies in the (mathematical) sensor modelling can be handled by measuring tie-points. Anyhow, these kinds of measurements lead to weak adjustment constellations as the ground coordinates of these points have to be estimated additionally.





h **= 25 m**	***p***	***GSD*** **= 5m**	***GSD*** **= 0.5m**
θ **= 10°**	4,4 m	0,9 pxl	8,8 pxl
θ **= 25°**	11,7 m	2,3 pxl	23,3 pxl

Figure 3: Displacement errors due to height inaccuracies for optical sensors at different looking angles

Thus for (fast) mapping applications a combination of sensor-model based rectification using the best available 3D information and an additional fine image-to-image registration procedure turned out to be "best practise" in the GMOSS GNEX and test case scenarios.

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AUTOMATIC PRODUCTION OF A EUROPEAN ORTHOIMAGE COVERAGE WITHIN THE GMES LAND FAST TRACK SERVICE USING SPOT 4/5 AND IRS-P6 LISS III DATA

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Since the mid 1980s an European Land Cover dataset has been regularly produced for land cover changes, land cover map (CORINE), high resolution forest layer and built-up areas including soil sealing. Within the GMES (Global Monitoring for Environment and Security) Fast Track Land Service 2006–2008 a new dataset of orthorectified satellite images has to be produced covering the EU25 and neighbouring countries (total 38 countries). On behalf of ESA/ESRIN the DLR established an automatic processing chain to orthorectify about 3800 satellite images (two European coverages) within a time frame of 5 months including quality control and creation of a consistent GCP database.

High resolution satellite images from SPOT 4 (20 m GSD), SPOT 5 (10 m GSD) and IRS-P6 LISS III (23 m GSD) serve as input to derive the orthoimages. These has to be created using only one resampling step on the one hand in European Map Projection with 25 m resolution for the EEA, ESA and the JRC. On the other hand in a National Map Projection for each of the 38 countries with 20 m resolution also using only one resampling step. The overall accuracy in both cases has to be better than 20 m RMSE in each direction with respect to the previous European Land Cover dataset Image2000 (EU25) and for neighbouring countries not included in Image2000 to USGS ETM+ Land Cover dataset respectively.

For SPOT4/5 the Line-of-Sight vector is derived from continues measurements of the state vectors and attitude parameters as well as the calibrated camera model provided by SpotImage. For IRS-P6 LISS III the RPCs (Rational Polynomial Coefficients) serve as input, which are provided by Euromap (Universal Sensor Model).

Further input is the European wide digital elevation model (DEM) from SRTM-C band Version 2 of NASA, improved by using inputs from MONAPRO and SRTM-X band DEM within a fusion process.

In order to achieve the required accuracy of 20 m RMSE ground control points (GCPs) are automatically extracted via image matching between the Image2000/USGS Land Cover dataset and the new satellite scenes.

From these GCPs corrections of the exterior orientation for SPOT4/5 and of the RPC for IRS-P6 LISS III (affine transformation) are derived.

For the treatment of the huge amount of images an automatic processing chain using distributed computing based on a mySQL database and an intuitive web interface together with a detailed job management and hardware surveillance was developed.

The established quality assessment is based on automatically extracted ICPs, from which mean RMSE values for each scene and whole countries are derived or from which residual plots are produced. The residual plots show the differences of measured GCPs and the values calculated using the corrected ephemeris data. These plots were controlled for correctness (equally distribution over scene). Beside these the fulfilment of the RMS errors requirement to be better than 20 m in each direction, the overlay of the resulting orthorectified image with the (re-projected) reference image and the fits with overlaid neighbour scenes where checked. The completeness quality checks consists of checking if the image mosaic shows no gaps and that the data set for a country is complete (country frontier polygons). Further checks consist of a visual inspection of radiometric quality and cloud coverage of the images, the DEM tiles (gaps, artefacts) and used reference tiles (cloud coverage, radiometric quality, artefacts, geometric errors).

Results show that all countries match the requirements most accurate by giving an overall average RMSE in every direction of about 10 m (requirement 20 m) corresponding to about 0.5 pixels of the ortho images. Also only about 3 to 5 % of the images have to be re-processed (manual GCP measurements) in cases the product does not pass the internal quality control.

The experiences show that the metadata quality (measurements) of SPOT 4/5 and IRS P6 LISS III used for orthorectification is excellent. Good candidates for the image matching in order to extract the GCPs and ICPs for correction of ephemeris information are arid areas (Spain, Turkey, …) or mountainous areas with time constant sharp ridges. Scenes containing land areas of small extend (e.g. islands) can cause problems because the image matching fails due to vanishing landscape in high pyramid levels. The time gap of five to six years between the provided new images and the image2000 reference data can cause problems because matching strongly depends on image similarity. Geometric errors in reference images due to false mosaicking or processing errors of the last coverage cannot be handled with RPC or DG methods rigorously.

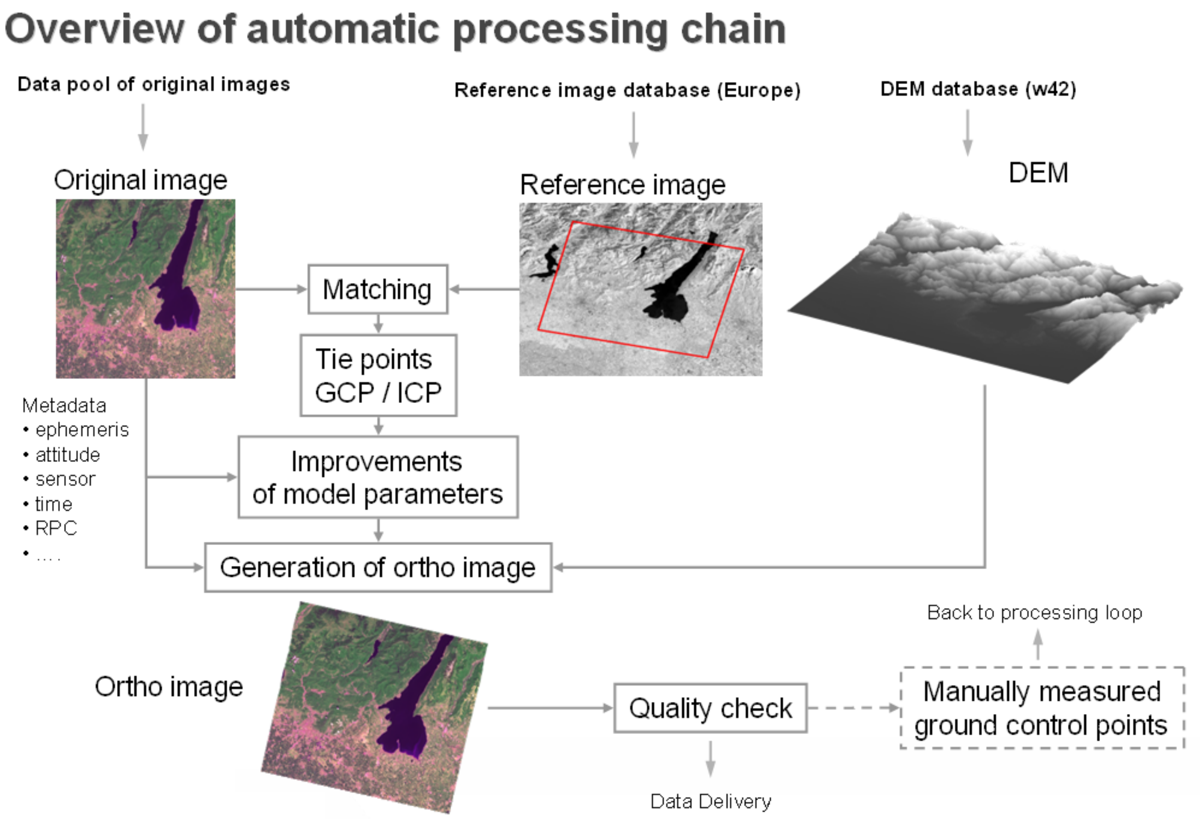

Figure 1: Overview of automatic processing chain (ProcChainOverview.png)

Figure 2: European mosaic of all processed images (EuropaMosaik.png)

A MULTIRESOLUTION-MRF APPROACH FOR STEREO DENSE DISPARITY ESTIMATION

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We propose a multiresolution-MRF approach for stereo dense disparity estimation.

Many efficient algorithm have been proposed in the literature [1,2] for stereo matching and they can be classified into two classes: local and global approach. The local approach uses a moving window and calculates a correlation measure in order to assign disparity to a pixel. The drawback of this method is that the optimal size of the correlation window highly depends on local variations of the intensity and the disparity. This window has to be large enough in order to handle textureless regions and in the same time has to be small to avoid to mix together pixels with different disparities. Many solutions have been proposed to overcome this problem. One of these is the use of adaptive windows [3] which makes the size dependent on the local variations of the intensity. Unfortunately, this method is very slow. In the global approach, the stereo matching problem is formulated in global energy optimization, with the energy function expressed in data term and smoothness term in order to penalize intensity differences between the corresponding pixels and discontinuities in the disparity map. They provide in general good results compare to local methods but have a high computational cost.

In this work we propose to use a global approach in a cooperating with a multiresolution local method. In a first step, using the local approach we compute successive disparity maps at different resolutions in order to estimate for each pixel a range of possible disparity values. This allows to reduce the size of the disparity search range in the global optimization and thus speeds up the minimization step. The test on different types of stereo images show that the method provides robust disparity maps.

Experimental Results

The proposed method was tested on the GMOSS stereo data set and one of the NGI Belgium aerial photography data.

- QuickBird Stereo Pair - Esfahan Nuclear Site – Iran (Nov. 2005)
- Ikonos Stereo Pair - Bagdad city – Iraq (Dec. 2005)
- Ikonos Stereo Pair – Graz – Benchmarking (June 2007)
- Aerial photography – Virton – Belgium (2005)

Qualitative results are given in the following figures:

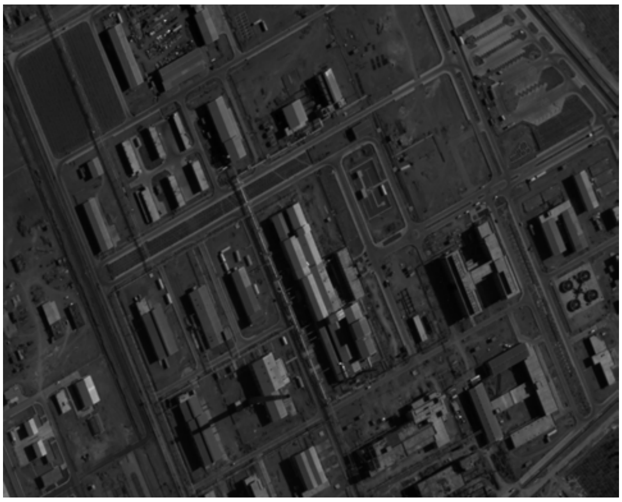
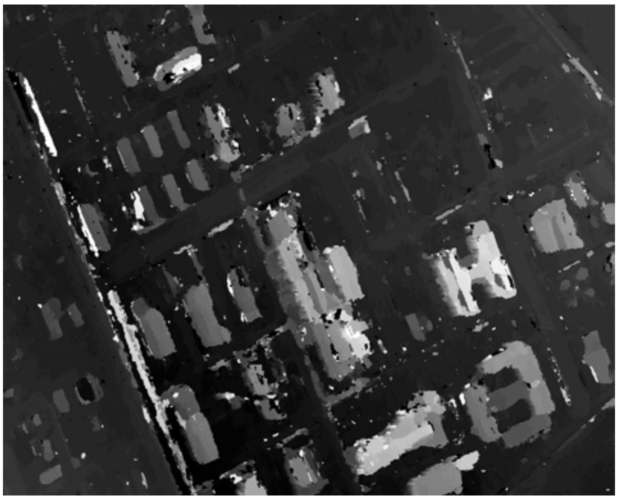
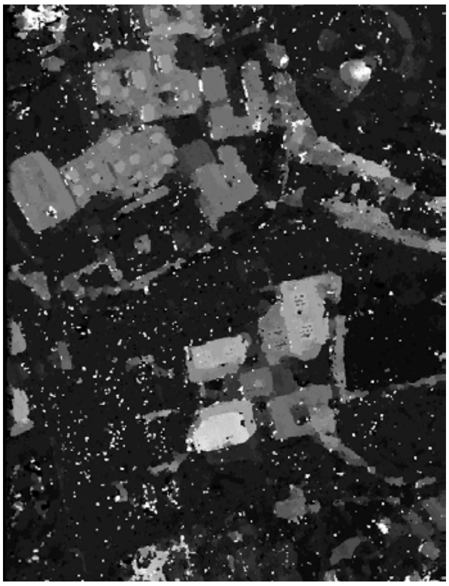


Figure 1: Esfahan Nuclear Site - Iran



Disparity map

Figure 2: Bagdad city – Iraq



Disparity map

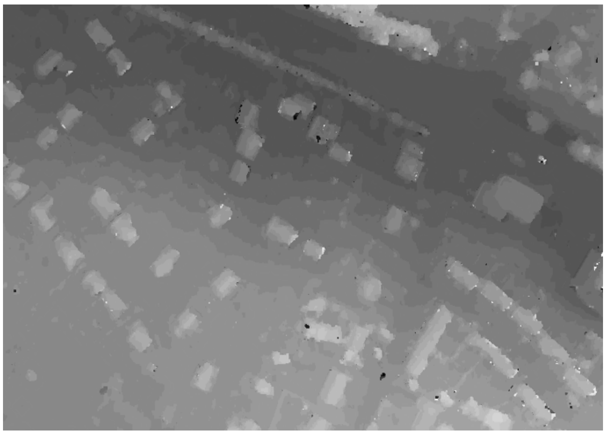
Figure 3: Bagdad city – Iraq

Disparity map

Figure 4: Graz - Austria

Disparity map

Figure 5: Virton - Belgium



Disparity map

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Feature Extraction

APPLICATION OF MATHEMATICAL MORPHOLOGY TO SATELLITE DATA

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In the framework of the NoE GMOSS (Global Monitoring for Security and Stability) the CRPSM (Centro di Ricerca Progetto San Marco) has developed automatic techniques devoted to detect different types of targets (civilian, military, etc.) available on high and medium spatial resolution satellite images (Quickbird, Ikonos, Spot 5, ASTER, aerial).

The paper aims at describing the results obtained by applying new techniques based on Mathematical Morphology (MM), in order to shown the versatility of this theory in the detection of objects, belonging to very different contexts, like dwelling units in refugee camps, roads of complex shapes and different background, main structures in nuclear plants, etc.

The purpose described above is obtained by using a series of algorithms based on the MM theory. These algorithms have been developed exploiting the functions available in the Matlab Image Processing Toolbox. In particular, some techniques able to automatically extract potential made-man structures, which could be present in complex images, have been developed. These techniques have been applied to a "mosaic of images" (about 4 GB, in the considered cases, corresponding to 40 ASTER images) covering the Kashmir region.

Further, MM has been used:

- to develop automatic procedures for detecting and counting dwelling units in several refugee camps located in Africa (Goz Amer, Mille, Lukole, etc) using very high spatial resolution (VHSR) images (Ikonos and Quickbird),
- to build automatic procedures for detecting roads of complex shape in the Kashmir region using SPOT 5 images and finally,
- to developed techniques able to extract the main structures inside to nuclear plants using VHSR images (Quickbird).

Remote sensing systems on board of satellites represent the best way to observe the earth without any constraint on the location of the region of interest. As a consequence of this possibility to access practically any place of the Earth satellites can be used to gather information everywhere without any restriction related to geographical and/or political reasons.

Refugee Camps

Besides the method used by JRC ([2]), CRPSM has explored a spectrum of different morphological approaches to solve, using Ikonos and Quickbird VHSR images, the tents counting problem for Goz Amer, Mille, Mukjar and Bindizi refugee camps located in western Chad, and Lukole camp in Tanzania.

Different methods have been applied according to the characteristics (shapes, dimensions and neat contrast with respect to the background) of the tents.

It is worthwhile to recall that the morphological techniques are applicable on grey-tones images for which the spectral information, associated with high-resolution multi-spectral detectors, results not exploited. This limit can be overcome using a Principal Component Analysis (PCA) ([8]) able to synthesize mostly of the spectral information in a couple of uncorrelated new spectral bands. For instance, the application to the Mille camp of the template matching technique, after a pre-processing phase aiming at extracting the PC bands, allows counting the tents with a good approximation everywhere in the camp. Thus, in an automatic way, an estimate of the number of tents, even in the parts of the camp less favourable from the point of view of the object/background separability has been obtained ([7]).

Automatic Extraction of Man-Made Structures from Mosaics

CRPSM has also developed some techniques able to automatically extract potential made-man structures (roads, airports, etc.), which could be present in a complex image, that's in a "mosaic of images". In particular, the considered satellite images mosaic has very big sizes (corresponding to 40 ASTER images) and the main goal of this research is to develop a technique that allows the automatic detection of given objects of interest by exploiting not only the spectral characteristics, but also the morphological characteristics in order to simplify the images analysis by the users.

The efficiency and robustness of the method is demonstrated by reporting the results obtained by applying the method to the Libya/Chad and Pakistan/India (Kashmir region) borders mosaics.

The same principles has been applied to the problem of automatically detecting structures like roads ([8]) having any complex shape to create an updated database of them, often needed for many African regions or simply to make a quick monitoring of the those hit from a disastrous events to verify the their state, as we did on the Kashmir region, which was struck from an Earthquake in October 2005.

The basic idea is again the exploitation of the Mathematical Morphology characteristics using suited structuring elements (like appropriate lines) to individuate and to extract any kind of roads. Further this approach was used to create a tool able to extract, in the Kashmir region, the roads having a complex shape.

Conclusions

This paper aims at presenting the interesting results reached in the latest four years of GMOSS activity, thanks to the ***versatility*** and ***robustness*** of the Mathematical Morphology theory.

This theory is very versatile and robust, allowing the detection of any kind of target on the base of the following observations:

- Defining “probe images” (the structuring elements) having any shape and dimension, gives us the possibility to search the objects of interest with more suited elements.
- Set of operations very powerful (Set Theory applied to the images) which act like not-linear space filters, and that if applied in sequence allow us to get the desired result.

To use the elementary morphological operators is very important since starting from not much basic concepts that define them, is possible create a important variety of operators useful in the more heterogeneous application fields. This fact allows exploiting the knowledge and the experiences gained in many fields to develop heuristic solutions to problems connected with the extraction of objects from an image. In particular, it is possible to obtain versatile and fast algorithms useful for a first approach to the image analysis, which can be extended to problems growing in complexity. The versatility of the morphological algorithms allows also to describe a wide range of problems from a point of view of the complexity of the topological description.

The velocity of the algorithms is due to the use of the Boolean algebra (in the binary case) or to the calculation of maximum and minimum (in the N grey levels) in the pixels that are examined and also to various expedients, which we can implement in a simple and effective way.

The thing emerged clearly from the previous examples is the existence of a narrow dependence between the usable strategies and the objective of interest. Such dependence brings to develop basic instruments able to cooperate for providing a solution to the problems of extracting all objects/structures/features we can meet.

