Terrestrial Scanning

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J. Boavida, A. Oliveira, A. Berberan
"Dam monitoring using combined terrestrial imaging systems",
Civil Engineering Surveyor (CES) December/January 2009

Thousands of registered large concrete and embankment dams have now more than five decades of operational and age related problems. Monitoring plays an essential role in evaluating the structural safety condition of dams. Monitoring activities are also useful for the collection of valuable data to enhance the understanding of the behaviour of these structures.
Embankment dams can suffer from surface displacements related to internal deterioration, such as internal erosion or slope failure. Surface displacements are important quantities to be determined, especially in relation to safety and long term behaviour. The determination of these values is made by measuring surface marks located at regular space intervals, usually in the dam crest and downstream face. However this methodology is based on a discrete sample instead of the surface itself.
Up until now, concrete dam visual inspections have been carried out by expert personnel, without the assistance of any dedicated device or system. Due to operational difficulties, the collected information is often inaccurate, from a positional point of view, rather subjective and costly, yet very important. Laser scanners combined with calibrated reflex digital cameras provide accurate and dense 3D numerical models as well as spatially continuous high-resolution colour (RGB) information of the objects under study. These combined terrestrial imaging systems (CTIS) provide a huge amount of geometric and radiometric well structured data in a short period of time. A 3D scanning company, Artescan, and a research organization, the Laboratório Nacional de Engenharia Civil, in Portugal (LNEC) have been developing positional monitoring methodologies for embankment dams and assisted visual inspection methodologies for concrete dams since 2003. This paper presents three case studies (two concrete and one embankment dam) of the developed methodologies as applied to dam monitoring.

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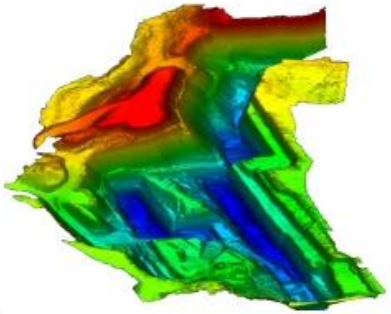
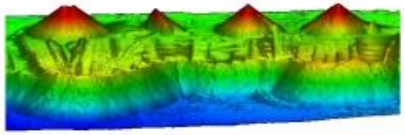
D. Rains "Laserscanning in Open Cast Mining"





Thiess, a leading Australian integrated engineering, construction and mining services provider, offers fully integrated engineering and construction services and employs more than 11,000 people throughout Australia, Asia and the near-Pacific region.

Laser scanning is now being used in Thiess to quickly create 3D surface models of mining and bulk-earthworks operations as well as a range of structural features, plant, and on-site infrastructure.

Periodic scans of mining excavations and ROM stockpiles for example, allow surveyors to accurately calculate volumes of material moved while mining engineers are able to monitor site productivities, accurately reconcile the movement of materials, and assess features such as the condition and grades of ramps, benches, and haul roads.

This rapid-mapping technology promotes ‘out-of-pit’ survey activities as the laser system measures surfaces through the natural reflectivity of materials. Therefore Laser Scanning can be used in situations where ground access is limited, prohibited to field crews, or where continuous subsidence monitoring or productivity applications are required.

Through this technology three-dimensional data is being utilised more than ever. Terrestrial laser scanning equipment is changing the way we control and/or manage our work in the mining and construction industry and will in the future be adopted and utilised as a key tool to support our operations.

Case Study “Plant & Equipment”

Case Study “Pits & Stockpiles”

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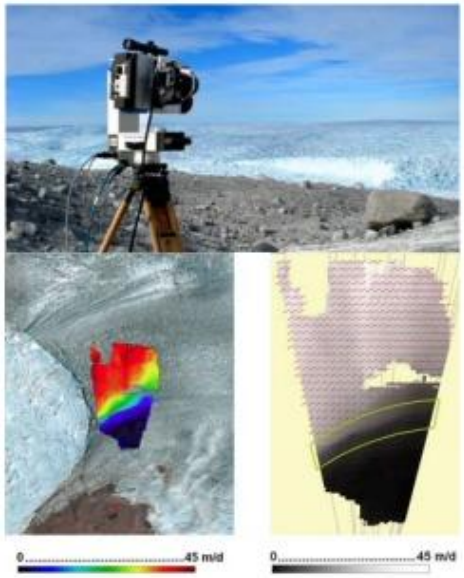
E. Schwalbe, H-G. Maas, R. Dietrich, H. Ewert

"Glacier Velocity Determination from Multi Temporal Terrestrial Long Range Laser Scanner Point Clouds"



The goal of the research work presented here was to determine spatio-temporal velocity fields at the glacier tongue of Jacobshavn Isbrae using photogrammetric methods. In 2004, a measurement campaign has been conducted in order to determine the glaciers movement characteristics using image sequence analysis. Velocities up to 40 m/d could be observed.

In a second campaign in 2007, multitemporal terrestrial laser scanner data were acquired in addition to the high-resolution terrestrial image sequences with the goal of determining glacier surface velocity fields.

A cross correlation technique for the determination of glacier surface velocity vectors is developed. We address some specific technical problems and describe a scheme for correcting timing and angular reference effects on the data. Finally glacier surface velocity fields obtained from the new described method are shown.

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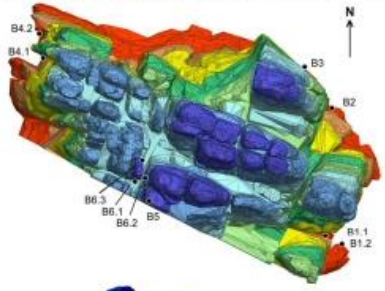
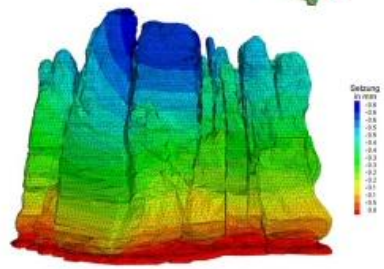
T. Martienßen und K.-H. Löbel
"TLS im Nationalpark Sächsische Schweiz – Datenerfassung und Modellbildung"





Im Sommer 2007 beteiligten sich die Institute für Geotechnik, Mineralogie sowie Markscheidewesen und Geodäsie der TU Bergakademie Freiberg gemeinsam an einem Ausschreibungsverfahren des sächsischen Landesamtes für Umwelt und Geologie (LfUG). Das Thema des Forschungsvorhabens lautet: “Entwicklung geotechnischer Methoden und eines geomechanischen Modells zur Beurteilung der Standsicherheit von Kreidesandsteinen bei fortschreitender Verwitterung zur Gewährleistung der öffentlichen Sicherheit.“

Die umfassende Leistungsbeschreibung beinhaltet eine komplexe Aufgabenstellung, um die physikalisch-chemischen und geodynamischen Prozesse bei der Verwitterung von Kreidesandstein hinreichend erfassen und beschreiben zu können.

Als Untersuchungsgegenstand für die methodischen Betrachtungen wurde das Felsmassiv der Wehltürme ausgesucht. Sie repräsentieren einerseits die stratigraphisch typischen Verhältnisse des Elbsandsteingebirges. Andererseits befindet sich unterhalb des Felsmassivs die Felsenbühne Rathen, so dass der Aspekt der Gewährleistung der öffentlichen Sicherheit einen hohen Stellenwert besitzt.