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RAPID ROAD MAPPING FOR SECURITY AND CRISIS MANAGEMENT

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[2] *University of Pavia, Italy*

This work describes a semi-automatic procedure for cartographic mapping using high resolution data. In these data, roads can no more be considered as a subset of the edges that one may extract from the image. Instead, they usually appear as elongated areas with lateral edges. Therefore, one may detect roads by looking for pairs of parallel edges or searching for homogeneous areas with strong contrast to the neighborhood. This is the aim of the algorithm used in this context which furthermore integrates road features into a multiscale-feature fusion framework whose results will be further elaborated by an alignment routine. The same routine could be used also to extract higher level elements of the scene, such as crossroads, bridges and overpasses, by data fusion at the feature level of the previously extracted information, because it is characterized by a multi-scale object-based approach (fig.1). According to the following figure, the first step of the procedure is to divide the starting image into several sub-images each of which has a maximum width in order to parallelize the overall work.

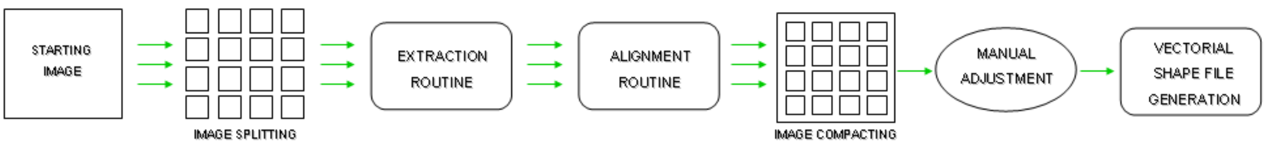

Figure 1

After this step, an extraction routine provides segments extraction for each sub-image. A general processing framework for road network extraction in high-resolution images is depicted in figure 2. It is based on a multiscale detection of street candidates, followed by an optimization step using a Markov Random Field approach. The latter step of this framework takes in account a priori knowledge about road shapes, automatically setting most of the involved parameters.

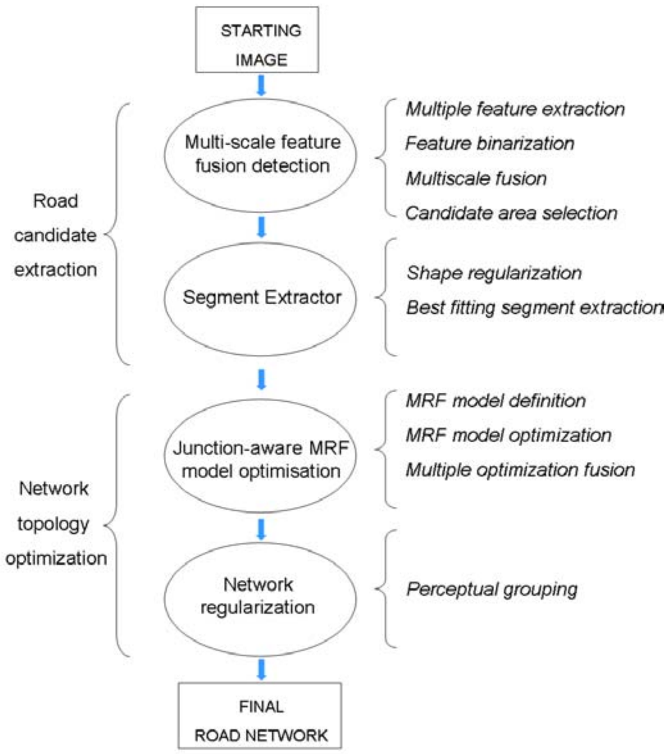

Figure 2

The final alignment routine is added to the whole method to improve the identification of the road network. It is based on perceptual grouping concepts and allows connecting segments where reasonable, based on their mutual positions (see fig. 3).

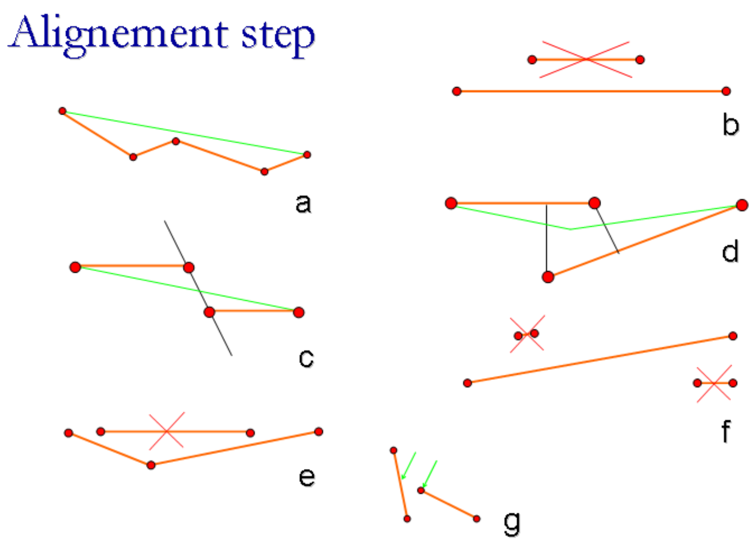

Figure 3

After that, a manual adjustment is required in order to fix false extraction and to discern among urban road, highways and rural network, that are transformed in the end in a georeferenced vectorial file ready to be used in common GIS environemts.

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HEIGHT ESTIMATION OF MAN MADE STRUCTURES USING HYBRID VHR OPTICAL AND SAR IMAGERY

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Introduction

In the domain of emergency response to natural disasters (e.g. earthquakes, tsunamis) and man-made conflict events (e.g. large scale destruction), rapid situation assessment is crucial for initiating effective emergency response actions. Remote sensing satellites such as optical and SAR sensors can provide important information due to their capability to map extended areas of interest in a fast and censorship free manner giving an objective overview of the crisis area shortly after the event.

Current spaceborne optical satellites such as Ikonos and Quickbird have meter and sub-meter resolutions, respectively. These sensors belong to the category of passive optical systems, depending on daylight and cloud free weather conditions during the acquisition phase. In contrast, active SAR sensors have their main advantages in the independence of the solar illumination as well as the relative insensitivity to weather conditions. However, until recently spaceborne SAR systems were only capable of imaging the earth surface with a spatial resolution of not better than 9 meter. This changed when the new VHR SAR sensors onboard the TerraSAR-X [1] and Cosmo-SkyMed [2] satellites were launched in 2007 with spatial resolutions up to 1 meter. In VHR imagery, features from individual urban structures, like buildings, can be identified in their characteristic settings in urban settlement patterns (e.g. residential areas, city centres, industrial parks).

The 3-D reconstruction of a building, or in more general terms of a man made structure, is a key issue for information retrieval from VHR SAR in urban areas. Existing methodologies are typically based on interferometric data, such as [3], presenting an automated procedure for building height retrieval based on shadow analysis, or [4] proposing a processing chain for the computation of a DSM over an urban area. However, the calculation of the interferogram fails if all of the roof backscattering is sensed before the double bounce area and therefore superimposes with the ground scattering in the layover area, which is usually the case for high buildings [3]. To tackle the problem of signal mixture from different altitudes, [5] proposes two models, one for interferometric and one for polarimetric data. Instead of using interferometric data, [6] emphasizes the usage of stereoscopic SAR. Recently, also methods based on multi-aspect data, where the same area is measured from different flight paths resulting in a more complete picture from the area, were proposed. For instance, [7] presents a concept for the reconstruction of a single building from multi aspect interferometric data based on a phenomenological approach using shadow areas and edge information, while [8] proposes an automatic 3D reconstruction methodology for multi aspect polarimetric SAR images, using polarimetric edge detection, Hough transformation and maximum likelihood estimation and probabilities. [9] demonstrates height extraction by radiometric analysis of the double bounce area of a building using an electromagnetic model for a simplified rectangular flat roofed building structure [10], which is based on the Kirchhoff physical optics and geometrical optics approximations.

SAR simulators [11]-[14] are not only suitable for the analysis of scattering phenomena, but also as part of information extraction methodologies for actual SAR imagery. In [15], for instance, the polarimetric GrecoSAR simulator is deployed for the detection of scattering hotspots of vessels, which are then used for the classification of ships in actual SAR imagery. In the case of building reconstruction from multi-aspect InSAR data [16] proposes a similar concept using an iterative procedure with predictions of height maps which are compared to the actual DEM. In [17] a method aiming at the improvement of the geo-referencing of SAR imagery from urban areas is described, detecting correspondences between a simulated city model and actual SAR imagery.

In this paper we propose a novel generic 3D reconstruction methodology capable to extract the height of man made structures from single detected SAR (power) imagery. The method is based on the combined application of a radar simulator and a matching procedure. The main advantage of the proposed procedure is the simultaneous consideration of all characteristics of a man made structure in SAR for estimating the height.

The remainder of this paper is organised as follows. In section 2 we introduce the test data set, while we describe in section 3 the methodology and its main components in detail. We finish with some conclusions and proposals for future work in section 4.

Test Data Set

To highlight the capabilities of the proposed method to extract the height of a man made object, we demonstrate the approach for the 3D reconstruction of the Menkaure pyramid in Giza Egypt from a recent TerraSAR-X image [18]. The image was acquired on 2 July 2007 in High Resolution Spotlight Mode with an azimuth and range resolution of 1.4 meter. The acquisition was made from a descending orbit with right looking direction in HH polarization, 120 MHz range and 6,775 Hz azimuth bandwidth, and 53 degree incidence angle. A subset of the image showing two pyramids is displayed in the Fig. 1, with the Cheops pyramid in the upper part and the Menkaure pyramid in the lower part of the image, which is marked with a white frame. For the height extraction we will focus on the Menkaure pyramid. At present, the pyramid is 62 meter high (original height was 65.5 meter), with a square base of 103.4 meter and an inclination angle of about 51 degree [19] and is made out of limestone and granite blocks, which gives it a staircase like structure. The pyramid has a 5 degree aspect angle with respect to the azimuth direction of the TerraSAR-X image.

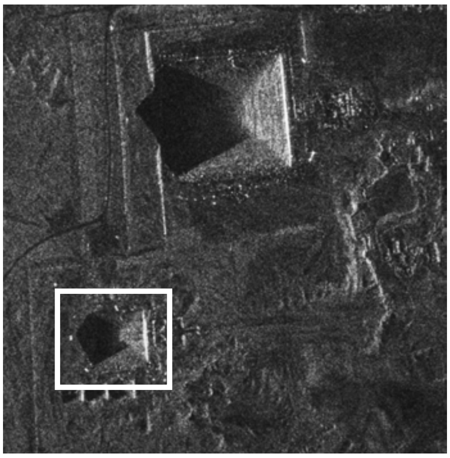

Figure 1: Subset of the TerraSAR-X image of the pyramids in Giza. The upper part shows the Cheops and the lower part, the Menkaure pyramid (white frame), respectively. (TerraSAR-X image © Infoterra GmbH / DLR, 2007).

Methodology

The method is based on the complementary usage of VHR optical and SAR imagery. From the optical data the location, the extends of the object in planar dimensions and the roof type is extracted. The height is determined from the SAR imagery using a radar simulator in combination with a matching algorithm. Using the object's footprint and roof characteristics for the model initialization, the simulation of the object with different heights results in a series of local backscattering images which are then correlated to the actual scene. The simulated image which has the best match with the actual SAR data provides an estimate of the actual height. The key principle of this method is to reduce the number of free parameters of the simulations S from $S \equiv f(location, width, length, height, rooftype)$ to $S \equiv f(height)$. Conversely, the height extraction complements single scene optical imagery by providing the height parameter for man made structures without the need for stereo pairs. In the following subsections we present the simulator and the matching procedure in more detail.

Simulation

The radar simulator uses ray tracing to determine which surfaces of a generic object are visible. It can handle any complex object which is composed by spheres, planes, and triangles or any arbitrary combination of one or several instances of these objects. An adjustable mixture of Lambertian and specular scattering is used as model to calculate the backscattering from the surface and model. The simulator optionally includes multiple bounce scattering, and can therefore distinguish between single and dual bounce reflections. This is a valuable feature if the scattering phenomenon of complex objects need to be analyzed.

To demonstrate the efficiency and the generic capabilities of the simulator to handle simple and complex man made structures, we compare in Fig. 2 simulation results from the Menkaure Pyramid, to the corresponding actual TerraSAR-X spotlight data. In Fig. 2 we show from the left to the right side the VHR SAR image (zoom of the white frame in Fig. 1), the single and double bounce contributions of the simulations, and the final synthetic image combining the different scattering mechanisms. Note how the separation of the scattering mechanisms assists in analyzing the various scattering effects of the pyramid in the actual SAR image.

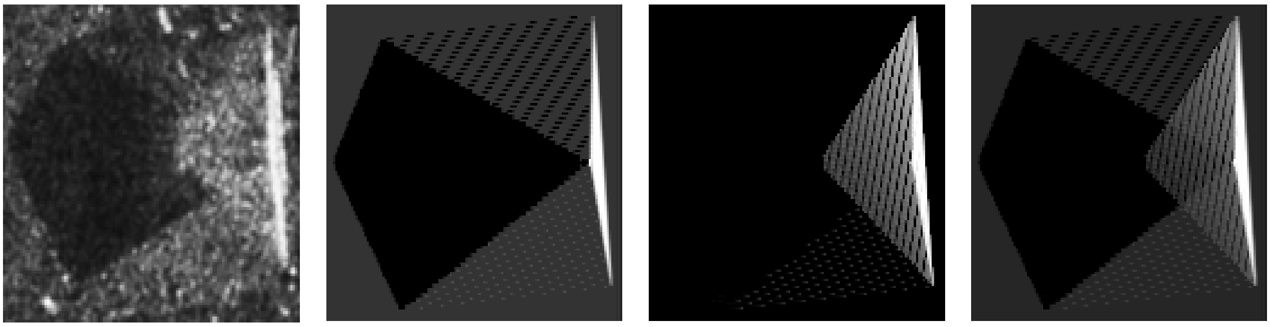

Figure 2 (from left to right): TerraSAR-X image from pyramid with look direction from the right side; Simulated single bounce image; Simulated double bounce image; Final simulation results combining single and double contributions.

Matching

The 3D reconstruction methodology requires for its initialization information about the footprint and the structure (for example, the roof type), of the object under investigation. This information can be extracted e.g. from VHR optical, large scale maps, cadastral data or from VHR SAR. From these data, triangulated 3D models with various heights are generated, which are simulated subsequently by the previously described simulator, taking into account the viewing configuration at which the actual SAR image was acquired. To evaluate the height of the object each simulation is compared to the actual VHR SAR image in a matching procedure.

For image matching, two types of methods exist: Area-based and feature based methods [20]. The first class calculates the correlation between a number of samples in the two corresponding images. In SAR imagery, these methods tend to be not very reliable due to the presence of speckle noise. In our case, however, we compare the actual SAR data with speckle to synthetic images without speckle, i.e. the local statistics of the images in the comparison are different. Furthermore, the absolute backscattering coefficients for the simulated image do not match exactly with those of the actual image, so that area-based methods have limited applicability to get a reliable match value between the images. To overcome this problem, we have defined our matching algorithm as a feature based method, where structural information such as lines and edges are extracted and compared.

The features which we consider in our feature matching are shadow regions and edges. For the matching of the features we use the normalized cross-correlation (NCC):

$$NCC(I_1, I_2) = \frac{(I_1 - \overline{I_1}) \cdot (I_2 - \overline{I_2})}{\left\| I_1 - \overline{I_1} \right\| \cdot \left\| I_2 - \overline{I_2} \right\|},$$

with the correlation windows I_1 and I_2, and $\overline{I_1}$ and $\overline{I_2}$ being the average values of I_1 and I_2, respectively. The matching procedure consists of three parts:

1. **Calculate match between shadows of simulated and actual images.** First, we apply the non-parametric mean shift filter [21], which is especially suitable for shadow detection, to the actual SAR image. Then we use a threshold operator to extract the shadow region of the object from the actual SAR image, followed by a morphological opening and closing operator to erase small objects and fill gaps within the shadow area. To extract the shadow region from the simulated image, we can directly apply the threshold operator, since the synthetic image is not affected by speckle. The resulting two shadow images are correlated with the NCC. This procedure is carried out for each simulation, resulting in the NCC as a function of the height, for shadow regions. An NCC maximum is expected for the best match between the shadow region of the simulation and the shadow of the actual image.
2. **Calculate match between edges of simulated and actual images.** In this step we first use a multi directional morphological filter with its extension for rank openings and closings [22] in order to reduce the speckle in the actual SAR image with an edge preserving filter. Then we use the Touzi edge detector [23] to extract edges from the actual image, while a Canny edge detector [24] is employed for the synthetic image, since it is not affected by speckle. As in the previous step, an NCC maximum should occur for the best match between the edges of the actual and simulated images, using height as the free parameter.
3. **Calculate final match**. To get the final match function we calculate the normalised sum of the match criterions of the shadow and edge features. The height at the maximum value of this final match function is the estimated height of the object in the actual SAR image.

For the latter step, also the product could be used to combine the edge and shadow measures, introducing non linear behaviour. This would have the advantage that if both measures coincide and have indeed the best match value at the actual height, the final match would have a very clear peak at the correct height. The risk is that if only one measure gives indication to a wrong height, this has a significant impact on the final match, which might lead to a wrong height estimate. Therefore we choose the more conservative summation of edge and shadow matches to calculate the final match.

Results

We demonstrate the proposed methodology for the height estimation of the Menkaure pyramid, displayed in the left image of Fig. 2. For the shadow extraction from the actual SAR image, we first apply the mean shift filter to the TerraSAR-X data, which is shown in the left part of Fig. 3. Then we extract all samples which are in the lower 25% quantile of the histogram applying a threshold operator. The extracted shadow regions are post processed by a morphological opening and closing, whose result is shown in the centre image of Fig. 3. The result of the edge detected actual scene is shown in the right part of Fig. 3.

For the height estimation we simulate the pyramid for heights from 49 meter – 76 meter in 1 meter steps, taking into account the parameters outlined in the data set description for the automated triangulated model generation and for the simulation itself. This results in 28 simulations each with single bounce image, double bounce image and its combination. As highlighted in Fig. 2, it is essential to consider the combination of single and double bounce scattering mechanisms for the comparison to the actual SAR data since the single bounce image is substantially different to the combination of single and double bounce data, which can be best seen at the shadow region.

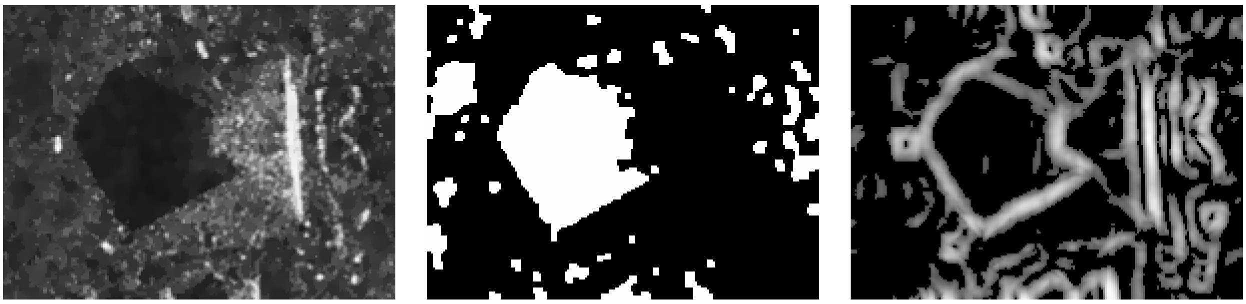

Figure 3: Left: Filtered TerraSAR-X image with mean shift algorithm. Center: Extracted shadow regions of pyramid. Right: Extracted edges of actual pyramid.

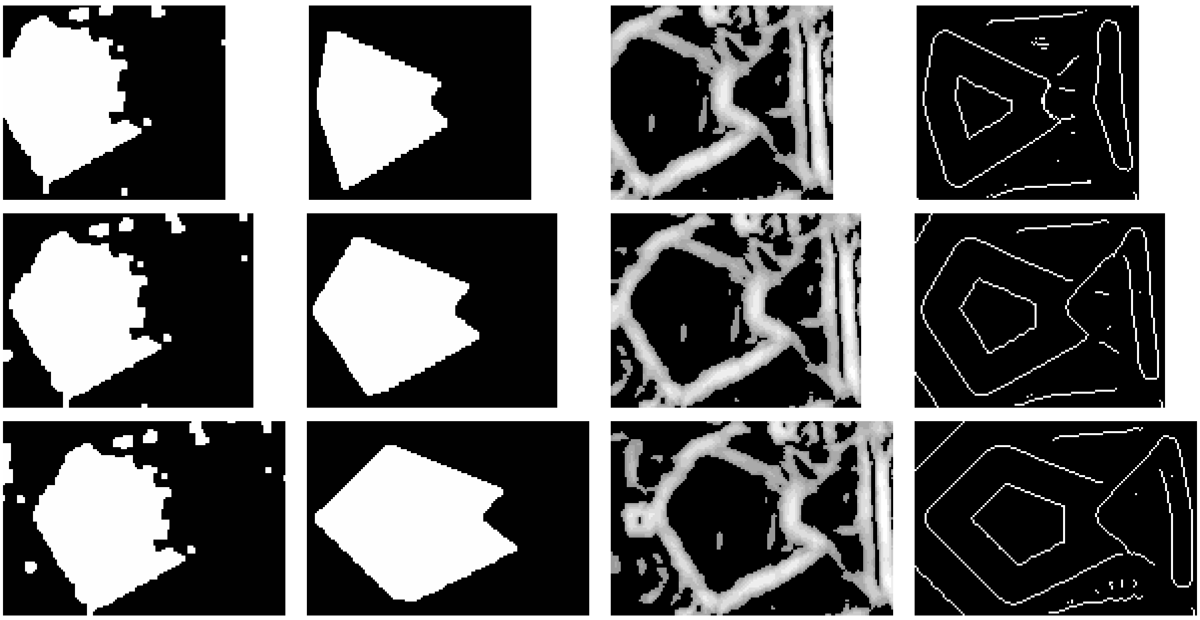

Figure 4: From left to right: Subset of shadow area of actual SAR image which matches best with shadow region of the simulation; Shadow region of synthetic image; Subset of edges of actual image which matches

best with edges of the simulation; Edges of synthetic image. From top to bottom: Pyramid height 49 meter; Pyramid height 62 meter; Pyramid height 76 meter.

Fig. 4 shows examples for the feature extraction from the simulated images for pyramids with height 49 meter (top row), 62 meter (middle row), and 76 meter (bottom row) and compares them to the features of the actual scene. The shadow and edge features of the synthetic images (center-left and right images of Fig. 4) are correlated to the shadow and edge features of the actual data (see Fig 3.) using the NCC. The subset of the features of the actual images which have the maximum NCC with the features of the synthetic images are shown in the left and center-right images of Fig. 4. The structure of the simulated pyramid with 49 meter height (top row) is too small, since the shadow and edge images of the actual data are truncated in the shadow region of the pyramid, which gives a low matching result. For the 76 meter high pyramid in the bottom row, this situation is the opposite: the shadow and edge features of the synthetic image are more extended than the features of the actual data, also resulting in a low match. The best match occurs in the middle row, where features extracted from the simulation of the pyramid with the true height of the Menkaure pyramid are compared to the features of the actual data.

Fig. 5 shows the results for the shadow (left), edge (centre) and final (right) match as a function of the height. All three graphs show strong matches around the true height of the Menkaure pyramid (62 meter), while the NCC drops off with increasing difference between simulated and actual height. Both the shadow region match and the edge match have their NCC maximum at 62 meter. Therefore, the final highest match between the actual and synthetic image, which is the estimate of the height provided by the methodology, is also at 62 meter, which in fact is the true height of the investigated pyramid.

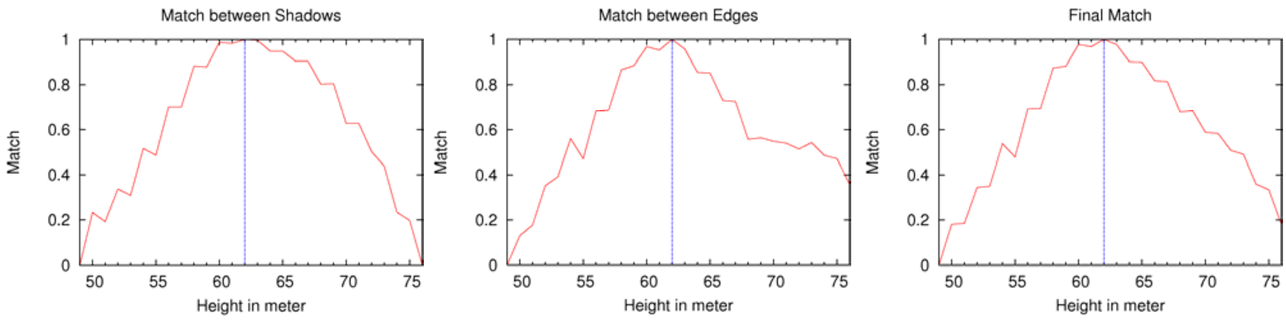

Figure 5: Left: Match between shadow regions. Center: Match between edges. Right: Final match.

Conclusions and future work

In this paper we proposed a novel method for the 3D reconstruction from detected VHR SAR imagery using a radar simulation and image matching procedure, which evaluates the match between the actual SAR scene and the simulations of an object with fixed planar dimensions, a known shape, but different heights. The simulator is based on ray tracing and an adjustable mixture of Lambertian and specular scattering. For the comparison between synthetic and actual SAR imagery we match edge and shadow features using the NCC. We demonstrated the efficiency of the method by estimating the height of the Menkaure pyramid in Giza, Egypt from a recent VHR TerraSAR-X image. It was shown that the method is able to accurately extract the actual height of the pyramid. We are currently testing our methodology for urban buildings in VHR airborne SAR and VHR TerraSAR-X data.

Acknowledgements

The authors would like to thank Harm Greidanus from the EC-JRC for fruitful discussions, and Richard Bamler and Michael Eineder from the DLR for providing information about the TerraSAR-X scene.

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Change Detection

MAD CHANGE DETECTION: A SIMPLE SPATIAL EXTENSION AND NONLINEAR VERSION

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The iteratively re-weighted Multivariate Alteration Detection (MAD) method transforms multivariate, bi-temporal data from ordering by wavelength to ordering by similarity. This is done by means of an iterative extension to an established technique from multivariate statistics called Canonical Correlation Analysis, CCA. Over a series of iterations we calculate no-change probabilities for each observation to be used as weights in the next iteration. These weights are approximately chi-squared distributed. We stop iterations when the canonical correlations stop changing (substantially). When we take differences between the canonical variates obtained when iterations stop, we obtain "generalized differences" which we call the MAD variates. These change variates are uncorrelated. The IR-MAD method generates an increasingly better background of no-change observations against which to detect change. The IR-MAD method can be applied to completely automatic normalization over time of multivariate, truly multi-temporal data. This contribution describes a simple spatial extension to the IR-MAD method: Carry the weights which are in turn the no-change probabilities in IR-MAD from coarse to finer scales across scale space. Here we construct the scale space simply by repeatedly smoothing with a 5 by 5 Gaussian filter. Results based on this type of analysis are encouraging. Also, the contribution describes our first attempt to build a nonlinear change detector based on an artificial neural network. Also in this case results are encouraging.

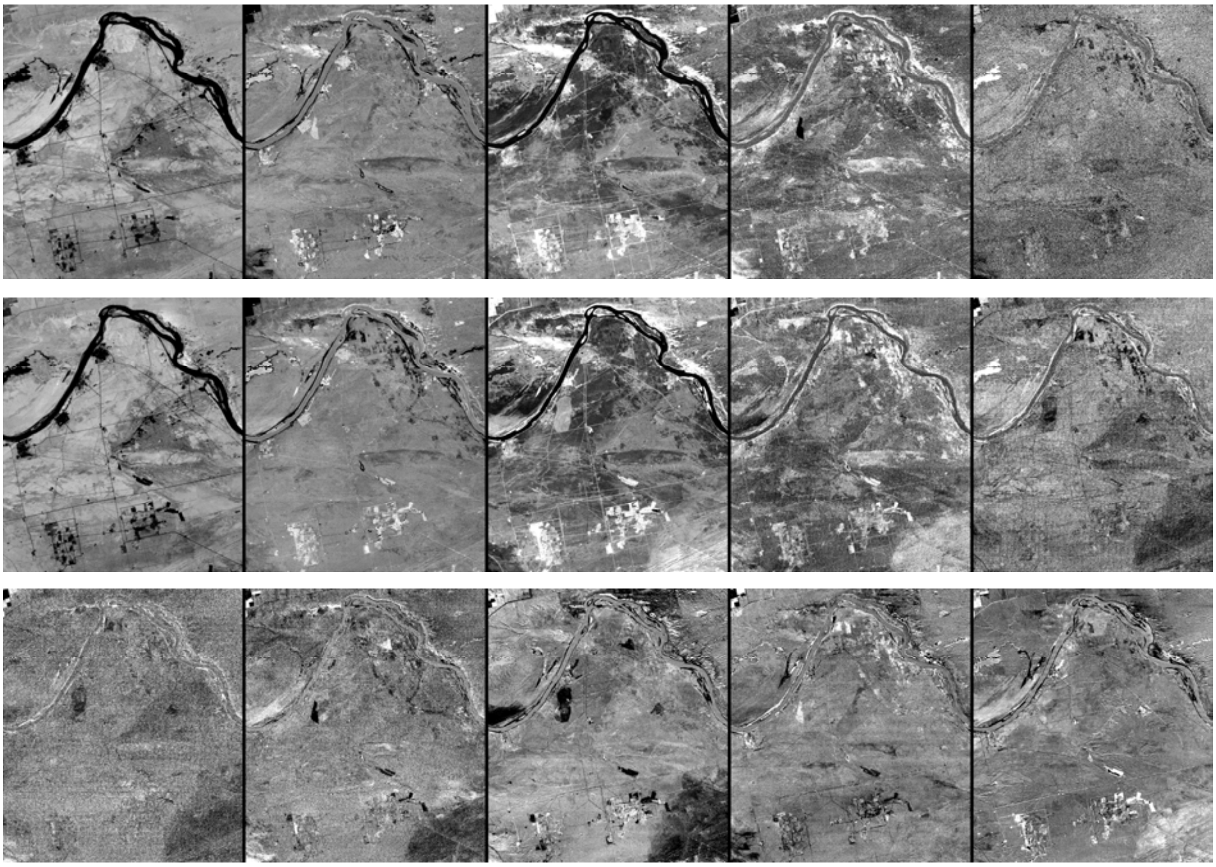

Figure 1: Canonical correlation analysis, MAD

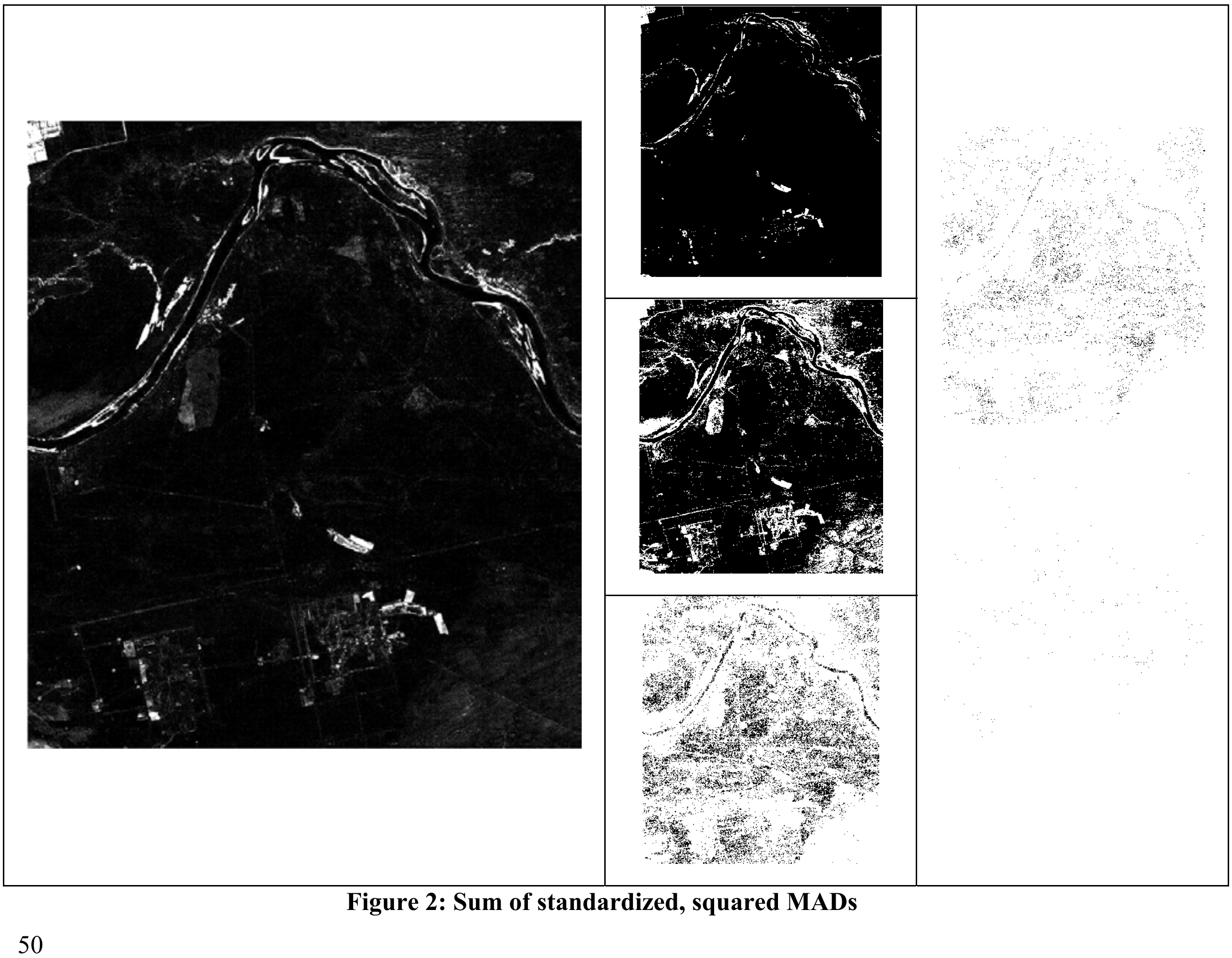

Figure 2: Sum of standardized, squared MADs

OBJECT-BASED CHANGE DETECTION FOR SECURITY APPLICATIONS: NPT VERIFICATION

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Background

Besides reviewing the "correctness", also the evaluation of the "completeness" of the State declarations has become a key issue within the safeguards system of the International Atomic Energy Agency (IAEA) today. The efforts for strengthening IAEA safeguards involve the implementation of various technical capabilities for verifying the absence of nuclear material diversion and undeclared nuclear material and activities. One of the technologies to be considered under the Additional Protocol and Integrated Safeguards respectively is remote sensing by commercial earth observation satellites.

In the absence of on-site inspections or environmental sampling, commercial remote sensing data provide one of the few opportunities to gather almost real-time data and thus information for the area of interest. The potential of commercial satellite imagery for strengthening IAEA safeguards has been effectually demonstrated in a number of case studies using date from the panchromatic, multispectral, hyperspectral and radar domain in the last years [1]. However, satellite imagery is far from being sufficient to solely confirm the existence or absence of nuclear activities.

For future NPT verifications tasks, however, both the number and area of sites monitored by satellite imagery data and the time intervals for observations are expected to increase permanently. From a remote sensing perspective, the technical developments in sensor technology led to improvements as to spatial, spectral and temporal resolution. Against this background, the image analysts could highly benefit from (semi-) automation and transferability of digital image processing steps in order to extract and utilise significant change information.

Change detection

Change detection is the process of identifying and quantifying temporal differences in the state of an object or phenomenon [2]. When using satellite imagery from two acquisition times, each image pixel or object from the first time will be compared with the corresponding pixel or object from the second time in order to derive the degree of change between the two times. Most commonly, differences in radiance values are taken as a measure of change.

A variety of digital change detection techniques has been developed in the past three decades. Reviews on the most commonly used techniques are given by i.e. [2,3,4,5]

Pixel-based change detection

For the detection of changes on a pixel basis, several statistical techniques exist, calculating e.g. the spectral or texture pixel values, estimating the change of transformed pixel values or identifying the change of class memberships of the pixels. In regard to the specific application of nuclear monitoring the most satisfactory results were carried out by the so-called Multivariate Alteration Detection (MAD) transformation [6,7].

Object-based change detection

Computer driven, object-based image analysis is in a first approximation comparable to visual perception. An image interpreter recognizes, along with the colour of an image, also the shapes, textures and coherent regions present within it, and associates meaningful objects and their contextual relations. A similar goal is intended in object-based image analysis, although the complexity and effectiveness of human perception is of course far from being achieved. The extraction of the objects from the analysed image occurs at the lowest level by segmentation, at which stage the primary segments should ideally represent the real world objects. The feature analysis provides the basis for the preparation of a ruled-based classification model resulting in a classified image. Analysing satellite image data in an object-based way generally extends the possibilities to detect changes between two or more dates. In addition to the change pixel measures listed before, object-based change detection techniques can also estimate the changes of the mean object , such as shape and size, assess the modified relations among neighbouring, sub- and super-objects and find out changes regarding the object class memberships. Moreover, specific knowledge can be easily involved into the procedure. Previous studies implying a combination of pixel- and object-based techniques have already demonstrated the advantages of firstly pinpointing the significant change pixels by statistical change detection and subsequently post-classifying the changes by means of a semantic model of change-related object features [8]. The software solution for an object-based image analysis is currently given by Definiens [9].

Feature extraction

Feature recognition is an essential part of object-based image analysis. A comprehensive feature extraction methodology is the precondition for successful work with image objects. Given the large number of possible features for object description, it is necessary to identify the characteristic, significant features for object-classes of interest. In order to avoid the time-consuming ``trial-and-error'' practice while seeking for significant class separating object features approaches towards an automatic feature extraction were used. In the given project the optimal object features and the range of its membership functions were automatically determined by the feature analyzing tool SEaTH (SEparability and THresholds) [10]. The feature analyzing tool SEaTH identifies the relevant features with a statistical approach based on training objects. The statistical measure for determining the representative features for each object class is the pairwise separability of the object classes among each other. Subsequently, SEaTH calculates the thresholds which allow the *maximum* separability in the chosen features

Conclusions and Outlook

For nuclear safeguards purposes a methodology was developed, in order to facilitate the extraction of change information on nuclear activities using high-resolution multispectral satellite imagery. The presented procedure started with the automated pre-processing of high-resolution data, including pan-sharpening, image-to-image registration and radiometric normalisation. Changes between the two image acquisition dates were detected by means of the MAD technique and analysed in combination with an object-based classification.