Für die terrestrische Datenaufnahme wurde der LMS Z-390, der Fa. *RIEGL* eingesetzt, der sowohl eine hohe Reichweite als auch eine herausragende Erfassungsgenauigkeit bietet.

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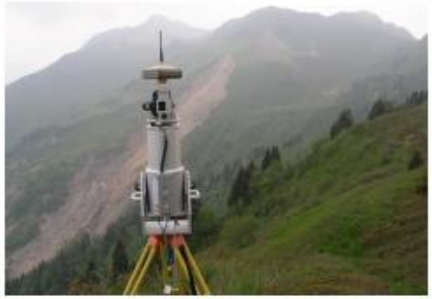
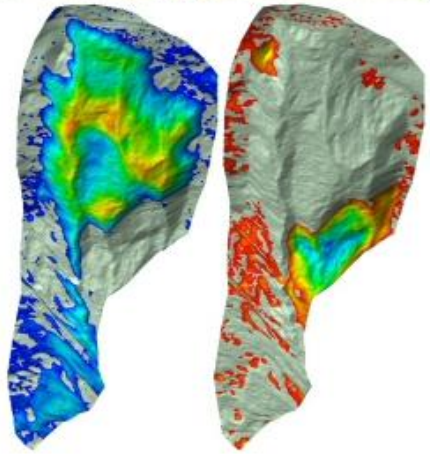
Landslide Monitoring
Visualization and Quantification of Material Movement





The Miozza basin, located in Carnia, a tectonically active alpine region of north-eastern Italy covers an area of 10.7 km². Elevation ranges from 471 to 2075 m a.s.l.. The slope angle has an average value of 33° with a maximum value of 77°. The area has a typical North Eastern Alpine climate with short dry periods and a mean annual precipitation of about 2200 mm. Vegetation covers 94% of the area and consists of forest stands (74%), shrubs (10%) and mountain grassland (10%); the remaining 6% of the area is landslide scars and deposits without vegetation.

In 2004 the largest single landsliding area was interested by slope failures that generated then several debris flows along the main channel. In November 2003 the whole area was covered by aerial LiDAR data . This data is showing the situation of the slope before the reactivation of largest landslide. Terrestrial Laser Scanning, cheaper in data-acquisition, was not a practicable approach, because of the long distance from possible scan position towards the area of interest. The *RIEGL*-Z620 is the first available scanner on the market offering a max. range up to 2000m in combination with high accuracy and high speed data acquisition. The measurement campaign was realized in spring 2008 after the snow-melting period.

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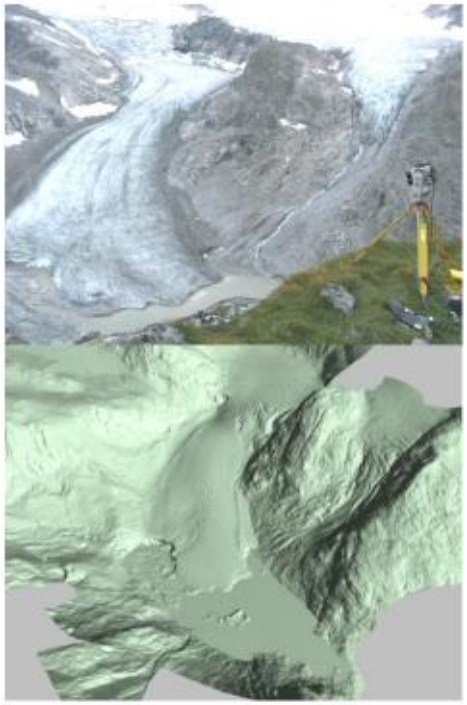
Glacier Monitoring Sulzbachkees, Alps, Austria
Monitoring Campaign 2008 using LPM-321



The monitoring time series of this glacier-field started in 2001. The first three measurement campaigns were realized by the use of LMS-Z210 and LMS-Z210ii. Due to the fact of the enormous decrease of the ice-shield within the last years, hiking-access on the glacier itself is not longer possible. The only reachable measuring-points are far away from the glacier. No instrument of our Z-series can realize such long measuring-distances. For this reason we have used in August, 2008 our new LPM-321, which offers a maximum range up to 6000m. The glacier-field was scanned from two different positions. The resulting DEM is covering an enormous area of more than 5 km².

Please refer also to the preceding project, published in January, 2007 on our webpage.

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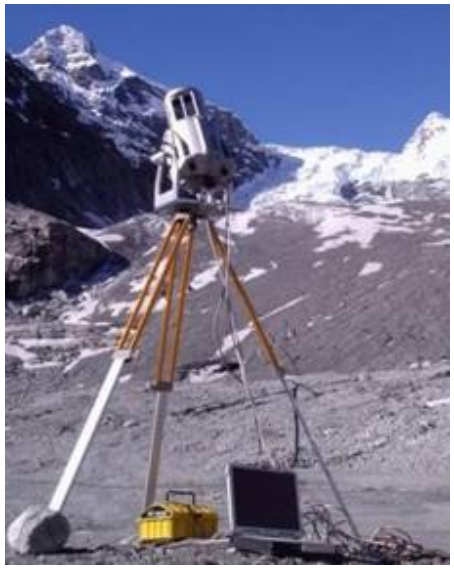
David Milan*, Geroge Heritage & David Hetherington

Application of 3D laser scanner in assessment of proglacial fluvial sediment budget

* Department of Natural & Social Sciences, University of Gloucestershire, UK.



The study was carried out on the proglacial outwash of the Mont Miné and Ferpècle glaciers situated in the Valais region of the Swiss alps. Survey work concentrated on a 4000 m2 reach of braided gravel-bed channel towards the tail of the outwash fan. The channel was fed primarily by meltwater originating from the Mont Miné glacier. Meltwater discharge displays a strong diurnal signal during the summer month. The channel was dry in the early morning, facilitating laser scanning.

A *RIEGL* LMS-Z210 laser scanner was used to collect a series of independent datasets recording range distance, relative height, surface colour and reflectivity. The scans were merged using RiSCAN PRO post-processing software. Reflectors were used in the field to help merge the scans.

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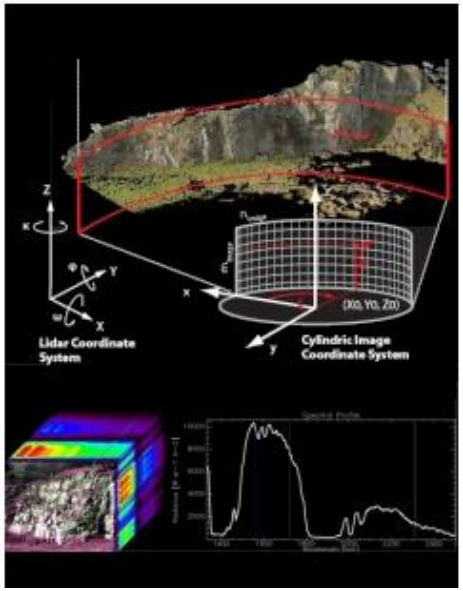
Geol. Outcrop Modelling and Interpretation
Using Ground Based Hyperspectral and Laser Scanning Data Fusion



Authors: Tobias H. Kurz, Simon J. Buckley, John A. Howell, Danilo Schneider

A method has been developed for capturing ground based hyperspectral images which allow the remote mapping of lithology and mineralogy. These data have been collected in combination with traditional ground based lidar data, acquired by *RIEGL*'s LMS-Z420i. The results allow the generation of hyperspectral virtual outcrops. Preliminary testing of the system has been undertaken on dolomitized limestone from a quarry in northern England. The results are encouraging and suggest that mineralogical variations can be mapped remotely. The resultant hyperspectral virtual outcrop has been used to quantify the spatially controlled degree of dolomitization with a degree of detail and precision not previously obtainable.