The results of image classification and change detection were satisfying for the case study. Especially, the buildings and their changes were identified with a high accuracy. The combination of pixel-based change detection and object-based image classification has been proven to be a viable method to detect and identify significant changes in multi-temporal data. The automation of change detection and analysis procedures appears feasible to a certain extent, therewith giving rough and fast information on changes.

For a comprehensive change detection and interpretation system the signatures of nuclear activities identifiable by satellite imagery have to be investigated and utilized for image processing. Moreover, also the automation of the procedures for orthorectification, object extraction, feature extraction and visualisation need to be improved or even brought forward.

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CHANGE DETECTION USING POLARIMETRIC SYNTHETIC APERTURE RADAR (SAR) DATA

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Change detection is a very important application of Earth observation data. A number of different applications rely on robust and accurate change detection from such data. An example may be monitoring of larger land areas for environmental or security applications. In many cases high resolution optical data are used for this purpose. However, SAR has also shown a potential due to the reliable data acquisition (i.e. independent of clouds), and the polarimetric SAR may provide the additional information that is needed compared to single polarisation SAR to provide reliable and robust detection of changes. Polarimetric SAR data are in principle available from satellites from the Japanese ALOS, the German TerraSAR-X and the Canadian Radarsat-2. An appropriate way of representing multi-look polarimetric synthetic aperture radar (SAR) backscatter data is the so-called covariance matrix data format. For each pixel this consists of a 3×3 Hermitian, positive definite matrix which follows a complex Wishart distribution. Based on this distribution a test statistic for equality of two such matrices and an associated asymptotic probability for obtaining a smaller value of the test statistic have previously been derived by the authors and applied successfully to change detection in bi-temporal polarimetric SAR data. An intrinsic problem with SAR data is the speckle noise, and hence to obtain appropriate detection accuracy, reduction of the speckle is often necessary. This may be done by segmenting the images prior to change detection and then applying change detection to the segmented images. In change detection applications, bi-temporal images must be available and used in the change detection process. If these images are segmented independently, the segments in the different images will most likely differ. Therefore, in this contribution an approach is used where the two images are segmented jointly. Hence, only one set of segments exists, where the segmentation is based on the information in both images, and therefore the segments represent areas that are homogeneous in both images but not necessarily unchanged from the first acquisition to the next. The Wishart test statistic is then used to detect possible changes within the segments between the two images. Results of the combined scheme segmentation/change detection are encouraging.

RADAR CHANGE DETECTION AND TARGET CHARACTERISATION FOR SECURITY APPLICATIONS

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Within GMOSS one of the image processing techniques that was studied is radar change detection. TNO developed a software tool for this purpose, including automatic co-registration, dedicated speckle filtering, false alarm reduction, attribute extraction, and export to ESRI Shapefile format so the output can be used in further geospatial information analysis and fusion in GIS systems. During the project this tool was applied to radar data in several case studies including damage assessment (natural, conflict), flood mapping, pipeline monitoring, monitoring of urban activities, and target detection.

Radar data that was applied came from Envisat (30 m), Radarsat-1 (10 m), and polarimetric airborne sensors (1-3 m). Especially the experience with the airborne sensors is valuable for the new generation of high-resolution radar satellites TerraSAR-X, COSMO-SkyMed, and Radarsat-2, that is operational since 2007. Radar polarimetry can be useful in false alarm reduction and target characterisation.

In general, medium-resolution (10-30 m) radar change detection is able to provide information on large scale natural damage (earthquakes, tsunami, floods), and large and compound building structures and infrastructures. High-resolution (1-3 m) radar change detection is able to provide more detailed information on natural and conflict damage, smaller housing structures and infrastructure, activities near infrastructures and borders, and target characteristics.

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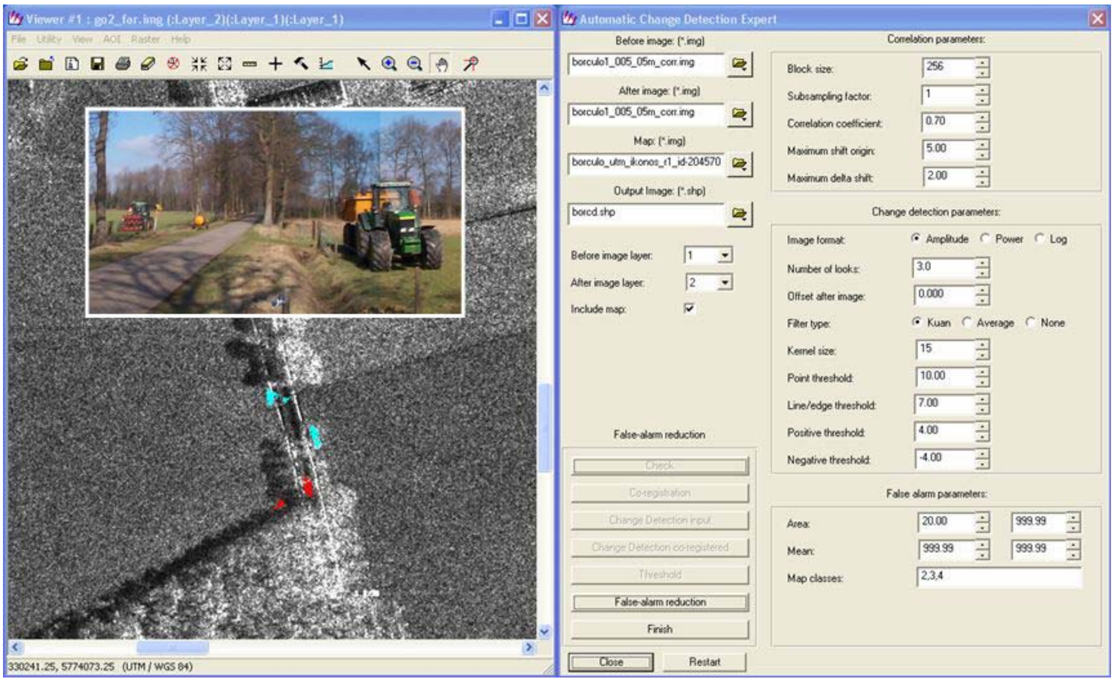

Figure 1. SAR change detection processing user-interface (right) applied to airborne radar images of a gas-pipeline corridor (left). Detected are potential pipeline threats (tillage machinery).

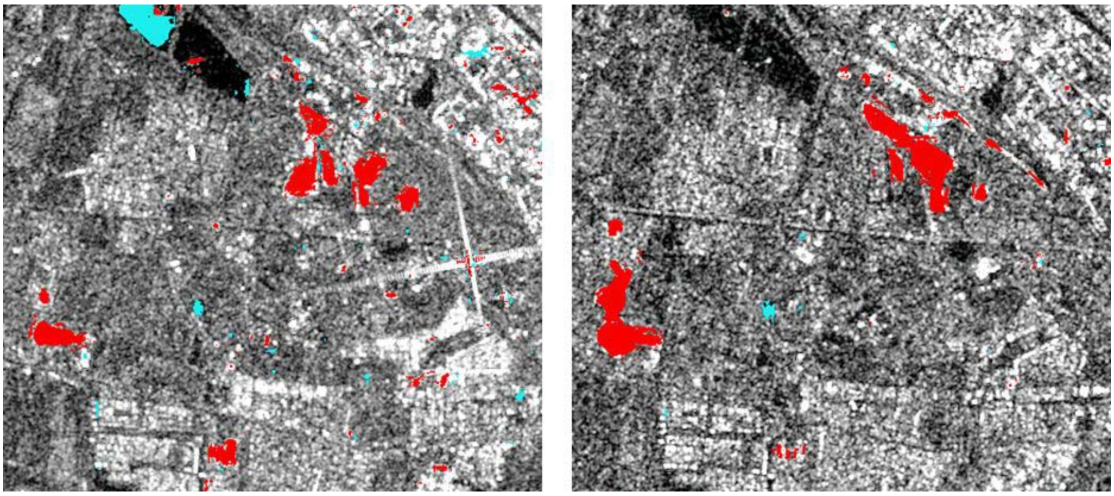

Figure 2. SAR change detection processing applied to dual-polarised Envisat ASAR imagery of an urban development project in the Netherlands: HH (left), HV (right). The results show that different polarisations detect different parts of the same changed surface as a result of different scattering mechanisms.

Applications

MANUAL VS. AUTOMATED DWELLING COUNTING IN CHAD, SUDAN, TANZANIA AND ZIMBABWE

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[3]*European Satellite Centre (EUSC), Madrid , Spain*

Within GMOSS, comparative studies on visual counting and automated detection of dwelling structures were carried out among partners EUSC, Z_GIS, CRPSM. Test areas in the Darfur region (Western Sudan, villages of Bindizi and Mukjar), in Zimbabwe (operation Murambatsvina and Garikayi around the capital of Harare) and two refugee camps in Chad (Goz Amer) and Tanzania (Lukole) were selected (cf. Lang et al. 2007, Lang et al. 2006a and Lang et al. 2006b).

The aim of the studies was on the one hand to identify numerous villages and huts damaged or destroyed during the humanitarian crises in these areas and on the other hand to gain population estimates in refugee camps and shanty towns. Since manual counting takes excessive time we were testing the potential of automated delineation in order to estimate the margin of error of the results. To this end, QuickBird (Sudan, Chad, Zimbabwe) and Ikonos (Tanzania, Zimbabwe) scenes were shared among the partners and analyzed.

Image analysis and GIS techniques provide means for estimating both number and type of structures destroyed and the scale of destruction. So far, visual interpretation and manual delineation have been the main techniques to fulfill this task. Due to the complex microstructure and high variance in geometrical features the automated, machine-based detection of such small structures faces high degree of freedom and the determination of distinct cues is often hampered; automated detection is therefore sometimes limited, despite the high technological standard available. Though any help in detecting and delineating may be very supportive to manual work, producing too many false positives is counter-productive, since this would cause extra work for checking quality of the results.

We used mathematical morphology (Matlab-based algorithms) and class modeling (as realized with Definiens) as automated delineation approaches. Comparing results with visual interpretation revealed that automated extraction could reach similar results as the visual interpretation in cases where structures of the dwellings were clearly visible (and describable). In this case automated extraction proved superior in terms of the number of dwellings detected per area unit. However, if – as in many cases – the structures are more or less imperfect the visual interpreter is much more flexible and the detection rate is in these cases much higher. Additionally, there were some specific pros and cons found for each of the automated approaches.

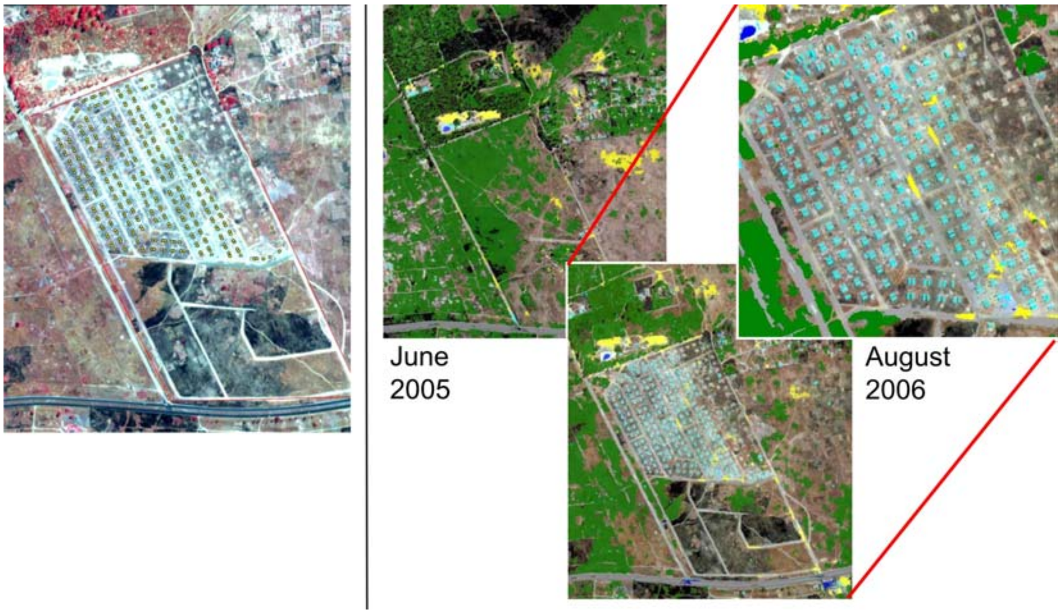

Figure 1: Results of visual detection (left) and semi-automated extraction (right) of reconstructed settlements in the Whitecliffe area, Zimbabwe (Uttenthaler, 2007; modified).

Thus, a targeted combination of automated extraction and visual interpretation could be an improvement for the future: automated extraction could support fast extraction of the unambiguous structures, with the visual interpretation focusing on more ambiguous structures.

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DEVELOPMENT OF A STRATEGY FOR APPLYING NIGHT TIME IMAGES TO RAPIDLY ASSESS DAMAGED AREAS AND REFUGEE MOVEMENTS AFTER DISASTERS

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In the mainframe of the EU funded NoE GMOSS (Global Monitoring for Stability and Security) the European Union Satellite Centre and the University of Rome (Centro di Ricerca Progetto San Marco) are studying the performances and limits of applicability of night-time satellite images for the prompt assessment of damaged areas and refugee movements after a disasters of natural or anthropic origin.

Presently, space based remote sensing systems result unsuitable to provide useful information when disastrous events require, simultaneously, high temporal and spatial resolutions. Mainly this is due to the fact that, even if many high resolution satellites are available they are not organized in a constellation and the image acquisitions, for observational reasons, are concentrated around convenient local time. Further, due to the technological limits of the transmission systems a very high resolution is usually coupled with a reduced sensor swath (typically $\approx$10x10 km^2). This means that the observation can be carried out when the area to be imaged is known. On the other side low-resolution satellite could provide, in principle, some information with the required promptness.

Few sensors, at present time, are operating at night in the visible/near infrared part of the spectrum (DMSP/OLS, SAC-C/HSTC). However, in the case of DMSP/OLS, the availability of a series of satellites arranged in a constellation and the width of the sensor's swath allows earth coverage twice nightly. This can result useful in the aftermath of a natural disaster such as earthquake, when first responders providing relief action need to know the location and the extent of the areas of damages, the potential amount of population involved and the place where survivors are concentrated. Further, the availability of a preliminary fast estimate of the areas mainly impacted can support a suitably selection of the VHSR images acquisition time since these sensors are characterized by a very small frame size that makes unpractical a blind acquisition of the whole region possibly impacted.

The areas of damage in urban areas are indicated by the reduction of "stable" lights after the event due to power failure as well as building damage and the reduction of human activity. As an important follow up, there is a related increase of the so called "ephemeral" lights in the vicinity of the damaged areas. These are caused by the affected population that relocates in open areas lighting bonfires to cook and to keep warm or in temporary camps suitably equipped. The geospatial location of these areas of ephemeral lights is important information for first responders to provide assistance to the affected population in the areas they are relocated to. Therefore, a methodology is needed to process nightlights imagery in the most suitable way to highlight the areas of both damage and relocation.

A couple of examples of the results obtainable using night-time images are provided. In detail, such examples regard the monitoring of civilian population movement during the Israel-Lebanon 2006 military crisis and after the Kashmir earthquake of October 2005. Preprocessing needs are discussed in detail, with a comparison of different noise filtering and image registration techniques. Overall results and recommendations for radiometric and geometric pre-processing of DMSP/OLS imagery are provided, along with a quantitative assessment of the populations involved their and movement. The results have been validated by using high-resolution images and are supported by extensive collateral data.

The analysis carried out in the paper is based on time series of OLS night-time images. These images are characterized by a spatial resolution of 1.0 km. According to [1] and [2] this sensor is able to detect radiance level as low as 1.54 10^{-9} [W/cm^2/sr/μm] and up to 3.17 10^{-7}. In terms of luminance this means that the sensor is able to detect two unshielded 250 W lamps with 125 lm/W efficiency, placed every square kilometre ([2]). This permits the detection of very faintly illuminated clouds, while city lights, gas flares and fires can be mapped in cloud-free areas ([3]).

In order to estimate in an early way the population impacted by a catastrophic event we can follow, in principle, the following approach: if a global population density map (like LandScan) is available the amount of people affected by an event can be computed simply multiplying the pixels, where a strong decreasing of the detected light is measured, for the corresponding population density.

In the past researchers have based their analyses on the relative frequency of saturated pixel counts over long OLS time series ([3]), or on the correlation between the areal extent of stable saturated lights and population estimates for individual cities ([4]). Both these approaches rely on stable light sources integrated over long time periods, and on *de jure* population as recorded in censual records rather than *de facto* population. Detecting fleeing population during a security crisis requires being able to track small radiance variations over short periods of time (in the order of days). The emphasis must therefore be placed on (1) detecting ephemeral light sources, as possible indicators of displaced population, and on (2) tracking changes in the areal extent of stable lights where damage has occurred.

However, important limitations of OLS may diminish its usability. In fact, in addition to its coarse resolution and low pixel-depth, OLS presents the following problems/limitations:

1. Blooming: it consists in an overestimation of the actual size of the human settlements due to the OLS capabilities to detect sub-pixel light source.
2. Registration: subsequent scenes on a time series often present an offset, or a displacement of a few pixels. The lack of recognizable features in nighttime data prevents traditional image registration approaches.
3. Cloud cover: causing deleterious reflections and obscuring ground features.

4. Variable gain settings: Gain adjustments to maintain constant cloud reflectance through time causes changes in OLS DN output between sensors and within sensor, and result in saturated urban areas.
5. Variable moon illumination contribution.

It is worthwhile to note that, in principle, analysing a time series of night-time images on an area affected by a disaster, we expect to observe:

- a reduction of lights immediately after the event,
- a displacement of lights some time after the event, as new settlements are established.

Emphasis has been placed on the development of a simple and rapid way of obtaining results that could be used to support first responders to know exactly where the areas of damage are located and where to assist the affected population. This information is important to allocate the limited human and physical resources quickly and effectively after a natural disaster such as an earthquake.

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POPULATION DENSITY ESTIMATIONS AND SETTLEMENT LOCATION ESTIMATIONS USING SRTM AND TM DATA

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Remote sensing and security, terms which are not usually associated, have found a common platform this decade with the conjuring of the GMOSS network (*Global Monitoring for Security and Stability*), whose mandate is to discover new applications for satellite-derived imagery to security issues. This study focuses on the population risk aspect of security, concentrating on the characterisation of vulnerable areas to conflict. A time-series of satellite imagery taken from Landsat sensors from 1987 to 2001 and the SRTM mission imagery are used for this purpose over a site in northern Iraq.

Security issues include the exposure to any type of hazard. The region of study is first characterised in order to understand which hazards are and were present in the past for the region of study. This is done through historical research and the study of open-sourced information about disease outbreaks; the movements of refugees and the internally displaced; and humanitarian aid and security issues. These open sources offer information which are not always consistent, objective, or normalized and are therefore difficult to quantify. A method for the rapid mapping and graphing and subsequent analysis of the situation in a region where limited information is available is developed.

The principal hazard for the region of study is armed conflict and the relative field data was analysed to determine the links between geographical indicators and vulnerable areas. This information is coupled with population numbers to create a “risk map”: A disaggregated matrix of areas most at risk during conflict situations. The results show that describing the risk factor for a population to the hazard conflict depends on three complex indicators: Population density, remoteness and economic diversity.

Each of these complex indicators is then derived from Landsat and SRTM imagery and a satellite-driven model is formulated. This model based on satellite imagery is applied to the study site for a temporal study. The output are three 90m × 90m resolution grids which describe, at a pixel level, the risk level within the region for each of the dates studies, and the changes which occur in northern Iraq as the result of the Anfal Campaigns.

Results show that satellite imagery, with a minimum of processing, can yield indicators for characterising risk in a region. Although by no means an adequate replacement for field data, this technological source, in the absence of local knowledge, can provide users with a starting point in understanding which areas are most at risk within a region. If this data is coupled with open sourced information such as political and cultural discrimination, economy and agricultural practices, a fairly accurate risk map can be generated in the absence of field data.

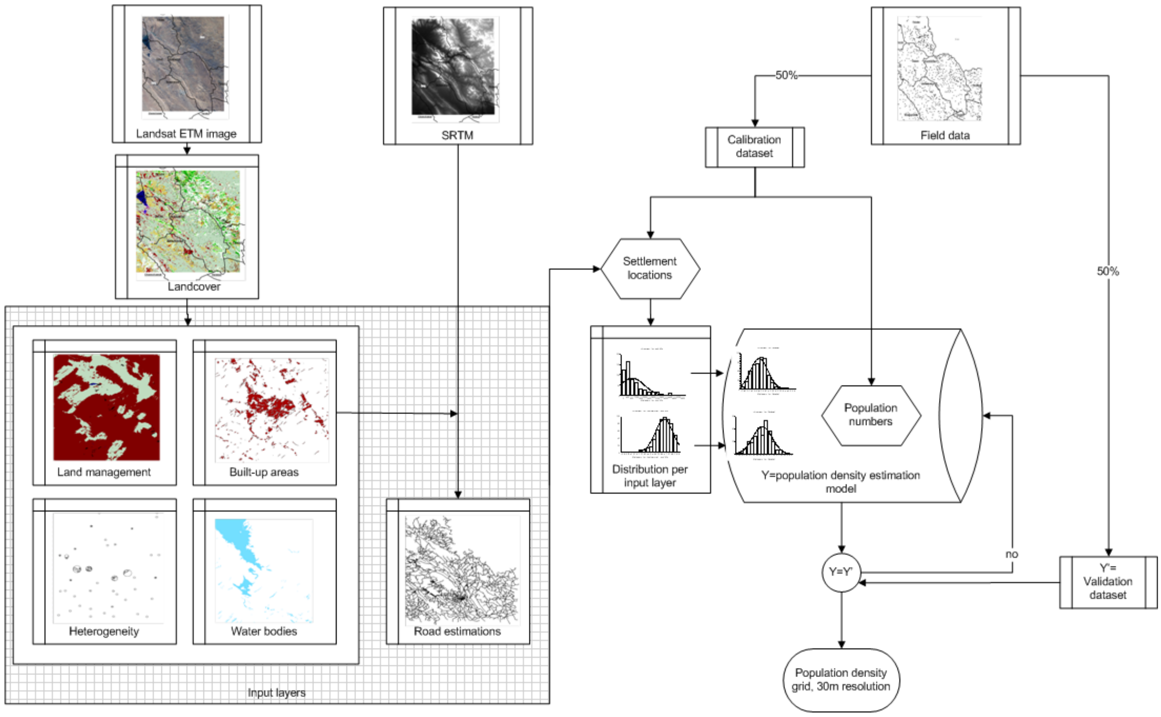

Figure 1: Population density and settlement location estimations

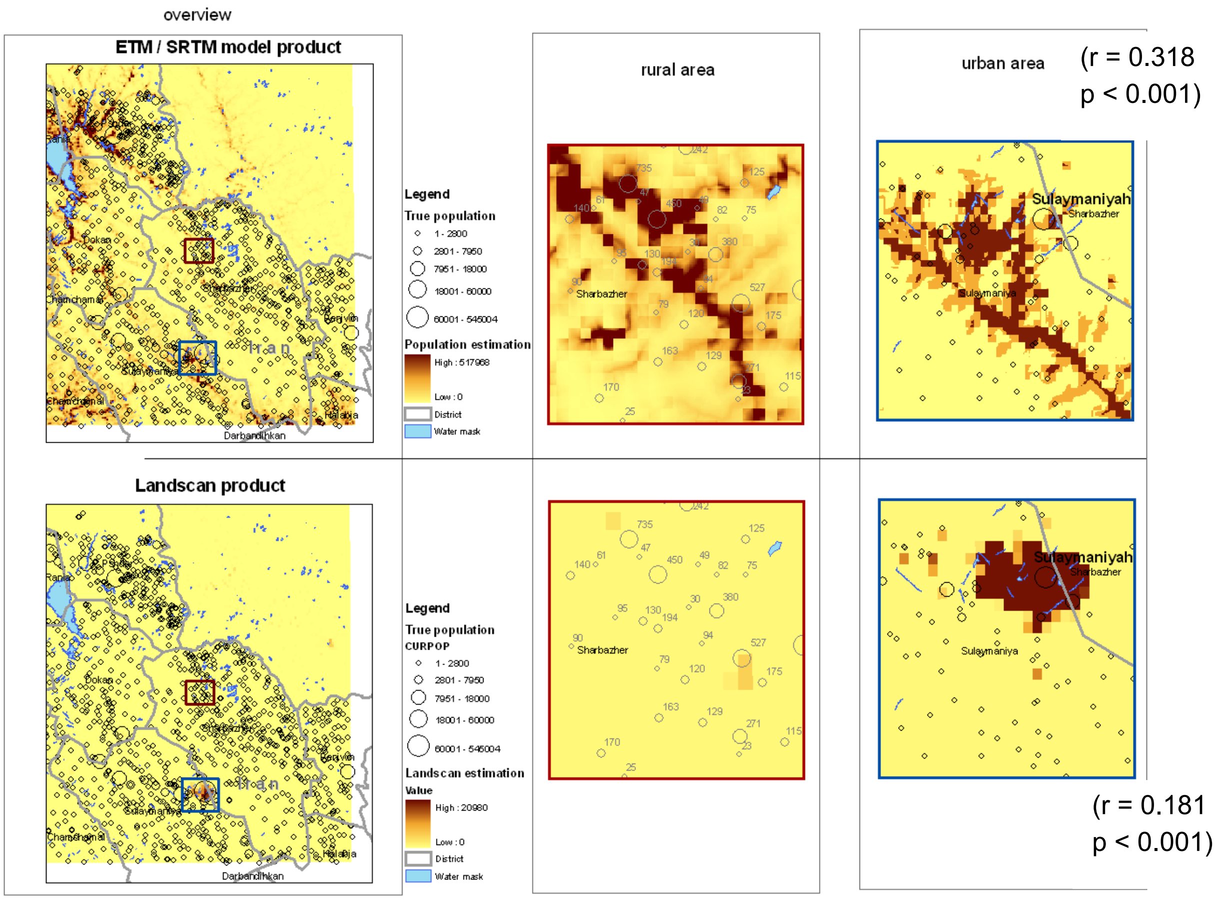

Figure 2: The resulting population density grid derived from Landsat ETM and SRTM data, compared with the Landscan product. Both a rural and an urban subset are shown.

Posters

3D CHANGE DETECTION FROM QUICKBIRD STEREO PAIRS OF A NUCLEAR FACILITY

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Coarse 3D models of cities can be derived with high resolution stereo data from space (e.g. IKONOS, QuickBird). Especially if the two images of the stereo pairs are taken from the same orbit (within a few minutes from different positions in the orbit), the possibilities to achieve good digital surface models (DSM) is enhanced because of the very similar illumination conditions. But with the large stereo angles of standard QuickBird stereo pairs, fully automatic methods for the derivation of building shapes don't show a good quality especially in images with low contrast. Therefore a method has been developed which uses manually measured tie-lines at building edges in addition to the tie point generation through the automatic matching process. This shows very improved results of the DSM for buildings in comparison to the DSM calculated from the purely automatic process. This method is applied to the stereo image data of the nuclear facility in Esfahan, Iran. A classification of the buildings on the basis of the maximum height is shown. For a procedure of 3D change detection, based on digital surface models, at least two stereo data sets are necessary. The result of the comparison of two DSM from different dates (June 2004 and December 2005) for a region near the same nuclear facility is shown. Also underground activities can be monitored by this method through the quantitative analysis of the dumping of material from the excavations, which results in volume changes of the DSM above ground near the excavation area (dump site).

Global Monitoring for Security and Stability

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

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3D Change Detection for Security
GMOSS WP 20300

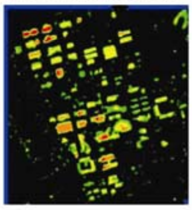
Nuclear Facility Esfahan, Iran
Building Heights using manual addition of points and lines

The automatic extraction of building shapes in low contrast stereo images with large covergence angles is a difficult task. With the introduction of tie lines this job can be fast and easily improved.

1,158,863 tie points from automatic matching (subarea)

1,158,863 tie points from automatic matching + manual measurements: 1300 points → 923 lines → 16865 tie points (15565 artificial tie points on lines)

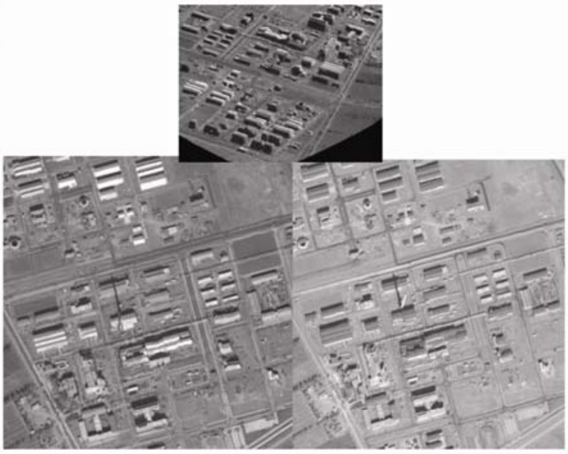
Building Heights
DSM accuracy



The accuracy of the derived building heights can be controlled through comparison of the single heights measured at the building edges. For these points a RMSE value of below 1 meter could be derived for a high number of buildings.

Generation of orthoimages and 3D views

After relative correction of RPC (using mean residuals from forward intersection) orthoimages fitting to the DSM and perspective views can be generated.



3D Change Detection, Esfahan (Iran)
Subsurface construction of nuclear facilities

Excavation between 6/04-12/05:
Excavation Volume: 103 000 cubic meter
Equivalent to a room-size: 7 football fields, 3 m high

Two images of different dates and combination of Orthoimage (green) and difference of two Digital surface models (red)

Through the comparison of DSM derived from two stereo data sets from space borne sensors, the volume of a dump or excavation site can be measured quantitatively.

http://gmoss.jrc.it

GMOSS is a network of excellence in the aeronautics and space priority of the Sixth Framework Programme funded by the European Commission's Directorate General Enterprise & Industry

DEM GENERATION FOR TEST CASE BAGHDAD

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High resolution satellites of newest generation like Ikonos or QuickBird allow the extraction of high resolution digital elevation models (DEM) from stereo image pairs. In the presented poster different DEMs are generated from a stereo scene of the test case Baghdad. For the DEM generation three methods are used: a method based on a classical hierarchical matching approach and two stereo epipolar methods, namely dynamic line warping and semi global matching, both developed at DLR. The resulting DEMs from these methods are presented and compared. Such high resolution 3D representations are necessary to derive a couple of interesting parameters for population and security appliances. High resolution DEMs are for example mandatory for the generation of true otho photos which are in turn necessary for change detection algorithms in the case of high resolution imagery. Also 3D change detection or volume estimation and derived from this population estimation can be deduced from good high resolution DEMs. Unfortunately all algorithms generate too much blunder in deriving DEMs of the same resolution as the source satellite images. A rule of thumb originating from aerial photography and stereo processing show that good DEMs derived from stereo images have a resolution of about one fourth of the original image resolution – 16 image pixels per DEM pixel.

Global Monitoring for Security and Stability

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

DEM generation for test case Baghdad

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GMOSS Integration Meeting, Den Haag, 16.-18.04.2007

DSM (digital surface model) generated from testcase data PAN stereo pair

Ikonos Stereo scene from Bagdad (po_2235045_0000010000, PAN)
Left and right images 2005-12-17, 08:01:26.4 and 08:00:14.2 (GMT)
Sun angles: azimuth 164.3°/164.0°, elevation 31.9°/31.8°
Collection angles: azimuth 200.2°/8.5°, elevation 72.3° /63.4°
Cloud cover: 0 %
Corner-coordinates (lat/long): 33.24°/44.32°, 33.31°/44.34°, 33.28°/44.46°, 33.21°/44.44°

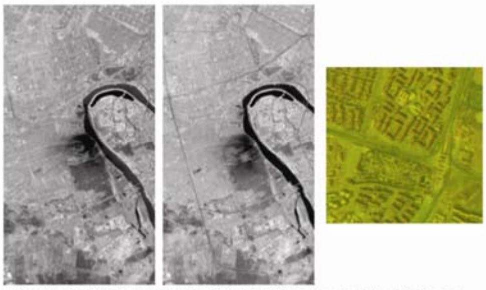


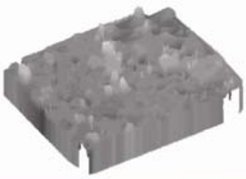
Figure 1: Stereo pair, left/right image and red/green composit of test area (800 m × 800 m)

3 DSM generation methods used:

- classical area based hierarchical matching developed for line scanner data from MOMS at DLR (coarse ground resolution of about 18 m)
- Dense stereo epipolar „dynamic line warping"
- Dense stereo epipolar „semi global matching"
- Tests with a small section

Figure 2: Test area, 3 methods, 4 parameter sets

Area based matching failed due to large convergence angle of 44.3°, steep walls and many occlusions



Remaining methods, both based on epipolar images for creating dense stereo DSMs by line wise matching using small correlation windows

Dynamic line warping:
- Fast (3.5 h) for 12000×8000 px²
- Line streaking effects
- Blunders at vegetation/water

Semi global matching
- Slow (18 h) for 12000×8000 px²
- No line streaking
- Smaller blunders

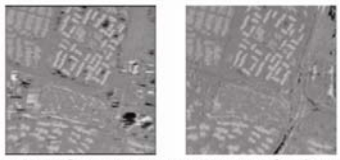


Figure 3: DSMs from test area generated using dynamic line warping (left) and semi global matching (right)

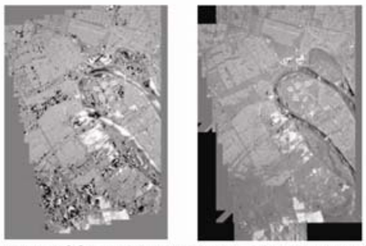
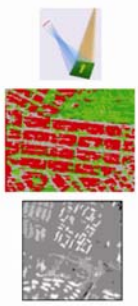


Figure 4: Resulting DSMs 8100×11700 px², TIFF, left dynamic line warping, right semi global matching

Outlook:

- Absolute geo referencing and transformation to object space using delivered RPCs and generated DSM
- Determining DTM (digital terrain model – ground)
- Fusion with multispectral data/ortho image generation
- Classification and extraction of buildings and vegetation
- Automatic characterisation and counting of industry/ dwelling units



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GMOSS PROGRAMME SUMMARY FOR INTEGRATING WORKPACKAGES: STANDARDS; DATA SHARING AND INFRASTRUCTURE

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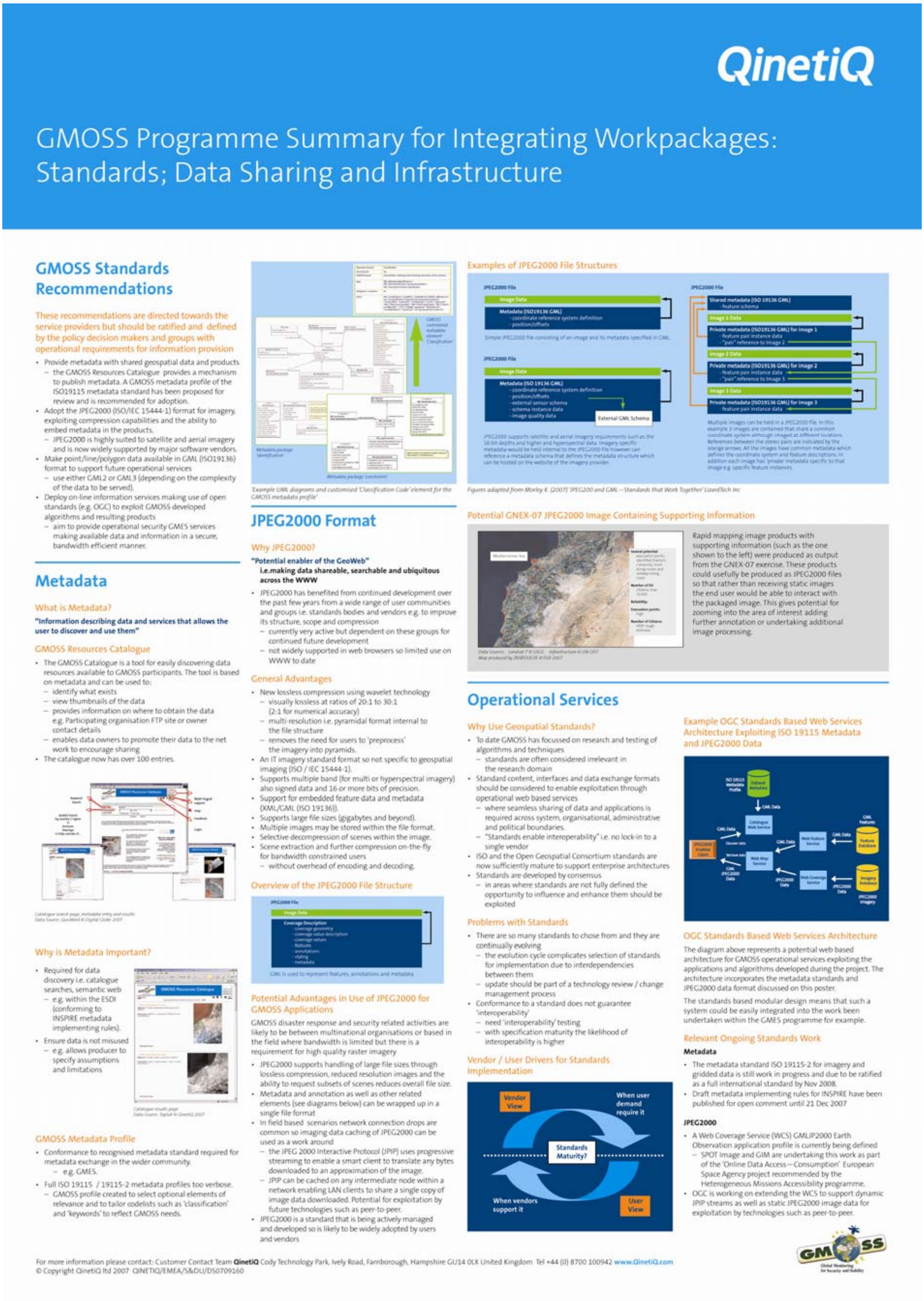
Poster Abstract GMOSS Programme Summary for Integrating Workpackages: Standards; Data Sharing and Infrastructure The poster provides a summary of some of the work undertaken in the WP10300 Standards and WP10400 Data Sharing and Infrastructure. The recommendations are directed towards the services providers but should be ratified and defined by the policy decision makers and groups with operational requirements for information provision. Information is provided on the work conducted regarding metadata in terms of the provision of a geospatial standards based online data catalogue and the definition of a GMOSS profile conforming to the ISO 19115 standard. Technical details of JPEG2000 are presented as a potentially suitable standard data exchange format which could be used for GMOSS type activities due to features such as its lossless compression, support for embedded feature and metadata in XML/GML, subset extraction for bandwidth constrained users. Finally a summary on the use of geospatial standards for operational services is given.