Poster

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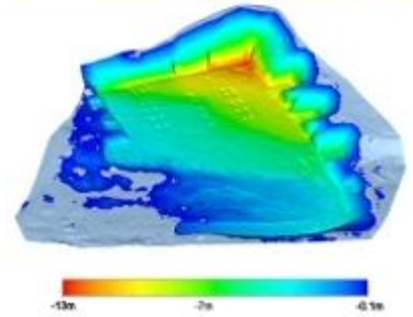
Building Pit Survey - Austria



TLS (Terrestrial Laser Scanning) is the most practicable workflow for this kind of application. The main factors are high speed data-acquisition in combination with high accuracy of the acquired data. The results can be delivered as written reports or as map-plots. The paper describes shortly the workflow of data-acquisition and points out the deliverable results. The field survey was carried out before starting excavation and after finishing excavation. *RIEGL*'s RiSCANPRO software offers tools for automatic extraction of noisy data like vegetation, vehicles, etc. After removing these wrong measurements, the point-cloud, consisting of around one million points per data-set, is triangulated to get a closed surface-mesh of the data. Based on the 3D-surfaces contour-lines and profiles of any orientation are extracted automatically. The resulting 3D-polylines can be exported in dxf-format to AutoCAD. By defining an outline-polygon the excavation-volume is calculated. The results are shown in numbers as cut- and fill-volume, and can be also visualized by colorizing the 3D-surfaces according to their height-differences.

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Eiger North Face – Switzerland

The Eiger North Face is one of the most famous and mentioned peaks in the world. The battle to climb this face has captivated the interest of climbers and non-climbers alike since the time of the first attempt in 1934.Using the *RIEGL* LPM-321, which offers a maximum range of 6km, it is possible to scan not only the Eiger North Face, but also the neighbouring rock-faces, from a single scan-position. Data acquisition needed approx. 7 hours. Finally the 3D-model based on approx. 600.000 measurements and 30 high resolution images should be used for visualization of the different climbing-routes.

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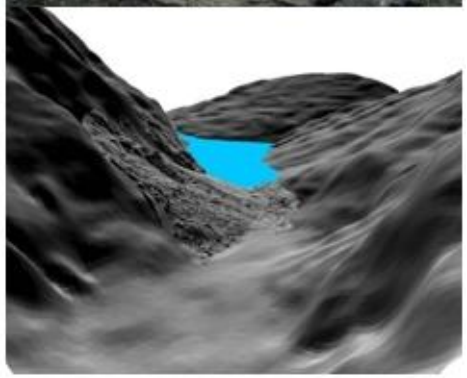
Young River Landslide – New Zealand



A landslide blocking the North Branch of the Young River near Haunted Spur occurred at 4:40 am on 29 August 2007. The landslide occurred in shattered and sheared schist rock adjacent to the Moonlight Fault Zone. The landslide formed a dam 100 m high blocking the valley. Immediately after the landslide occurred water began impounding behind the dam. It has taken more than five weeks for the lake to fill completely and at the time of this report now needs only a further rise of less than one metre to overtop the dam. After heavy recent rainfall the lake is now close to overtopping. Using a tripod-mounted *RIEGL* LMS Z420i, geologist Chris Massey and surveyor Neville Palmer, both of GNS Science, have measured the volume of the landslide at 11 million cubic meters.

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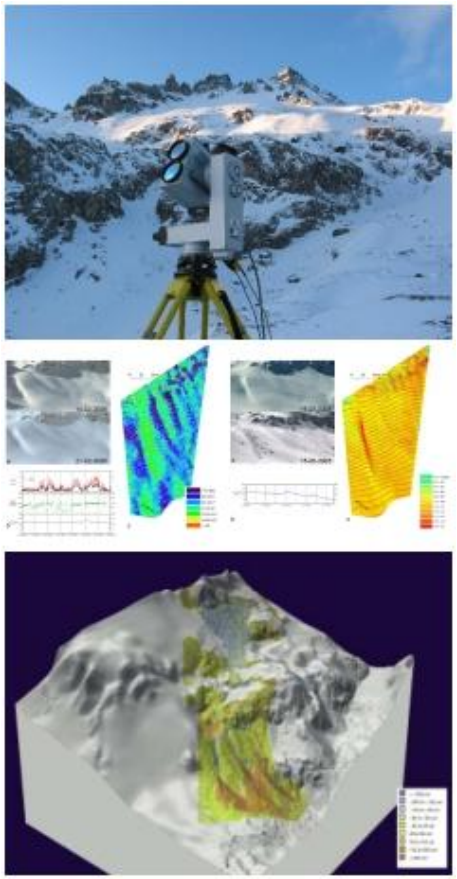

Snow Depth Monitoring, Tyrol, Austria

Knowledge on the spatial and temporal distribution of snow depth is one of the key parameter in the assessment of avalanche hazards, for snow drift and avalanche modelling and model verification. Reliable measurements of snow depth distribution are of interest for practitioners as well as for scientists. Most of the conventional methods like snow pits, probing or profiling deliver point information or transects of snow depth, snow density or snow water equivalent. At that, direct (in situ) measurements are chancy in High Alpine terrain. To overcome these restrictions, remote monitoring techniques are applied. Terrestrial scanning lidar survey represents a powerful tool to map inaccessible alpine terrain. In winter 2005/2006 numerous measurements with the terrestrial scanning lidar have been done at the test site in the Wattener Lizum (Tyrol, Austria). The analysis of the repeated surveys provide changes in the depth of the snow cover.