QinetiQ

GMOSS Programme Summary for Integrating Workpackages: Standards; Data Sharing and Infrastructure

GMOSS Standards Recommendations

These recommendations are directed towards the service providers but should be ratified and defined by the policy decision makers and groups with operational requirements for information provision

- Provide metadata with shared geospatial data and products
  - the GMOSS Resources Catalogue provides a mechanism to publish metadata. A GMOSS metadata profile of the ISO19115 metadata standard has been proposed for review and is recommended for adoption.
- Adopt the JPEG2000 (ISO/IEC 15444-1) format for imagery, exploiting compression capabilities and the ability to embed metadata in the products.
  - JPEG2000 is highly suited to satellite and aerial imagery and is now widely supported by major software vendors.
- Make point/line/polygon data available in GML (ISO19136) format to support future operational services
  - use either GML2 or GML3 (depending on the complexity of the data to be served).
- Deploy on-line information services making use of open standards (e.g. OGC) to exploit GMOSS developed algorithms and resulting products
  - aim to provide operational security GMES services making available data and information in a secure, bandwidth efficient manner.

Metadata

What is Metadata?

"Information describing data and services that allows the user to discover and use them"

GMOSS Resources Catalogue

- The GMOSS Catalogue is a tool for easily discovering data resources available to GMOSS participants. The tool is based on metadata and can be used to:
  - identify what exists
  - view thumbnails of the data
  - provides information on where to obtain the data e.g. Participating organisation FTP site or owner contact details
  - enables data owners to promote their data to the net work to encourage sharing
- The catalogue now has over 100 entries.

Why is Metadata Important?

- Required for data discovery i.e. catalogue searches, semantic web
  - e.g. within the ESDI (conforming to INSPIRE metadata implementing rules).
- Ensure data is not misused
  - e.g. allows producer to specify assumptions and limitations

GMOSS Metadata Profile

- Conformance to recognised metadata standard required for metadata exchange in the wider community.
  - e.g. GMES.
- Full ISO 19115 / 19115-2 metadata profiles too verbose.
  - GMOSS profile created to select optional elements of relevance and to tailor codelists such as 'classification' and 'keywords' to reflect GMOSS needs.

'Example UML diagrams and customised 'Classification Code' element for the GMOSS metadata profile'

JPEG2000 Format

Why JPEG2000?

"Potential enabler of the GeoWeb"
i.e.making data shareable, searchable and ubiquitous across the WWW

- JPEG2000 has benefited from continued development over the past few years from a wide range of user communities and groups i.e. standards bodies and vendors e.g. to improve its structure, scope and compression
  - currently very active but dependent on these groups for continued future development
  - not widely supported in web browsers so limited use on WWW to date

General Advantages

- New lossless compression using wavelet technology
  - visually lossless at ratios of 20:1 to 30:1 (2:1 for numerical accuracy)
  - multi-resolution i.e. pyramidal format internal to the file structure
  - removes the need for users to 'preprocess' the imagery into pyramids.
- An IT imagery standard format so not specific to geospatial imaging (ISO / IEC 15444-1).
- Supports multiple band (for multi or hyperspectral imagery) also signed data and 16 or more bits of precision.
- Support for embedded feature data and metadata (XML/GML (ISO 19136)).
- Supports large file sizes (gigabytes and beyond).
- Multiple images may be stored within the file format.
- Selective decompression of scenes within the image.
- Scene extraction and further compression on-the-fly for bandwidth constrained users
  - without overhead of encoding and decoding.

Overview of the JPEG2000 File Structure

Potential Advantages in Use of JPEG2000 for GMOSS Applications

GMOSS disaster response and security related activities are likely to be between multinational organisations or based in the field where bandwidth is limited but there is a requirement for high quality raster imagery

- JPEG2000 supports handling of large file sizes through lossless compression, reduced resolution images and the ability to request subsets of scenes reduces overall file size.
- Metadata and annotation as well as other related elements (see diagrams below) can be wrapped up in a single file format
- In field based scenarios network connection drops are common so imaging data caching of JPEG2000 can be used as a work around
  - the JPEG 2000 Interactive Protocol (JPIP) uses progressive streaming to enable a smart client to translate any bytes downloaded to an approximation of the image.
  - JPIP can be cached on any intermediate node within a network enabling LAN clients to share a single copy of image data downloaded. Potential for exploitation by future technologies such as peer-to-peer.
- JPEG2000 is a standard that is being actively managed and developed so is likely to be widely adopted by users and vendors

Examples of JPEG2000 File Structures

JPEG2000 File
Image Data
Metadata (ISO19136 GML) - coordinate reference system definition - position/offsets

Simple JPEG2000 file consisting of an image and its metadata specified in GML

JPEG2000 File
Image Data
Metadata (ISO 19136 GML) - coordinate reference system definition - position/offsets - external sensor schema - schema instance data - image quality data
External GML Schema

JPEG2000 supports satellite and aerial imagery requirements such as the 16 bit depths and higher and hyperspectral data. Imagery specific metadata would be held internal to the JPEG2000 file however can reference a metadata schema that defines the metadata structure which can be hosted on the website of the imagery provider.

JPEG2000 File
Shared metadata (ISO 19136 GML) - feature schema
Image 1 Data
Private metadata (ISO19136 GML) for image 1 - feature pair instance data - "pair" reference to image 2
Image 2 Data
Private metadata (ISO19136 GML) for image 2 - feature pair instance data - "pair" reference to image 3
Image 3 Data
Private metadata (ISO19136 GML) for image 3 - feature pair instance data

Multiple images can be held in a JPEG2000 file. In this example 3 images are contained that share a common coordinate system although imaged at different locations. References between the stereo pairs are indicated by the orange arrows. All the images have common metadata which defines the coordinate system and feature descriptions. In addition each image has 'private' metadata specific to that image e.g. specific feature instances.

Figures adapted from Morley K. (2007) 'JPEG200 and GML – Standards that Work Together' LizardTech Inc

Potential GNEX-07 JPEG2000 Image Containing Supporting Information

Rapid mapping image products with supporting information (such as the one shown to the left) were produced as output from the GNEX-07 exercise. These products could usefully be produced as JPEG2000 files so that rather than receiving static images the end user would be able to interact with the packaged image. This gives potential for zooming into the area of interest adding further annotation or undertaking additional image processing.

Operational Services

Why Use Geospatial Standards?

- To date GMOSS has focussed on research and testing of algorithms and techniques
  - standards are often considered irrelevant in the research domain
- Standard content, interfaces and data exchange formats should be considered to enable exploitation through operational web based services
  - where seamless sharing of data and applications is required across system, organisational, administrative and political boundaries.
  - "Standards enable interoperability" i.e. no lock-in to a single vendor
- ISO and the Open Geospatial Consortium standards are now sufficiently mature to support enterprise architectures
- Standards are developed by consensus
  - in areas where standards are not fully defined the opportunity to influence and enhance them should be exploited

Problems with Standards

- There are so many standards to chose from and they are continually evolving
  - the evolution cycle complicates selection of standards for implementation due to interdependencies between them
  - update should be part of a technology review / change management process
- Conformance to a standard does not guarantee 'interoperability'
  - need 'interoperability' testing
  - with specification maturity the likelihood of interoperability is higher

Vendor / User Drivers for Standards Implementation

Vendor View
When user demand require it
Standards Maturity?
When vendors support it
User View

Example OGC Standards Based Web Services Architecture Exploiting ISO 19115 Metadata and JPEG2000 Data

OGC Standards Based Web Services Architecture

The diagram above represents a potential web based architecture for GMOSS operational services exploiting the applications and algorithms developed during the project. The architecture incorporates the metadata standards and JPEG2000 data format discussed on this poster.

The standards based modular design means that such a system could be easily integrated into the work been undertaken within the GMES programme for example.

Relevant Ongoing Standards Work

Metadata

- The metadata standard ISO 19115-2 for imagery and gridded data is still work in progress and due to be ratified as a full international standard by Nov 2008.
- Draft metadata implementing rules for INSPIRE have been published for open comment until 21 Dec 2007

JPEG2000

- A Web Coverage Service (WCS) GMLJP2000 Earth Observation application profile is currently being defined
  - SPOT Image and GIM are undertaking this work as part of the 'Online Data Access – Consumption' European Space Agency project recommended by the Heterogeneous Missions Accessibility programme.
- OGC is working on extending the WCS to support dynamic JPIP streams as well as static JPEG2000 image data for exploitation by technologies such as peer-to-peer.

For more information please contact: Customer Contact Team **QinetiQ** Cody Technology Park, Ively Road, Farnborough, Hampshire GU14 0LX United Kingdom Tel +44 (0) 8700 100942 www.QinetiQ.com

THE IRAN TEST CASE: MONITORING OF THE IRANIAN NUCLEAR PROGRAMME

Irmgard Niemeyer

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Institut für Markscheidewesen und Geodäsie, D-09599 Freiberg, Germany

Is the Iran developing nuclear weapons? The test case on the Iran investigated whether satellite imagery analysis could give answers to this question. International Atomic Energy Agency (IAEA) inspections since 2003 have revealed two decades' worth of undeclared nuclear activities in Iran, including uranium enrichment and plutonium separation efforts. The aim of the was to monitor the development of some relevant sites in the Iran: Arak, Bushehr, Esfahan, Natanz and Saghand. In particular it was investigated - which kind of significant features of nuclear facilities / activities / processes are identifiable from space, - how these signature could be utilised for image analysis (visual interpretation / semantic modelling). Different pre-processing, change detection, classification and visualisation techniques were applied to multispectral, radar, and hyperspectral satellite imagery, such as QuickBird, ASTER, Radarsat and HYPERION.

Global Monitoring for Security and Stability

Co-Ordination:
Freiberg University of Mining and Technology

Test Case "Iran"

Context:

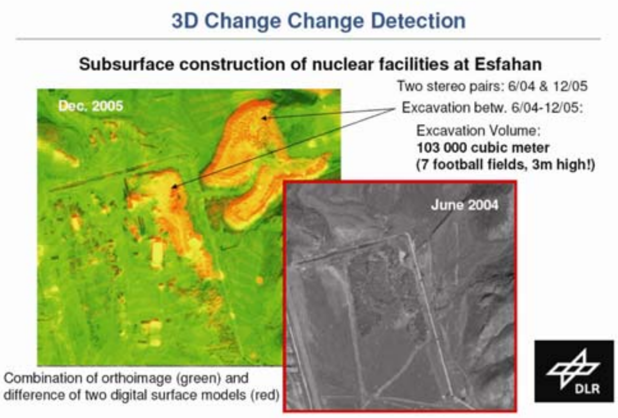
Is the Iran developing nuclear weapons? The test case on the Iran investigated whether satellite imagery analysis could give answers to this question.

Work done:

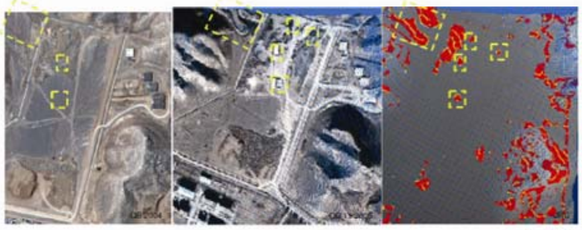
Different pre-processing, change detection, classification and visualisation techniques were applied to radar, multispectral, hyperspectral satellite imagery. The aim was to monitor the development of some relevant sites in the Iran: Arak, Bushehr, Esfahan, Natanz and Saghand.

Conclusions:

Remote sensing data ranging from the visible to the microwave region of the electromagnetic spectrum could provide nuclear safeguards-relevant information. Change detection algorithms are essential for wide-area monitoring and detailed detection of small-scale infrastructure. However, the sensor characteristics still restrict the application of satellite imagery analysis for verifying the Treaty compliance. Moreover, robustness, accuracy and false alarm rate of procedures still have to be improved before becoming operational.



Esfahan



EUROPEAN COMMISSION
Joint Research Centre

http://gmoss.jrc.it

GMOSS is a network of excellence in the aeronautics and space priority of the Sixth Framework Programme funded by the European Commission's Directorate General Enterprise & Industry

TREATY MONITORING USING SATELLITE IMAGERY: LESSONS LEARNED IN GMOSS

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The poster will highlight on: - Earth observation policies and data availability; - parameters measurable from space for verification purposes - digital image processing vs. visual interpretation - integration within relevant models - confidence building, improvement of openness and transparency - verification responsibilities and capacities.