Schneehöhen-Messung

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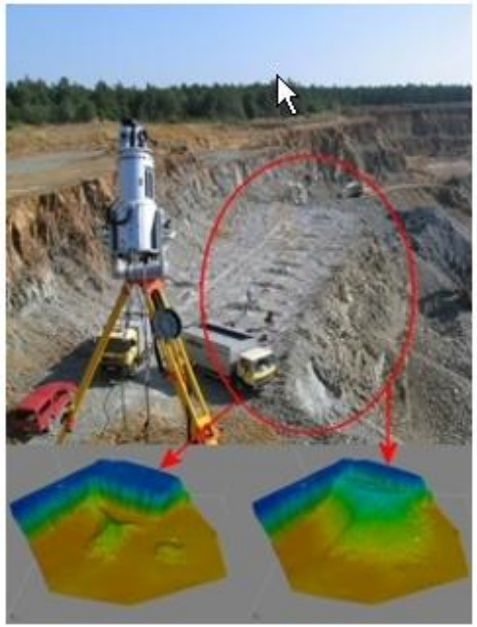
Sprengtechnik-Optimierung im Bergbau



Derzeitige Verfahren zur Lademengenberechnung, Dimensionierung einer Sprenganlage für verschiedene Sprengziele und die Vorgehensweise für die Erarbeitung einer Erschütterungsprognose sind empirisch bzw. werden auf der Grundlage vereinfachter, bekannter Zusammenhänge durch-geführt. Durch den Einsatz des 3D Laserscanner LMS Z390 der Firma *RIEGL* wird aus der Volumenberechnung der Auflockungsfaktor bestimmt, die Lage des Kluftsystems abgeleitet und andererseits nutzt man den Scanner in Kombination mit der Digitalkamera für die Aufnahme des gesprengten Haufwerks, um am Ende die Kurven der Korngrößenverteilung abzuleiten. All diese Daten dienen einer genaueren Parametrisierung des physikalischen Modells für die Beurteilung des Sprengvorganges. Das Ziel dieser Berechnungen ist die Optimierung des Sprengstoffeinsatzes, die bessere energetische Ausnutzung der Sprengstoffe und die Verringerung sowie Beeinflussung der Erschütterungsimmissionen.

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Dachstein-Cave Austria

Together with the Technical University of Dresden (Germany) *RIEGL* has realized an expedition into the Dachstein-Cave (Austria). In the last years the South-Access of the Dachstein-cave was measured using traditional surveying-equipment. Using these traditional methods, measuring the extreme large hollows inside the cave was unrealistic. Using the *RIEGL* LMS-Z420i it was possible to measure also in areas, in which no physical access was possible. The results of this measurement-campaign give a volume-estimation of the large hollows inside the cave, which is necessary to get a better understanding of the water-balance of the whole cave-system. The whole operation was realized under extreme circumstances regarding climbing-routes and accessibility of the cave. Also the *RIEGL* Z420i has shown its outstanding qualities regarding robustness and usability in extreme situations.

Sächsische Zeitung Reportage

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Road Topography – Cunningham Creek - USA

RIEGL USA in cooperation with LD Bradley Company Jacksonville established detailed 3D survey topography in CAD format for the Florida Department of Transportation based on a mobile system, which ensures productive, efficient, and safe data-acquisition. Specialized road topography software-tools for identification, modelling, and analysis of complex conditions deliver results of any complexity. Feature points are accurately extracted from spatial data. All data is mapped on calibrated images as reference to existing conditions to maintain quality control. Detailed line work can be easily extracted, and constant feedback to CAD technician for QA/QC is given.

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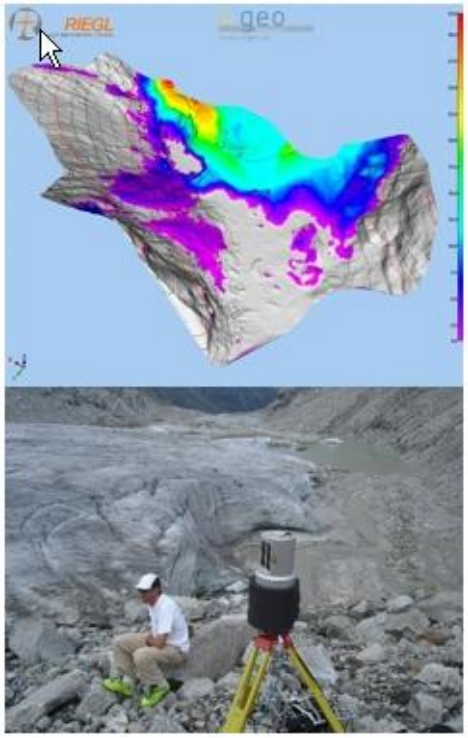
Glacier Monitoring Sulzbachkees, Alps, Austria



Since 2001 the glacier-field “Sulzbachkees” was scanned several times to calculate the height- and length- decrease, which is supposed to be initialized by the global climate warming. The field work was done during the summer-months of 2001, 2003 and 2006, when reaching the glacier-field by hiking is possible. The paper describes the workflow and is visualizing the mass-balance of the glacier-field. Project partners are EGEO and *RIEGL* LMS in coordination with university of Salzburg (Institut of Geography) and local government of Salzburg.

Please refer also to the subsequent project, published in September, 2008 on our webpage.

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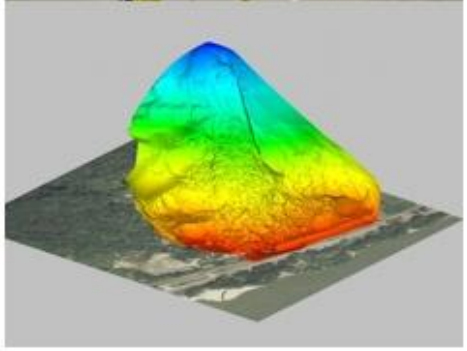
Quarry Spitz



This quarry was scanned in 2005 and 2006, because between these two measurements a big rock-landslide has taken place. The data was used to calculate the exact volume of rock-mass moved by the landslide. Besides the volume-calculation also geotechnical analysis was made on the 3D-data. As input for these geotechnical analysis of endangered areas (by rock falls), dip-angle and –direction of faults, joints and beddings are essential. These parameters mainly determine the mechanical behaviour of rock masses. Normally specialists have to climb up into dangerous areas to measure these values by hand, which is hazardous, difficult, and time-consuming.RiSCANPRO offers functionality to calculate directly on the 3D-model best-fitting-planes, describing direction and orientation of faults, joints, and beddings. Relevant parameters of extracted planes can be exported for further analysis (e.g. polar-plots) in geotechnical software packages.

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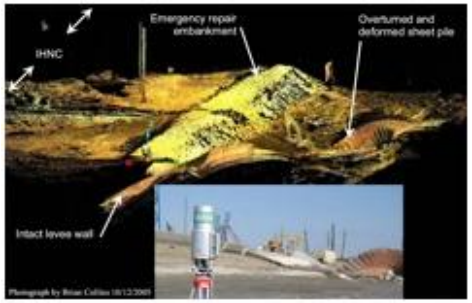
Hurricane Katrina – New Orleans, USA



Preservation of information regarding the magnitude and geometry of structural and geotechnical deformations is paramount for the analysis of levee failure modes. This chapter describes the areas of focus and methodology used in laser mapping of surface evidence of levee deformation and distress at ten areas within the greater New Orleans area. The NSF-investigation team included two researchers from the United States Geological Survey (USGS) who brought to the field area a terrestrial laser mapping tool to perform laser scanning or LIDAR (LIght Detection And Ranging) data collection.

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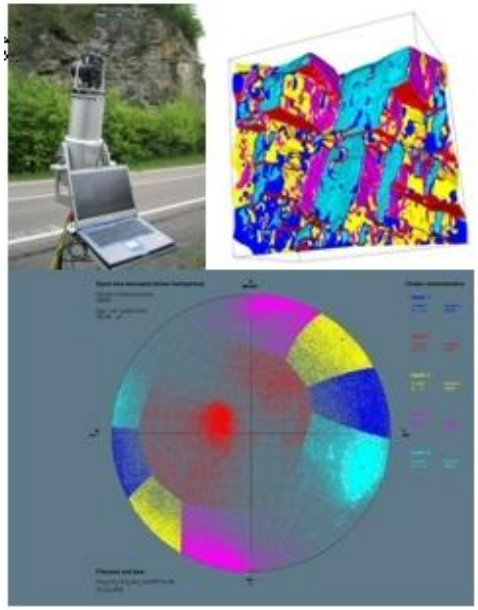
Rock outcrop near the village of Dave, Belgium



It is generally accepted that the identification and characterisation of discontinuities in discontinuous rock masses is one of the most important aspects in rock mass modelling. Traditional manual field survey methods for gathering discontinuity properties are biased, hazardous, difficult and time-consuming. This paper describes a computer approach, based on terrestrial laser scan data, which seems promising as an alternative survey technique. A terrestrial laser scanner can create rapidly, a highly accurate 3D point cloud models of any outcropping rock mass. The point cloud model can be converted into a virtual 3D surface using digital surface reconstruction. This paper describes a method using clustering algorithms, that allow for automated identification and calculation of different discontinuity sets using these virtual rock surfaces. Not only is laser scanning a safer and faster surveying technique, it also provides a more accurate, precise and reliable basis for discontinuity identification and characterisation.

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Ca’ di Malta landslide near Bologna, Italy

Photogrammetry and laser scanning are comparable surveying techniques to generate - without object contact and with a precision commensurate with scale - Digital Terrain Models (DTMs), a fundamental tool todetect, classify and monitoring landslides. 3D reconstruction of the terrain with terrestrial laser scanning methods is a modern way to reproduce the natural surface of the ground with high accuracy and high automation. The present work describes the terrestrial laser scanning and photogrammetric surveys realised on a small landslide body located on the Northern Apennines in Italy (municipality of Vergato, Bologna), an interesting case in order to test the laser scanning capabilities and the procedure of laser data processing, also in comparison with photogrammetry.

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Glacier Monitoring Everest

The Lobuche Glacier and Ice Fall Glacier are located in the Sagarmatha (Everest) National Park – Himalaya Nepal. During the Changri Nup Monitoring Expedition 2003 the two glaciers were surveyed using *RIEGL* terrestrial laser scanner LPM2K. Six days of high mountain trekking were required to reach Lobuche and Ice Fall glaciers. The Base camp for Lobuche glacier survey is situated at 5200m. Special Solar panels were adopted for laser and computer power supply. This report shows that *RIEGL* Laser Scanners work also under extreme climate-situations.

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B. Riveiro, P. Arias, J. Armesto, F. Rial, M. Solla

"Multidisciplinar Aproach to Historical Arch Bridges Documentation"

The paper describes the project of the Close Range Photogrammetry and Remote Sensing Group, University of Vigo, Spain, involving historic arch bridges in Galicia, Spain. The first aim of this Project consists on building a database of the historic arch bridges in Galicia, documenting location, surroundings, geometry, singular characteristics, structural faults, building material and state of conservation. On the other side, a methodology is being designed to optimize measuring and analysing techniques: Close Range Photogrammetry and Laser Scanning as 3D modelling tools for geometry and cracks documentation (Arias et al, 2005), Ground Penetrating Radar for inner material characterization and zones description, and FEM as structural analysis tool to establish stress distribution compatible with the detected damages, allowing identifying its possible causes. This stage includes the development of a procedure to synergize these techniques to obtain more reliable results.

The data and results that have obtained until the date are described in detail. Building styles, singular characteristics of the arch bridges in this region, building materials, and the state of conservation are reported. Further, the methodology for the 3D modelling by digital close range photogrammetry of the bridges, which have varying locations, size, geometry and accessibility is also described, including the requirements which have been considered to grant the utility of the 3D models in further stages of the project: GPR analysis and structural analysis by FEM.

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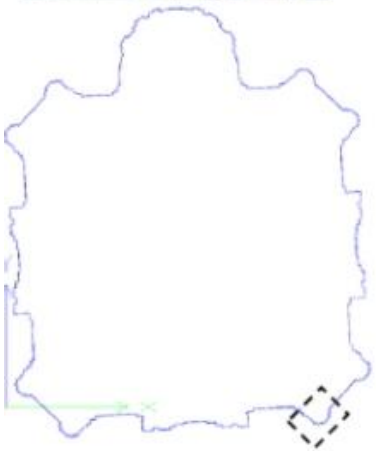
A. Bienert "Vectorization, Edge Preserving Smoothing and Dimensioning of Profiles in Laser Scanner Point Clouds"



The 3D geometry of an object can be captured very efficiently using a terrestrial laser scanner. By modelling and visualisation of these 3D data, it is possible to obtain vectorized geometric information of the object. Many users prefer to work on profiles, motivated by the handling of paper prints in the field by their own familiarization. Profiles extracted from laser scanner point clouds will inherit the noise characteristics of the original points. The effect of noise can be reduced by applying filtering operations. Straight profile sections can be smoothed by using a straight line filter kernel, while incurved profiles can be smoothed by arcshaped structure elements. Because of the scanner resolution and the beam divergence, edges are usually not measured exactly.

The paper presents an edge preserving algorithm to extract and smooth profiles and an approach for automatic vectorization. Smoothed laser scanner data profiles are represented as key points, straight line and arc segments. In addition to the profile vectorization, a CAD-format oriented dimensioning is derived from the data and added to the output. Results from practical applications in cultural heritage documentation and as-built documentation are shown. A profile length comparison between automatically extracted profiles and manually vectorized lines shows a standard deviation σ of 7 mm and a maximum deviation of 1.2 cm.

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W. Neubauer, M. Doneus:

"Digital recording of stratigraphic archaeological excavations using terrestrial 3D laser scanners", VIAS

Any archaeological site shows a stratification formed by single 3D volumes, the deposits and specific 3D surfaces of human origin as pits, ditches or wall-surfaces known as the units of stratification. Excavation forms the main data retrieval process in field archaeology - a destructive process to be documented in three dimensions. To fully reconstruct the part of the site destroyed by excavation these units have to be documented in 3D. The outstanding importance of a 3D documentation of the stratification by the means of the single surfaces indicates the use of terrestrial 3D laser scanners combined with digital imagery as a standard documentation tool. They provide high topographic detail and texture for the efficient digital documentation and monitoring of the excavation process. This monitoring demand opens a wide field of future development – hardware and software - to integrate laser scanners in the daily archaeological work flow.

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W. Neubauer:

"From Practice to Theory – Expanding the stratigraphic recording into real 3D", VIAS 02/2008

On many archaeological excavations world-wide latest technological equipment is in use for digital documentation of the excavation process. Digital cameras, total-stations, computer hard- and software speed up the documentation and enhance the quality as well. We worked for years mainly at the site Schwarzenbach-Burg on the problem of a complete digital documentation of the archaeological stratification destroyed by the excavation process. Our practical fieldwork showed that there is still no profound theoretical background defining the practical framework of documentation and therefore the efficient use of latest technology. As any archaeological excavation deals with a unique stratification - a four dimensional phenomenon - the complete three-dimensional documentation of any unit of stratification and its order in the time arrow by the means of a stratigraphic sequence is of crucial importance for a complete recording of the archaeological excavation process.