GMOSS
Global Monitoring for Security and Stability
Challenges in Treaty Monitoring using Satellite Imagery
BERGAKADEMIE TECHNISCHE UNIVERSITÄT FREIBERG
Introduction
In the absence of "ground truth", commercial satellite imagery provides one of the few opportunities to gather "real" information.
satellite image data
comparable
remotely
verifiable
continuously
spectral resolution
political restrictions / "shutter control"
financial budget
technical limitations
availability of data
spatial resolution
temporal resolution / revisit cycle
• In the last decades, the international community has signed several international treaties.
• These multilateral agreements oblige parties, directly or indirectly and at different extent, to implement procedures for monitoring and assessing the environment on a regular basis and report about their effort to combat environmental degradation.
• Different Conventions imply different obligations and implementation practices for the parties.
• However, Earth Observation (EO) generally represents a key source of information for the different national and international bodies involved in the implementation of Environmental Treaties.
• EO technology may provide a significant contribution to achieving the objectives of multilateral environmental agreements:
- Increasing scientific and technical knowledge about the environment.
- Supporting the efficient management of environmental problems.
- Contributing to improve the performance of the Convention.
[Arino et al. 2003]
Multilateral Environmental Agreements (MEA)
• World Summit on Sustainable Development (WSSD), 2002
• Agenda 21 and UN Commission for Sustainable Development, 1992
• UN Framework Convention on Climate Change (UNFCCC), 1992
• Kyoto Protocol, 1997
• UN Convention to Combat Desertification (CCD), 1992
• United Nations Convention on Biological Diversity (CBD), 1992
• Montreal Protocol and Vienna Convention on Protection of the Ozone Layer, 1987
• UN Convention on the Law of the Sea, 1982
• Convention on Long-Range Transboundary Air Pollution (CLRTAP), 1979
• International Convention for the Prevention of Pollution from Ships (MARPOL), 1973
[Aschbacher 2002]
Arms Control and Non-Proliferation Treaties
Multilateral and intended to coverall States:
• Treaty on the Non-Proliferation of Nuclear Weapons (NPT)
• Conventions on Biological Weapons (BWC)
• Conventions on Chemical Weapons (CWC)
• Comprehensive Nuclear Test Ban Treaty (CTBT)
Applicable to a particular region:
• Conventional Forces in Europe Treaty (CFE)
• Open Skies Treaty
• Antarctic Treaty
• Treaty of Tlatelolco
• other nuclear weapon-free zone treaties
Bilateral at origin:
• Intermediate Nuclear Forces Treaty (INF)
• Strategic Arms Reduction Treaty (START)
Parameters measurable from space for verification purposes
Application of Satellite Imagery for NPT Verification
1. Verification of Member States declarations (Correctness?)
• Changes of infrastructure, changes of the operational status within the facility.
• Imagery: optical & SAR (very high resolution), thermal infrared.
2. Verification of Member States declarations (Completeness? Undeclared activities?)
• Changes of infrastructure, changes of the operational status within the facility, in the neighborhood areas, in any area of interest.
• Imagery: optical, (very high, high & medium resolution), SAR (very high resolution), thermal infrared, hyperspectral.
3. Preparatory information for
• Overview of the facility and the neighborhood areas.
• Imagery: optical (very high, high & medium resolution), SAR (very high resolution).
Application of Satellite Imagery for CTBT Verification
• Monitoring technologies: Seismology, Hydroacoustics, Infrasound or Radionuclide
• Remote sensing data can support the analysis
→ integrated approach combining geophysical measurements, such as seismic recordings, and satellite imagery analysis, for example optical change detection or SAR interferometry.
CTBTO
IAEA
[http://www.ctbto.org]
[http://www.iaea.org]
Monitoring the Kyoto Protocol
Remote sensing technology could be applied to support implementation of the treaty in the following areas:
• provision of systematic observations of relevant land cover (Articles 5 and 10);
• support to the establishment of a 1990 carbon stock baseline (Article 3);
• detection and spatial quantification of change in land cover (Articles 3 and 12);
• quantification of above-ground vegetation biomass stocks and associated changes therein (Articles 3 and 12);
• mapping and monitoring of certain sources of anthropogenic CH4 (Articles 3, 5 and 10);
[Rosenquist et al. 2003]
Earth Observation Policies: Open Space?
Is the space an "open space"?
• Following the launch of the first civilian remote sensing satellite in 1972 some developing countries demanded a special regime in 1978.
• Remote sensing satellites make it possible to gather information on mineral resources, weather and climatic changes, as well as resources management.
• The Principles Relating to Remote Sensing of the Earth from Space which were adopted in a UN resolution in 1986 confirm the unrestricted right to remote sensing without prior consent or notification.
• In return, the state subject to remote sensing has access to the data on a non-discriminatory basis and at a reasonable price. The principles do not apply to military reconnaissance.
National operators:
• Four privately funded systems in orbit: US (3), Israel (1)
• Operation/development of very high-resolution optical and high-resolution SAR satellites by national space agencies, partly as Public-Private-Partnerships: Canada, France, Germany, Italy, India, Russia, South Korea
Dual use (military/civil):
• Example: The planned European satellites are part of the EU/ESA-funded initiative "Global Monitoring for Environment and Security" (GMES). How the data will be shared between military and civil users, has not been revealed.
Shutter control:
• Satellite image data is freely available in general, unless the national security is at risk.
• Example: Satellite imagery over Israel is restricted to 2m resolution.
Priority costumers:
• Example: The U.S. exclusively bought all imagery acquired over Afghanistan during the war of 2001 as a priority costumer.
Imagery costs:
• Very high-resolution optical imagery, e.g. Ikonos
geo-rectified products: 16 - 27.5 US-$ / km²
ortho-rectified products: 27,5 - +55 US-$ / km²
stereo pair: 80 - 100 US-$ / km²
priority tasking with acquisition window of 1-7 days : plus 70%
minimum order size: 100 km² (new), 49 km² (archive)
• High-resolution SAR imagery, e.g. TerraSAR-X: appr. 8.000 EUR for a 10x10 km scene in spotlight mode
• Multi-user licenses necessary (with higher costs, e.g. Ikonos +15%)
Acquisition schedule, data access time:
• Quantity buyers, such as international organisations or national agencies, may have the possibility to place a special agreement with the data providers, including data access from the database archive or on-demand acquisition within a few days after order placement.
Digital image processing vs. visual interpretation
Importance of digital image pre-processing
Geometric correction
• (Automatic) image-to-image registration
• Georeferencing
Radiometric correction
• Atmospheric modelling
• Radiometric normalisation
Pan-sharpening / image fusion
Noise reduction
• Speckle filter
• MNF transformation
Example: Semantic classification of changes
• processing time
• signatures identifiable in satellite imagery
• semantic modelling
• accuracy vs. automation
• transferability of models/techniques
(Credit: DigitalGlobe)
[Nussbaum & Niemeyer 2007]
Integration within relevant models
International Data Centre
11 May 1998 - Event in India
CTBTO
[Canty & Schlittenhardt 2001]
NPT Monitoring platform: GIS-based data integration
Partners:
• JRC (lead)
• EUSC
• Freiberg
• CEA
Land/Sea Integrated Monitoring for European Security (LIMES) - a GMES Integrated Project in the Aeronautics and Space Priority of the EU 6th Framework Program
LIMES
Confidence building, improvement of openness and transparency
2003
2005
[Nussbaum & Niemeyer 2007]
Credit: Spaceimaging
Construction of defences at Iran's enrichment facility at Natanz observed on Ikonos-2 image of 29 January 2004.
Example from the Air: Open Skies Treaty
• The Treaty on Open Skies entered into force on January 1, 2002, and currently has 30 States Parties.
• The treaty is designed to enhance mutual understanding and confidence by giving all participants, regardless of size, a direct role in gathering information about military forces and activities of concern to them.
• The Treaty establishes a regime of unarmed aerial observation flights over the entire territory of its participants.
• Open Skies is one of the most wide-ranging international efforts to date to promote openness and transparency of military forces and activities.
OPEN SKIES
[Dunay 2004]
Principles:
• improving openness and transparency
• supporting the verification of existing or future arms control agreements;
• strengthening the capacity for conflict prevention and crisis management.
• Right to observe any point on the territory of the states parties, imagery taken during flights is accessible to all state parties
• Cooperative elements; confidence building.
Verification responsibilities and capabilities
• Who has the "mandate" for verification? Competent authority?
• Is satellite imagery mentioned in the agreement as verification mean?
• Expertise for using EO data?
• Training, consultancy from scientific community?
References
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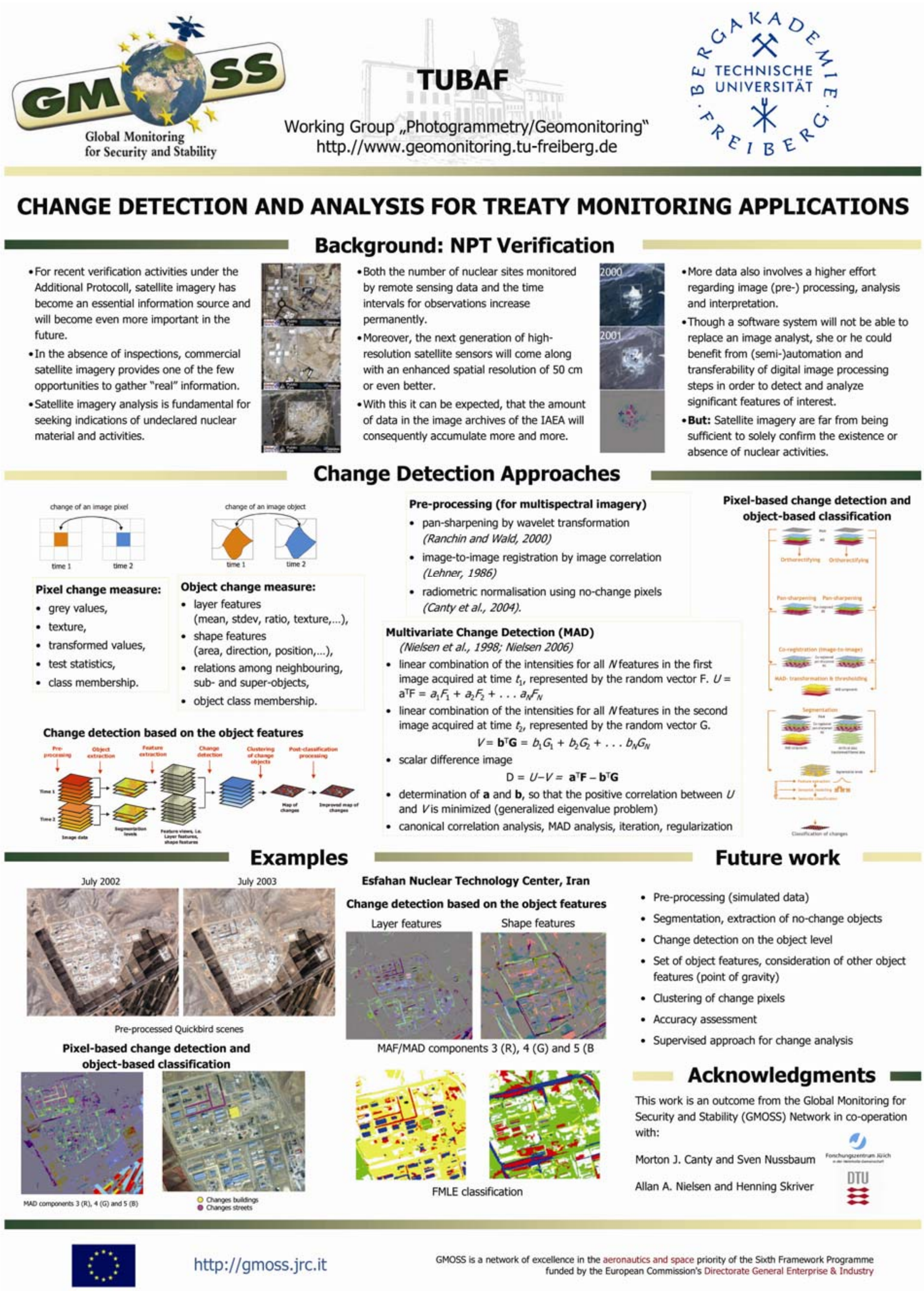
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Working Group „Photogrammetry/Geomonitoring"
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BERGAKADEMIE TECHNISCHE UNIVERSITÄT FREIBERG
CHANGE DETECTION AND ANALYSIS FOR TREATY MONITORING APPLICATIONS
Background: NPT Verification
• For recent verification activities under the Additional Protocoll, satellite imagery has become an essential information source and will become even more important in the future.
• In the absence of inspections, commercial satellite imagery provides one of the few opportunities to gather "real" information.
• Satellite imagery analysis is fundamental for seeking indications of undeclared nuclear material and activities.
• Both the number of nuclear sites monitored by remote sensing data and the time intervals for observations increase permanently.
• Moreover, the next generation of high-resolution satellite sensors will come along with an enhanced spatial resolution of 50 cm or even better.
• With this it can be expected, that the amount of data in the image archives of the IAEA will consequently accumulate more and more.
2000
2001
• More data also involves a higher effort regarding image (pre-) processing, analysis and interpretation.
• Though a software system will not be able to replace an image analyst, she or he could benefit from (semi-)automation and transferability of digital image processing steps in order to detect and analyze significant features of interest.
• But: Satellite imagery are far from being sufficient to solely confirm the existence or absence of nuclear activities.
Change Detection Approaches
change of an image pixel
time 1
time 2
change of an image object
time 1
time 2
Pixel change measure:
• grey values,
• texture,
• transformed values,
• test statistics,
• class membership.
Object change measure:
• layer features (mean, stdev, ratio, texture,...),
• shape features (area, direction, position,...),
• relations among neighbouring, sub- and super-objects,
• object class membership.
Change detection based on the object features
Pre-processing
Object extraction
Feature extraction
Change detection
Clustering of change objects
Post-classification processing
Time 1
Time 2
Image data
Segmentation levels
Feature views, i.e. Layer features, shape features
Map of changes
Improved map of changes
Pre-processing (for multispectral imagery)
• pan-sharpening by wavelet transformation (Ranchin and Wald, 2000)
• image-to-image registration by image correlation (Lehner, 1986)
• radiometric normalisation using no-change pixels (Canty et al., 2004).
Multivariate Change Detection (MAD)
(Nielsen et al., 1998; Nielsen 2006)
• linear combination of the intensities for all N features in the first image acquired at time t_1, represented by the random vector F. $U = \mathbf{a}^T\mathrm{F} = a_1F_1 + a_2F_2 + \ldots a_NF_N$
• linear combination of the intensities for all N features in the second image acquired at time t_2, represented by the random vector G.
$V = \mathbf{b}^T\mathbf{G} = b_1G_1 + b_2G_2 + \ldots b_NG_N$
• scalar difference image
$D = U - V = \mathbf{a}^T\mathbf{F} - \mathbf{b}^T\mathbf{G}$
• determination of a and b, so that the positive correlation between U and V is minimized (generalized eigenvalue problem)
• canonical correlation analysis, MAD analysis, iteration, regularization
Pixel-based change detection and object-based classification
Orthorectifying
Orthorectifying
Pan-sharpening
Pan-sharpening
Co-registration (image-to-image)
MAD- transformation & thresholding
Segmentation
Classification of changes
Examples
July 2002
July 2003
Pre-processed Quickbird scenes
Esfahan Nuclear Technology Center, Iran
Change detection based on the object features
Layer features
Shape features
MAF/MAD components 3 (R), 4 (G) and 5 (B
Pixel-based change detection and object-based classification
MAD components 3 (R), 4 (G) and 5 (B)
Changes buildings
Changes streets
FMLE classification
Future work
• Pre-processing (simulated data)
• Segmentation, extraction of no-change objects
• Change detection on the object level
• Set of object features, consideration of other object features (point of gravity)
• Clustering of change pixels
• Accuracy assessment
• Supervised approach for change analysis
Acknowledgments
This work is an outcome from the Global Monitoring for Security and Stability (GMOSS) Network in co-operation with:
Morton J. Canty and Sven Nussbaum
Forschungszentrum Jülich
Allan A. Nielsen and Henning Skriver
DTU
http://gmoss.jrc.it
GMOSS is a network of excellence in the aeronautics and space priority of the Sixth Framework Programme funded by the European Commission's Directorate General Enterprise & Industry

THERMAL IMAGING SPECTROSCOPY: INNOVATIVE TECHNOLOGY FOR DUAL USE APPLICATIONS

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Rapid advances in hyperspectral technologies have led to new sensors, which greatly improve our ability to gather information about distant objects without direct physical contact. While many of these sensors and technologies were designed for environmental monitoring and earth science, they may have important uses for security application and humanitarian aid missions. As the number and capabilities of these sensors continue to grow, the evaluation of their capabilities in a support to environment and security operations setting has become increasingly important. Because of its freedom from the restraint of solar illumination, TIR hyperspectral sensor may represent a step forward in the security support capabilities of hyperspectral sensors. This presentation summarises the results of a study, done in the frame of ESA's, and which set up requirement consolidation for future hyperspectral thermal infra-red imager mission devoted to dual "civil" (GMES applications) and "security" applications. In this survey we have found that by using hyperspectral sensor in the thermal infrared wavelengths we could large extend our knowledge and give usable tools to the following dual use application: volcanism (monitoring SO2 and lava flow), soil monitoring (mineral and organic matters composition), atmosphere (aerosol), environment (greenhouse gasses), risk management (pollutant gasses and oil spills), geology (silicate mineral composition) and security operational and surveillance support (target identification and mitigation). For the above application set, spectral, spatial, radiometrical and temporal requirements were summarised. Those requirements vary from high demands in all the domains for the military application to relatively low demands for atmospheric aerosols applications. The contents for the presentation are as follow: - Short introduction for hyperspectral; - Thermal hyperspectral: concepts, spectroradiometer, benefits; - GMES and GMOSS relevant applications; - TIR Hyperspectral application requirements; - Existing sensors: airborne, sensors.

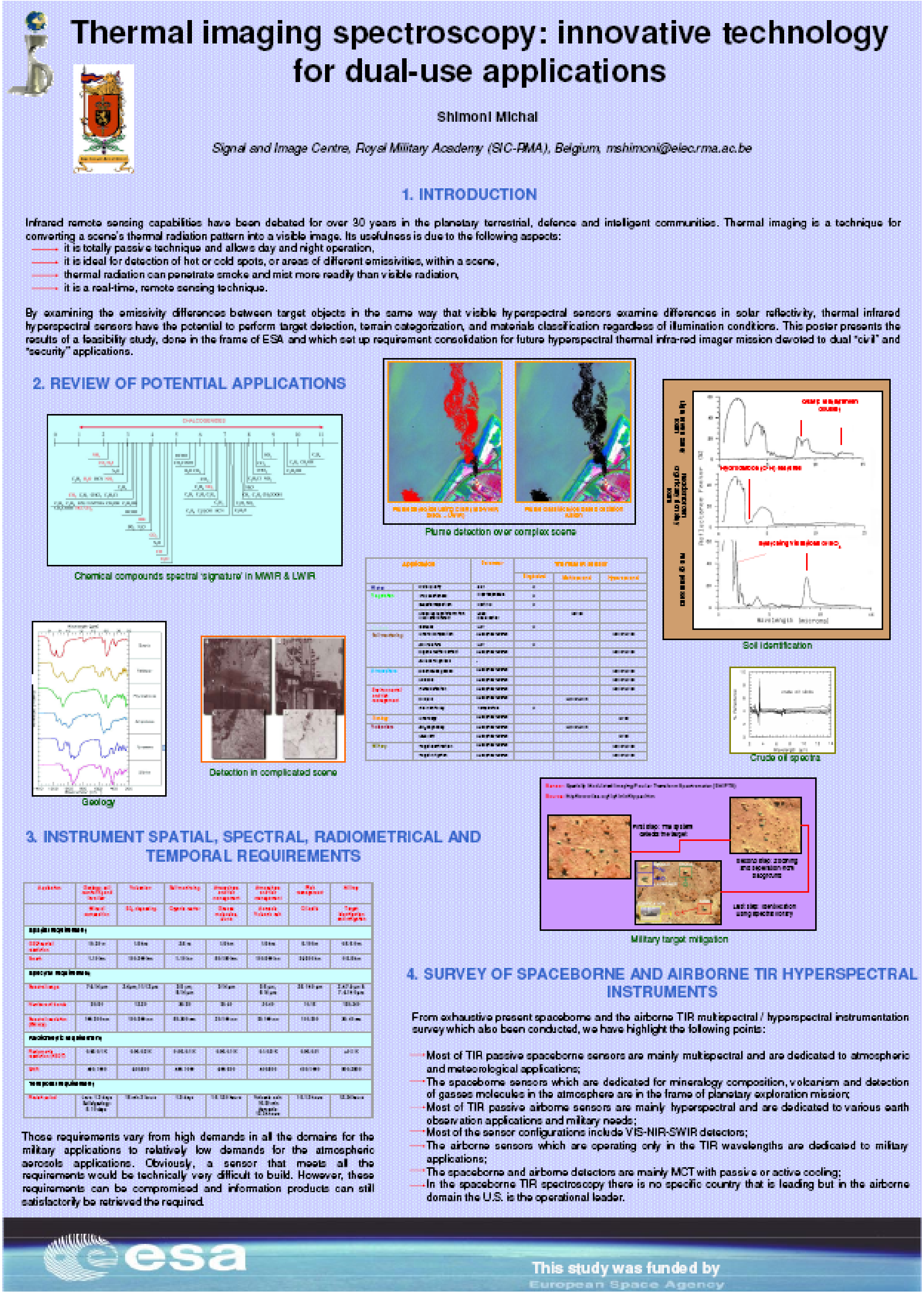

Figure 1: Thermal Imaging spectroscopy: innovative technology for dual-use applications

SATELLITE EARTH OBSERVATIONS SUPPORT CTBT MONITORING: A CASE STUDY OF THE NUCLEAR TEST IN NORTH KOREA OF OCT. 6, 2006 AND COMPARISON WITH SEISMIC RESULTS

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Two satellite data analysis techniques for the detection and characterization of underground nuclear explosions using optical and Radar data were successfully applied to historical tests at the Nevada Test Site (NTS). Both methods (MAD – Multivariate alteration detection and DInSAR – Differential Synthetic Aperture Radar Interferometry) were now used to analyze the recent nuclear test in North Korea at the German NDC (National Data Center) at BGR, Hannover. Due to its small size this event may be typical for problem events under the Comprehensive Nuclear-Test-Ban Treaty monitoring regime; this made it an ideal test case to explore how commercially available satellite data can be used to supplement seismological monitoring techniques stipulated in the treaty. Unfortunately, the available multispectral optical data (ASTER) for the change detection study covered only partly the area of the seismic location confidence ellipse (Figs. 1 & 2), however, included the region that has been reputed to be a possible test site. The detected changes are compared with the seismic epicenter locations of the CTBTO, USGS and BGR's location using regional IRIS and IMS stations. The changes that occurred within a time span of 17 days enclosing the explosion (Figs. 3 & 4) are co-located with buildings and small roads in an otherwise uninhabited region (Figs. 7 & 8). The DInSAR technique, which clearly revealed co-seismic and post-seismic subsidence signals for underground explosions at the NTS, gave less valuable results due to the mountainous topography which caused disturbing layover and shadowing effects in the calculated phase maps (Figs. 5, 6 & 7). The study showed the synergy, and limitations, between remote EO and seismology, especially for the investigation of dubious seismically detected events.

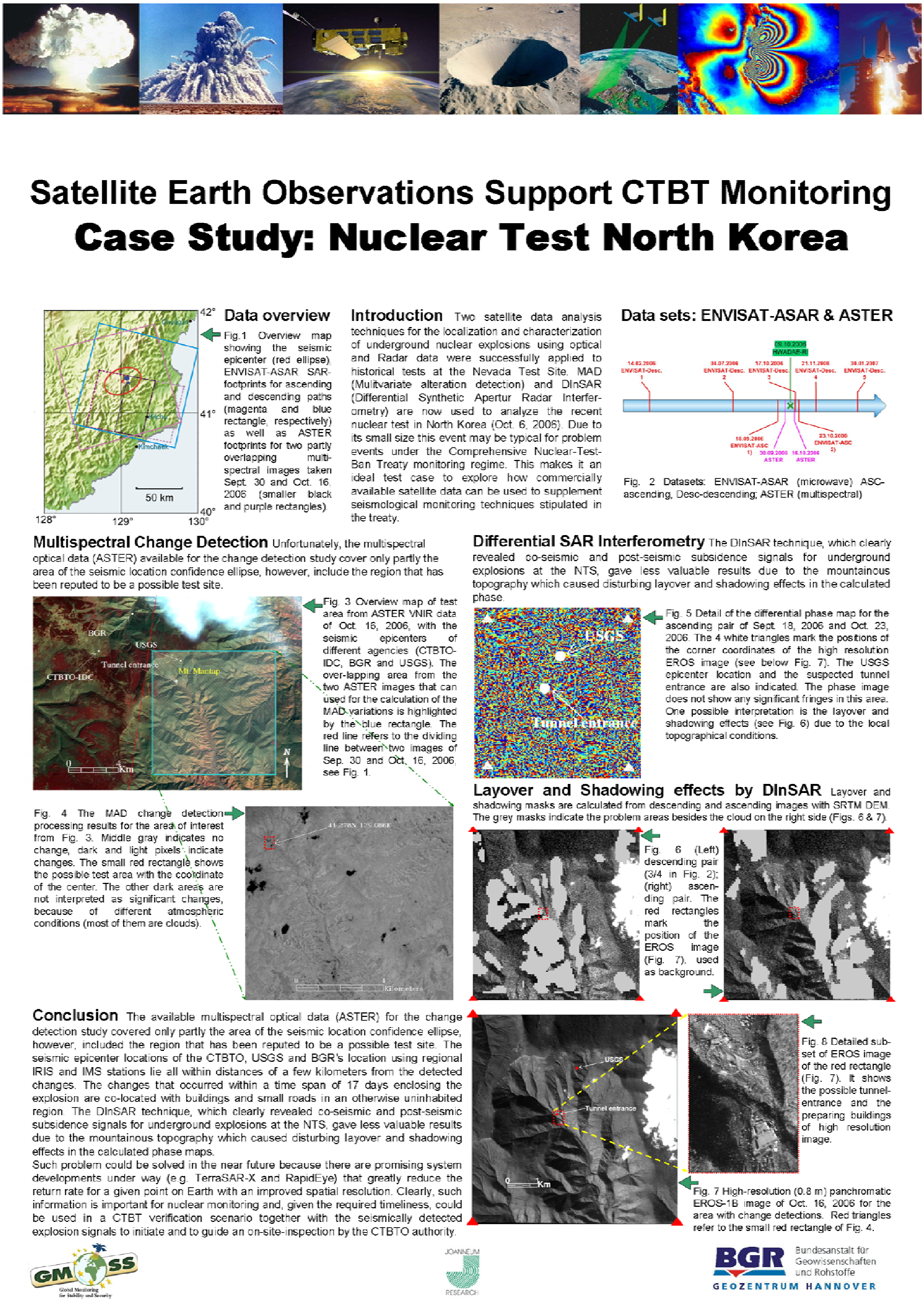

Figure 1: Compilation of figures used for the study together with explanatory text.