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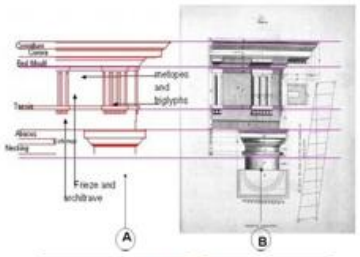

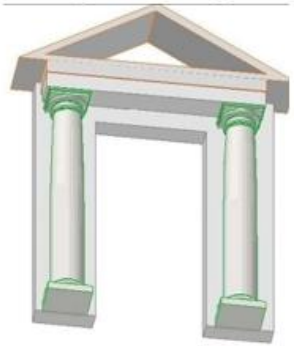

Parametric Vector Modelling of Laser and Image Surveys

Current research into automated recording and surveying techniques has been promoted by CIPA which is the International Scientific Committee for Documentation and Architectural Photogrammetry (CIPA) and is a joint committee set up by the International Council on Monuments and Sites (ICOMOS) and the International Society for Photogrammetry and Remote Sensing (ISPRS). The current research within CIPA promotes the development and application of laser scanning and digital photomodelling for recording architectural heritage, which is emerging as an innovative and novel solution for automating the process of surveying and recording large amounts of architectural data.A method to improve automation of vector mapping by plotting parametric vector objects on to the point cloud is examined in this paper. This study is based on a laser scan and image-based survey of 17th century classical architecture in Dublin. The survey was realized by using The parametric objects are created from the geometry of the point cloud correlated with the historic design principles of classical architecture and then directly mapped on to the point cloud survey. The laser survey can only record the surface of the object; construction details behind the surface can be detected from historic data, thus producing a full 3D and orthographic vector survey of an object or building.

Cultural Heritage Dublin 1
Cultural Heritage Dublin 2

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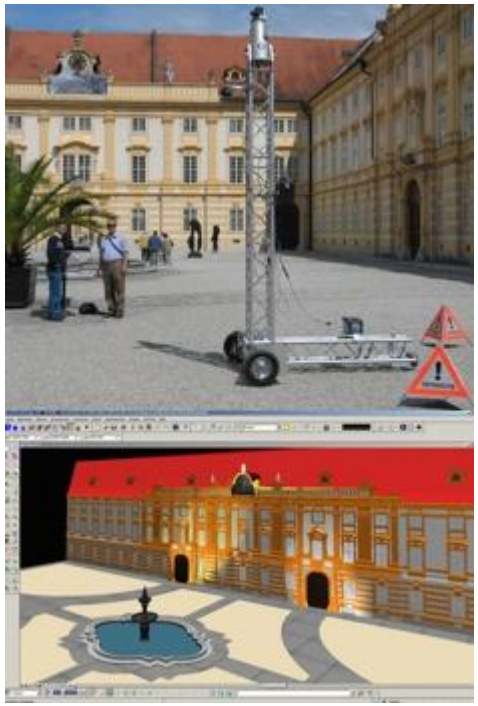
Melk Monastery



Monastery Melk was scanned in 2005 as a *RIEGL* demo-project. The field campaign concentrated on the main inner-court of the monastery. The surrounding parts of the monastery are just visualized as a block-model. The aim of this pilot-project was to show the workflow of creating a high-accurate 3D-model. Besides, high resolution 3D-orthophotos were also calculated, to be used for facade-measurements. For visualization-purposes also external data like CAD-planes and aerial orthophotos were integrated in the RiSCANPRO-project. The data of our pilot-project was adopted by the local government of Lower Austria, a *RIEGL* customer, who will continue the data-acquisition at this site.

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Cheops Pyramid and Sphinx

The aim of the Scanning of the Pyramids Project 2004 was to apply latest state-of-the-art terrestrial laser scanner combined with a calibrated digital camera for high accuracy, high resolution and long distance topographic scanning in archaeology. The monuments selected for the first campaign are the Cheops Pyramid and the Sphinx. The data form the basis for a detailed three-dimensional modelling of the monuments to show and to test the instrumentation as a general-purpose tool for the documentation and monitoring of standing monuments. This has to be seen as a primary data base for the preservation of the monuments investigated by the method. The acquired data can be automatically or semi-automatically processed to generate products such as textured triangulated surfaces or orthophotos with depth information. All the tools developed for image analysis, such as edge detection or signal detection, can be used for direct extraction of 3D content from the combined image data and scan data. The collected data therefore provide a solid and large data base for any further analysis related to scientific problems of the construction, the destruction and decay of the World Heritage Monuments. The data collected are an important extension to the Giza Plateau Mapping Project, and will be made available to the scientific community.

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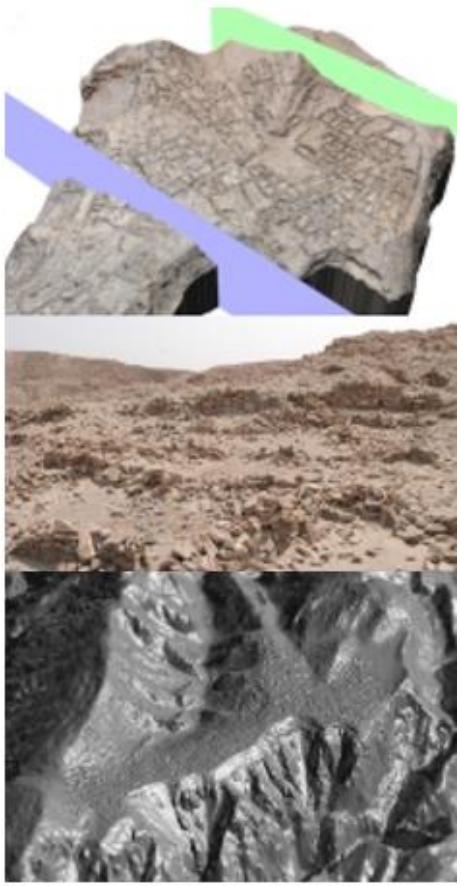

Nasca-Palpa, Pinchango Alto, Peru

Pinchango Alto - 3D archaeology documentation using the hybrid 3D laser scan system of *RIEGL*

Pinchango Alto, a hilltop site of the Late Intermediate Period (1000-1400 AD) in Palpa, on the south coast of Peru, is supposed to be an ancient mining settlement where gold bearing minerals have been processed. We report on the extensive survey carried out in order to gain a detailed site plan making use of *RIEGL*'s hyprid 3D laser scan system consisting of the high-performance 3D imaging laser sensor Z420i and a mounted high-resolution camera. As the site is situated on an outlying plateau all the equipment had to be carried over rather long distances through a deep canyon southwest of the area of interest.

Combining photogrammetry and laserscanning for the recording and modelling of the Late Intermediate Period site of Pinchango Alto, Palpa, Peru

This paper describes the 3D modelling of Pinchango Alto, Peru, based on a combination of image and range data. Digital photogrammetry and laser scanning allow archaeological sites to be recorded efficiently and in detail even under unfavourable conditions. In 2004 we documented Pinchango Alto, a typical site of the hitherto poorly studied Late Intermediate Period on the south coast of Peru, with the aim of conducting spatial archaeological analyses at different scales. The combined use of a mini helicopter and a terrestrial laser scanner, both equipped with a camera, allowed a fast yet accurate recording of the site and its stone architecture. In this paper we describe the research background, the 3D modelling based on different image and range data sets, and the resulting products that will serve as a basis for archaeological analysis.

Pinchango Alto 2

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Excavation at Karstadt Area Leipzig, Germany

The goal of the 3D-laserscan-documentation is the complete 3-dimensional acquisition of the excavated basement-rooms, and to show the possibilities of the *RIEGL* Z420i laser-scanner in urban archaeology. The focus is not only on accuracy of the documentation, but also on post processing of the scan data including creation of triangulated meshes, orthophotos, 3D models, and CAD-drawings.

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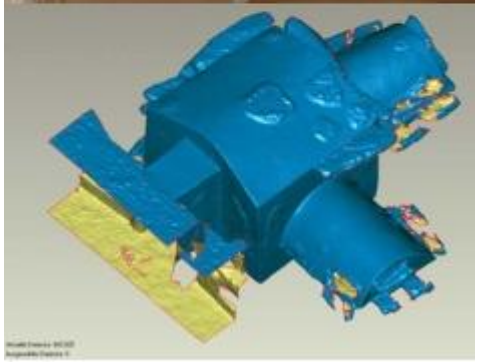
The Domitilla-Catacomb in Rome, Italy



N. Zimmermann - G. Esser: "Showing the Invisible - Documentation and Research on the Roman Domitilla Catacomb based on Image-Laser-Scanning and 3D-Modelling", CAA Berlin 2007

The possibilities offered by new technologies do not automatically substitute traditional techniques. Es-pecially in the collaboration between humanities and natural sciences, not all that is technically possible is also helpful for the study. In this paper we want to present an archaeological project that connects both, solid basic research and newest technologies, offering a new way to perceive historical space by creating three-dimensional virtual reality models. We will give an overview of the technical aspects of the first year of the Domitilla project: The first part introduces the catacomb and shows the state of study and the concept of the research, while the second part will report on the strategy and on the first results of the documentation.

G. Esser - I. Mayer: "3d-geometry and 3d-texture. Documenting early-Christian wall paintings at the Domitilla Catacomb in Rome.", Archäologie & Computer Wien 2007

The paper is intended to refer what is to become the new standard in catacomb documentation, being evolved as one of the major research strategies of the Austrian START Project “The Domitilla Catacomb in Rome. Archaeology, Architecture and Art History of a Late Roman Cemetery”. The approach is based on image laser scanning and mapping of separately taken photographs, creating photorealistic 3d models, which are to serve as a new kind of data-base for further studies.

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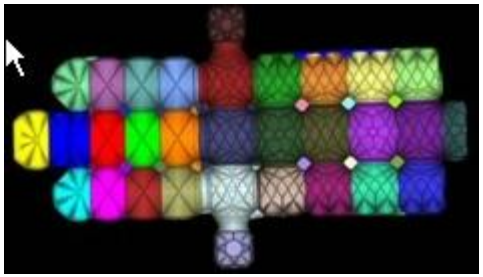
St. Stephans Cathedral Vienna



The *RIEGL* LMS-Z420i has proven as extremely valuable tool in applications of cultural heritage, architecture, and archaeology. We demonstrate the capabilities of this system with an integrated high resolution camera by presenting the work flow of data acquisition and post-processing performed for modeling St. Stephens Cathedral in Vienna/Austria, with an emphasis on the construction of CAD models.

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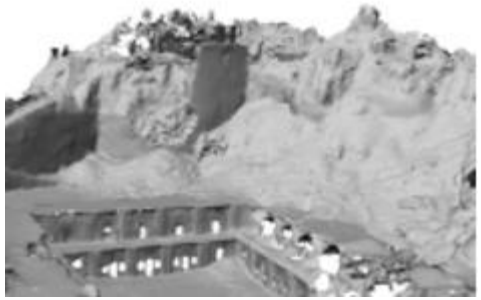
Bam Citadel, Iran



In the last days of the year 2003 a terrible earth quake afflicted Bam, Iran, (26.12.2003, 6.3 Richter Scale) leaving behind more than 50,000 casualties. Invited by the Iranian Cultural Heritage Organisation ICHO [www.iranmiras.org], *RIEGL* LMS GmbH /Austria [www.riegl.com] and their Iranian agent, NPR Co. [www.nprco.com] performed a 3D-mapping of the greatest mud-brick and adobe complex of the world, the ancient Citadel of Bam (Arg-E-Bam), making use of a unique system integration of close range photogrammetry and laser scanning technology. The impressive results of the scanning campaign prove this method a highly efficient bi-technique whose capacities have yet to be fully discovered and exploited.

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Palestrina excavation, Italy

Der Einsatz rechnergestützter Lasermesstechniken auf dem Gebiet der historischen Bauforschung ist seit Jahren ein heiß diskutiertes Thema zwischen Verfechtern des Handaufmaßes und jenen, die sich von den neuen Aufnahmemethoden einen erheblichen wissenschaftlichen Fortschritt versprechen. Hintergrund ist dabei die Frage, ob die moderne „berührungsfreie“ Messtechnologie für den Bauaufnehmer – durch seine „Distanz zum Bauwerk“ - einen Verlust an Kontrollmöglichkeiten zeitigt und dieser so Arbeitsergebnisse minderer Qualität vor allem im Sinne der inhaltlichen Aussagen in Kauf nehmen muss oder ob im Gegensatz dazu die Vorteile einer korrekten geometrischen Erfassung und einer verbesserten Arbeits- und Zeitökonomie überwiegen. Eine Bauuntersuchung am republikanischen Propylon der antiken Stadt Preneste, durchgeführt vom Institut für Kunstgeschichte, Bauforschung und Denkmalpflege der TU Wien, bot die Gelegenheit, in diesem Punkt größere Klarheit zu gewinnen.

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Bridge Surveying, USA

RIEGL Lidar scanner LMS-Z420i utilized by the Federal Bureau of Investigation Lab in support of the National Transportation Safety Board to conduct a structural analysis of the collapsed I-35W Bridge in Minneapolis, Minnesota. The I-35W Mississippi River Bridge collapsed on August 1, 2007 at 6:05 pm when the main spans of the bridge collapsed, falling into the river and the surrounding banks. By utilizing *RIEGL* Lidar scanning technology government officials will assist in the analysis of the failure of the bridge. The *RIEGL* LMS-Z420i is a rugged and fully portable sensor designed especially for the rapid acquisition of high-quality three dimensional images. It consists of a high performance, long-range 3D laser scanner in conjunction with a calibrated Nikon digital camera. Laser scanning is quickly emerging as an important and indispensable metrology tool in the area of surveying, engineering and forensics. The FBI uses this important tool for analysis of important segments of the Nations Infrastructure.