POTENTIAL GMES SERVICES DERIVED FROM CRISES INDICATORS

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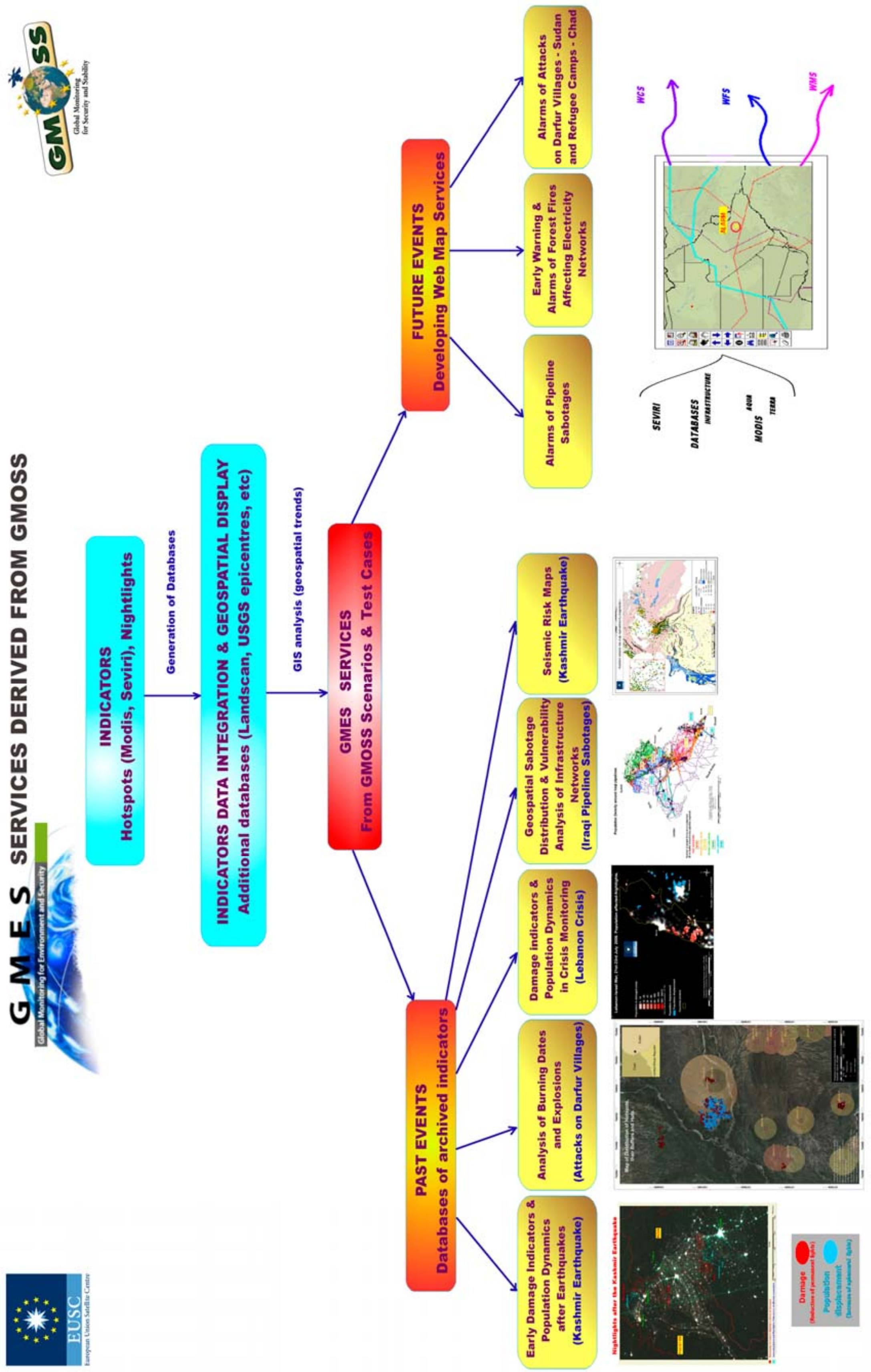
European Union Satellite Centre (EUSC), Torrejon de Ardoz, Madrid, Spain E-2885

The use of crisis indicators such as hotspots (from the thermal bands of Modis and Seviri sensors), nightlights from DMSP-OLS sensor and others such as earthquake epicentres (USGS) and population datasets (LandScan), etc. have been collected into databases and integrated in GIS applications that offer good potential to provide GMES services from the research conducted in the GMOSS project. These crises indicators may refer to past and future events thus extending the number of potential GMES services. Regarding past events, the following cases have been addressed in GMOSS by generating databases of archived indicators: Early damage indicators and population dynamics after earthquakes (Kashmir nightlights) Analysis of burning dates and explosions (attacks on Darfur villages) Damage indicators and population dynamics in crisis monitoring (Lebanon crisis) Geospatial sabotage trends and vulnerability analysis of oil and gas infrastructure (Iraq GIS) Seismic risk maps (Kashmir, nuclear installations in Iran). Regarding future events, the development of web mapping services in buffered areas surrounding the location of interest where hotspots occur, offer the following potential for GMES services: Alarms of pipeline sabotages Early warning and alarms of forest fires affecting electricity networks Alarms of attacks on Darfur villages (Sudan) and refugee camps (Chad). In the light of the new operations in Darfur (joint UN/AU), the services above (Sudan/Chad) offer good potential. Presentations made during the GMOSS dissemination phase, have attracted the interest of end users regarding the services above. Some of these applications have been developed with the assistance of several GMOSS partners (Univ. of Basilicata and CRPSM of Rome University). A poster entitled: "GMES services derived from GMOSS" was presented at the "GMOSS Final Event in Brussels" in December 2007.



GMES SERVICES DERIVED FROM GMOSS
Global Monitoring for Environment and Security
EUSC
European Union Satellite Centre
GMOSS
Global Monitoring for Security and Stability
INDICATORS
Hotspots (Modis, Seviri), Nightlights
Generation of Databases
INDICATORS DATA INTEGRATION & GEOSPATIAL DISPLAY
Additional databases (Landscan, USGS epicentres, etc)
GIS analysis (geospatial trends)
GMES SERVICES
From GMOSS Scenarios & Test Cases
PAST EVENTS
Databases of archived indicators
FUTURE EVENTS
Developing Web Map Services
Early Damage Indicators & Population Dynamics after Earthquakes (Kashmir Earthquake)
Analysis of Burning Dates and Explosions (Attacks on Darfur Villages)
Damage indicators & Population Dynamics in Crisis Monitoring (Lebanon Crisis)
Geospatial Sabotage Distribution & Vulnerability Analysis of Infrastructure Networks (Iraqi Pipeline Sabotages)
Seismic Risk Maps (Kashmir Earthquake)
Alarms of Pipeline Sabotages
Early Warning & Alarms of Forest Fires Affecting Electricity Networks
Alarms of Attacks on Darfur Villages - Sudan and Refugee Camps - Chad
Nightlights after the Kashmir Earthquake
Damage
Population displacement
SEVIRI
DATABASES
INFRASTRUCTURE
MODIS
AQUA
TERRA
WCS
WFS
WMS

MONITORING THE MARINE ENVIRONMENT IN RUSSIA, UKRAINE AND KAZAKHSTAN USING SATELLITE SYNTHETIC APERTURE RADAR – THE MONRUK PROJECT

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European Commission - Joint Research Centre (EC-JRC), 21027 Ispra (VA), Italy

The overall objective of the project MONRUK is to develop and implement satellite SAR monitoring of the marine environment in Russia, Ukraine and Kazakhstan as a component of GMES.

Satellite SAR images for the three study areas will be collected in order to develop and validate retrieval algorithms for ocean and sea ice parameters. The SAR data collection will be done by a) using existing ERS and ENVISAT SAR data retrieved from ESA archives; b) new acquisition of ENVISAT ASAR data, including alternating polarization images, and c) RADARSAT SAR images.

The initial set of SAR data will be analyzed in combination with optical and IR satellite data, metocean data from models and in situ platforms. The main tools in the SAR analysis will be the Radar Imaging Model (RIM) and the Atmospheric Boundary Layer (ABL) model provided by NIERSC and the SARTool provided by BOOST Technologies. These tools will be further developed and validated in order to retrieve more quantifiable parameters from SAR. The performance of existing algorithms for retrieval of oil slicks, wind, waves, and sea ice parameters will be investigated as part of a benchmarking process.

SAR monitoring exercises will be conducted in the three study areas with support from other metocean and satellite data. The data analysis will result in geophysical information (wind, waves, currents, fronts, slicks, sea ice parameters). Identified users will receive and assess the information and provide feedback to the service providers. The monitoring exercise will test the functioning of the service chain starting with input data and resulting in products delivered to users. The lessons learned from this exercise will be used to develop fully operational systems for SAR monitoring in the context of GMES.

An important element of marine monitoring services is to provide efficient and user friendly access to the products delivered by the service providers. For this purpose, MONRUK will develop and implement a webmap server system based on a prototype developed in the DISMAR project. The prototype is a web-based, distributed, marine information management system following INSPIRE guidelines and is operated by CMRC (http://dispro.ucc.ie/apps/dismar). By using the same webmap server system in several GMES projects, there will be a significant progress towards implementation of harmonized, pan-European, interoperable systems to provide data and information about the marine environment. Finally, MONRUK will establish a network with other related projects, organizations and agencies that are involved in developing operational oceanography services across Europe.

More information concerning MONRUK is available on following URL: http://monruk.nersc.no

Joint Research Centre

www.jrc.ec.europa.eu

Monitoring the marine environment in Russia, Ukraine and Kazakhstan using Synthetic Aperture Radar

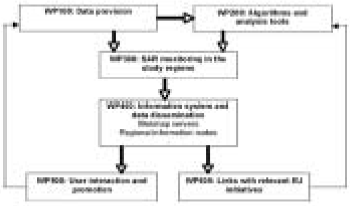
O. Müllenhoff, G. Ferraro, K. Topouzelis

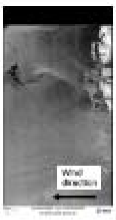
INTRODUCTION

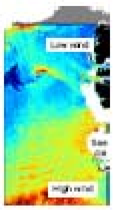
The overall objective of MONRUK is to develop and implement satellite Synthetic Aperture Radar (SAR) monitoring of the marine environment in the Black Sea, the Caspian Sea, the Barents and Kara Seas. SAR images from satellites contains detailed information about ocean surface conditions, such as wind, waves, currents, fronts, slicks, sea ice and oil spill detection. The SAR data are analysed in combination with optical and infrared satellite data, met-ocean data from models, and in situ observations from an offshore platform.

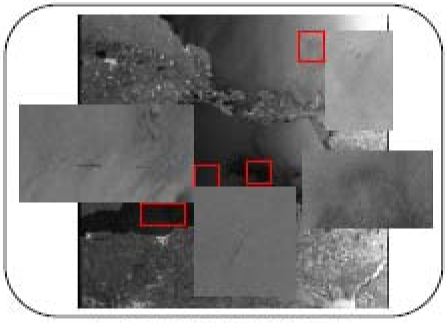
METHODOLOGY

The main tools in the SAR analysis will be the Radar Imaging Model (RIM) and the Atmospheric Boundary Layer (ABL) model provided by NIERSC and the SARTool provided by BOOST Technologies. These tools will be further developed and validated in order to retrieve more quantifiable parameters from SAR. Identified users will receive and assess the information and provide feedback to the service providers.









Examples of oil spill detections and look-alikes (ASA_WSM from 04/09/2007).

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PRELIMINARY RESULTS

A prototype web map server system (DISPRO) is under development for dissemination of satellite data and other results produced in MONRUK. DISPRO is capable of integrating distributed multi-source data and as well as numerical model simulations from several providers. The DISPRO architecture is consistent with INSPIRE's general model of an SDI (Spatial Data Infrastructure). DISPRO is a multi-tier system with four main groups of components: user applications, geo-processing and catalogue services, catalogues and content repositories.

In the context of GMES, MONRUK will establish links to other related projects, activities and organizations involved in developing operational monitoring services in order to exchange results and have a dialogue for coordinated planning of future development of monitoring services.

http://monruk.nersc.no

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Annex

Agenda

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Tuesday, 19 February 2008

09:00-09:20 **Welcome & Introduction**
D. Al Khudhairy , SES Unit Head,
M. Pesaresi, GMOSS Scientific Coordinator

Session 1 **The "S" in the GMES landscape**

09:20-10:40 **Presentation of GMES projects RESPOND, LIMES, Risk-EOS, Preview, BOSS4GMES, TANGO, SAFER & G-MOSAIC**
Project representatives

10:40-11:10 *Break*

Session 2 **Information Exchange**

11:10-11:40 **World Information Fusion Model**
H. De Smet, RMA, Belgium

11:40-12:10 **Collaborative geospatial processing and visualization for situation assessment**
G. Lemoine, JRC, Italy

12:10-13:30 *Lunch*

Session 3 **Preprocessing**

13:30-14:00 **Geometric pre-processing for security and stability applications**
K. Gutjahr, JR, Austria

14:00-14:30 **Automatic production of a European orthoimage coverage**
T. Krauss, DLR, Germany

Tuesday, 19 February 2008

14:30-15:00 **A Multiresolution-MRF Approach for Stereo Dense Disparity Estimation**
Mahamadou Idrissa, RMA, Belgium

Session 4 **Feature Extraction**

15:00-15:30 **Application of Mathematical Morphology to Satellite Data**
G. Laneve, CRPSM, Italy

15:30-15:50 *Break*

15:50-16:20 **Rapid Road Mapping for Security and Crisis Management**
G. Lisini, Uni Pavia, Italy

16:20-16:50 **Height extraction for man made structures from single detected VHR SAR imagery**
D. Brunner, JRC, Italy

Session 5 **Poster Session**

16:50-18:00 **3-D change detection from Quickbird stereo pairs of a nuclear facility**
P. Reinartz, M. Lehner, DLR, Germany

DEM generation for Baghdad test case
T. Krauss, DLR, Germany

GMOSS Programme Summary for Integrating Workpackages: Standards; Data Sharing and Infrastructure'
D. Kodz, W. Cudlip, QinetiQ, UK

The Iran Test Case: Monitoring of the Iranian Nuclear Programme'
I. Niemeyer, TUB Freiberg, Germany

Treaty Monitoring using Satellite Imagery: Lessons learned in GMOSS
I. Niemeyer, TUB Freiberg, Germany

Thermal imaging spectroscopy: Innovative technology for dual use applications'
Michal Shimoni, RMA, Belgium

Satellite Earth Observation Support to CTBT Monitoring: A Case Study of the Nuclear Test in North Korea of Oct. 6, 2006 and Comparison with Seismic Results
J. Schlittenhardt, X. Cong (BGR), M. Canty (FZJ), K.-H. Gutjahr (JR)

Potential GMES Services derived from crisis indicators
A. de la Cruz, M. Mielewczyk, V. Navarro, EUSC, Spain

Monitoring the marine environment in Russia, Ukraine and Kazakhstan using satellite Synthetic Aperture Radar – the MONRUK project
G. Ferraro, JRC, Italy

18:00 *Shuttle Bus to the Hotel*

20:00 *Workshop Dinner*

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Wednesday, 20 February 2008

Session 6 **Change Detection**

09:00-09:30 **MAD change detection: a simple spatial extension and a nonlinear version**
A. Nielsen, TUD, Denmark

09:30-10:00 **Object-based change detection for security applications**
I. Niemeyer, TUB Freiberg, Germany

10:00-10:30 **Pixel- and segment-based complex Wishart distribution change detection for polarimetric SAR data**
H. Skriver, TUD, Denmark

10:30-11:00 **Radar Change Detection and Target Recognition for Security Applications**
R. Dekker, TNO, The Netherlands

11:00-11:20 *Break*

Session 7 **Applications**

11:20-11:50 **Extracting Dwelling Structures - Experiences of Comparative Dwelling Counting in Refugee Camps and Shanty Towns**
D. Tiede, Z_GIS, Austria

11:50-12:20 **Development of a strategy for applying night time images to rapidly assess damaged areas and refugee movements after disasters**
A. De la Cruz, EUSC, Spain

Wednesday, 20 February 2008

12:20-12:50 **Population density estimations and settlement location estimations using SRTM and TM data**
S. Mubareka, JRC, Italy

12:50-14:30 *Lunch*

14:30-16:00 **Wrap-up of the sessions and discussions on collaboration, common problems, new research topics for coming calls and outlook by GMES Bureau on next calls**

16:15 *Shuttle bus to the airport Milano Malpensa (MXP)*

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Abstract

The Joint Research Centre of the European Commission hosted a two-day workshop "Remote sensing for international stability and security: integrating GMOSS achievements in GMES". Its aim was to disseminate the scientific and technical achievements of the Global Monitoring for Security and Stability (GMOSS) network of excellence to partners of ongoing and future GMES projects such as RESPOND, LIMES, RISK-EOS, PREVIEW, BOSS4GMES, SAFER, G-MOSAIC.

The objectives of this workshop were:

• To bring together scientific and technical people from the GMOSS NoE and from thematically related GMES projects.

• To discuss and compare alternative technical solutions (e.g. final experimental understanding from GMOSS, operational procedures applied in projects such as RESPOND, pre-operational application procedures foreseen from LIMES, etc.)

• To draft a list of technical and scientific challenges relevant in the next future.

• To open GMOSS to a wider forum in the JRC

This report contains abstracts of the fifteen contributions presented by European researchers. The different presentations addressed pre-processing, feature recognition, change detection and applications which represents also the structure of the report. The second part includes poster abstracts presented during a separate poster session.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

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