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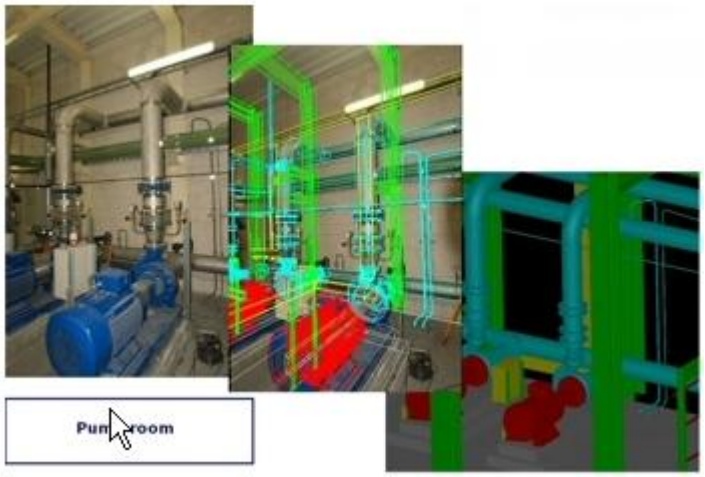
Steelwork ETA Germany

This pump room in EKO-steelwork Eisenhüttenstadt (Germany), was scanned using the *RIEGL* LMS Z420i, in order to create a high accurate 3D-Inventory. 12 different scan-positions were used to guarantee a complete data-acquisition without any scan-shadows. Also high-resolution images from the camera mounted on the scanner were acquired. Based on Phidias for Microstation, which guarantees a seamless data-transfer from RiSCANPRO including scan- and image-data, a 3D-model of the entire pump-room for future-planning was generated.



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Gas Station in Germany

For planning structural changes at and/or in existing industrial plants and for the documentation of structural facilities the knowledge of existing geometry is of great importance. The structural facility, the material world object, must be transferred in a planning and/or a documentation system. Photogrammetry and laser scanning simultaneously used in a combined system offers high speed data capture of the geometry and details of the scene. The captured data are used for the extraction of geometric primitives namely points, lines and surfaces, which are combined, forming a model of the object. Presented is the combined modeling of laser scanning and photogrammetric data in PHIDIAS modeling system

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Vermessungstechnische Erfassung von Bahnübergängen - Germany

Hochgenaue Laserscanner wurden zuerst in der Industrie für die Erfassung von Oberflächen im Nahbereich verwendet. Später wurden in der Architektur für die Bereiche bis zu 30 m neue Wege beschritten und eine neue Generation von Laserscannern eingesetzt. Seit 2003 ist auf Grund der Entwicklung dieser Technologie der Einsatz auch für die Geodäsie bei der Eisenbahnvermessung interessant geworden. An Hand der Entwurfsvermessung eines Bahnüberganges soll diese Technologie hier beispielhaft vorgestellt werden.

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Deformation measurements on Dams, Austria

This Dam is scanned from both sides using the high accurate *RIEGL* LMS Z420i. The scan-data is used as input to generate a 3D-model of the dam as reference to future-measurements. Monitoring and observation of changes in the structure of the dam, after filling the water-basin, have been the main-interests.

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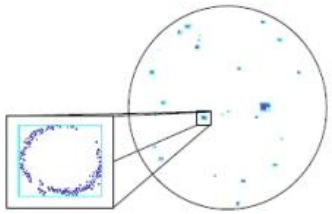
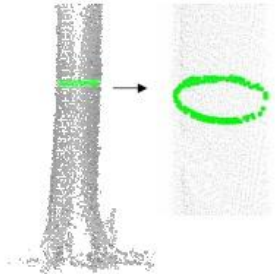
A. Bienert, H.-G. Maas, S. Scheller "Analysis of the Information Content of Terrestrial Laserscanner Point Clouds for the Automatic Determination of forest Inventory Parameters"





Terrestrial laserscanners find rapidly growing interest in photogrammetry as efficient tools for fast and reliable 3D point cloud data acquisition. They have opened a wide range of application fields within a rather short period of time. Beyond interactive measurement in 3D point clouds, techniques for the automatic detection of objects and the determination of geometric parameters form a high priority research issue. The quality of 3D point clouds generated by laserscanners and the automation potential make terrestrial laserscanning also an interesting tool for forest inventory.

The paper will first review current laserscanner systems from a technological point of view and discuss different scanner technologies and system parameters regarding their suitability for forestry applications. In the second part of the paper, results of a pilot study on the applicability of terrestrial laserscanners in forest inventory tasks will be presented. The study concentrates on the automatic detection of trees and the subsequent determination of tree height and breast height diameter.

Reliability and precision of techniques for automatic point cloud processing were analysed based on scans of a test region in a Saxonian mixed forest. In the pilot study, which represents an early stage of software development, more than 95% of the trees in a test region could be detected correctly. Tree heights could be determined with a precision of 80 cm, and breast height diameters could be determined with a precision of less than 1.5 cm.

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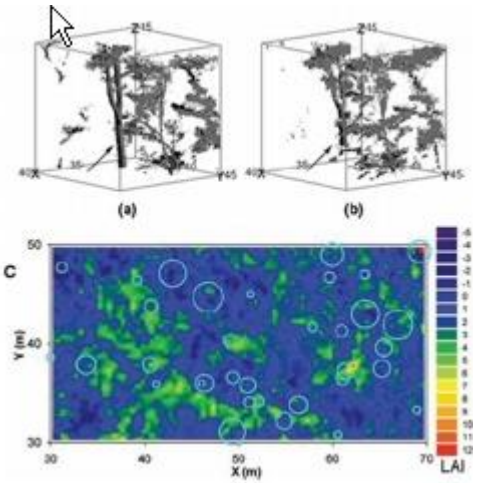
Ground-based laser imaging for assessing three-dimensional forest canopy structure, USA



Improved understanding of the role of forests in carbon, nutrient, and water cycling can be facilitated with improved assessments of canopy structure, better linking leaf-level processes to canopy structure and forest growth. We examined the use of high-resolution, ground-based laser imaging for the spatially explicit assessment of forest canopies. Multiple range images were obtained and aligned during both leaf-off and leaf-on conditions on a 20m x 40m plot.

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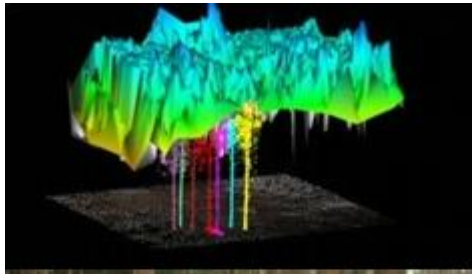
Canopy modelling, Germany



Das Ziel dieser methodischen Untersuchung ist die zerstörungsfreie Bestimmung der Blattbiomasse von stehenden Fichten auf Einzelbaumbasis. Es soll dabei sowohl die Gesamtnadelmasse erfasst als auch die Verteilung der Nadelbiomasse in der Krone bestimmt werden. Im Folgenden soll beispielhaft eine zerstörungs-freie Methode auf der Basis eines terrestrischen Laser-scanners vorgestellt werden, die es gestattet, die Nadelmassenverteilung und -entwicklung ohne Fällung des Baums zu ermitteln. Die Untersuchung ist als Mach-barkeitsstudie angelegt, mit welcher der Einsatz des terrestrischen Laserscannings (terrestrisches LIDAR) erprobt und die Einsatzmöglichkeit für die Biomassen-schätzung ausgelotet werden soll.

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