PHOTOGRAMMETRY FOR NATURAL AND CULTURAL HERITAGE SITE DOCUMENTATION, MAPPING AND VISUALIZATION

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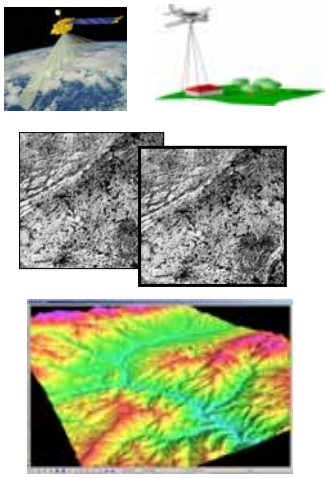

PART 2

with contributions from:
Prof. Armin Gruen, Henri Eisenbeiss, Zhang Li, Jana Niederoest, Daniela Poli, Martin Sauerbier, Gerhard Schrotter

UNESCO Training Workshop for Site Managers
25-27 November 2005 - Campeche, Mexico

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Photogrammetry with ...

+ spaceborne images

+ aerial images

+ helicopter / baloon images

+ terrestrial images

500-700 km

altitude

1-10 m

IMAGES

PHOTOGRAMMETRIC PROCESSING

Photogrammetric workflow for the production of

Digital Surface Models (DSM),

orthoimages,

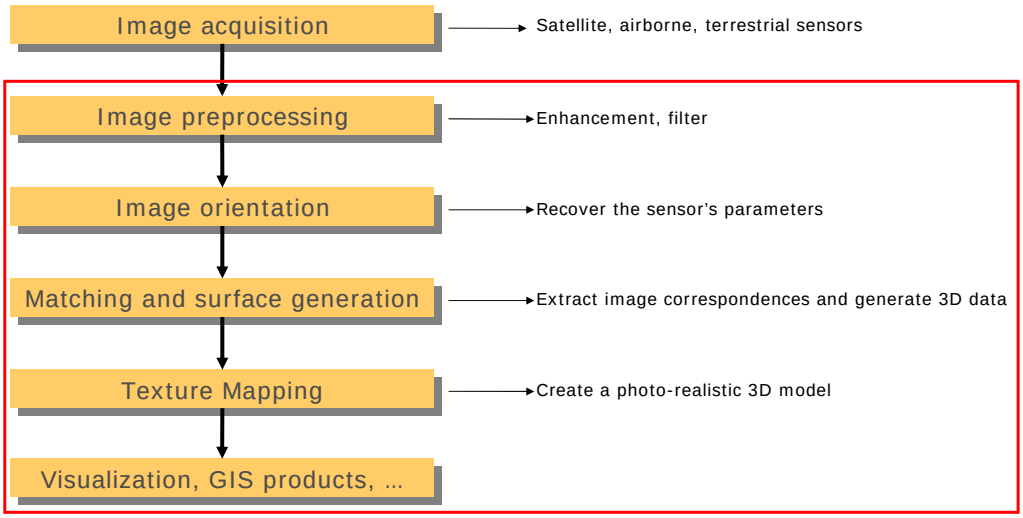
2D and 3D GIS vector data with attributes,

photorealistic 3D models

traditional 2D maps

...

Processing of (digital) images – Photogrammetric pipeline



Photogrammetric software

Commercial systems for satellite, aerial (and terrestrial) applications

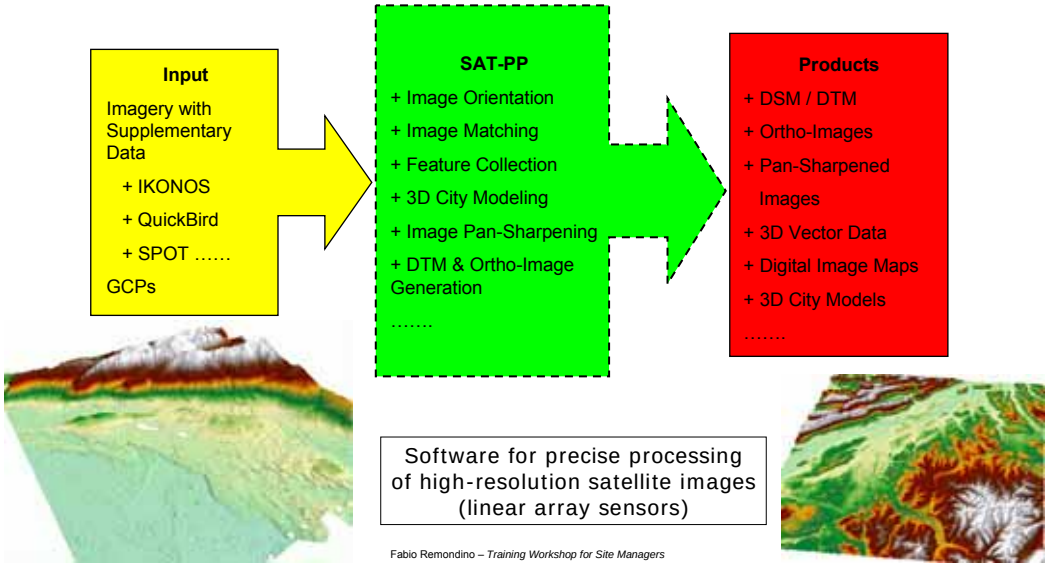
- Image Station (Z/I Imaging, Windows NT/2000, SGI)
- SocetSet (BAE, UNIX, NT/2000/XP) + optional BINGO
- LPS (Leica Geosystems, Windows 2000) + optional ORIMA
- Erdas Imagine Ortho Base, OrthoMAX, VirtualGIS, Vector Module (Erdas, Win2000)
- Match-T, Match-AT, Scop+, Cobra… (INPHO, NT/Linux)
- VirtuoZo (Supresoft Inc., NT/2000)
- PhoTopoL Atlas (Topol+Atlas, NT)
- Imageworks, Orthoengine (PCI, UNIX/Windows 2000)
- DVP (Geomatics System Inc., NT)
- CC-Modeler (Cybercity AG)

Only Terrestrial:

- PhotoModeler (EOS Systems Inc., Windows 2000) Nahbereich
- Australis 3D (University of Melbourne, Dep. Of Geomatics)
- Phidias (PHOCAD)
- iWitness (Photometrix)
- Shape Capture (Shape Quest Inc.)

Photogrammetric software – SAT-PP

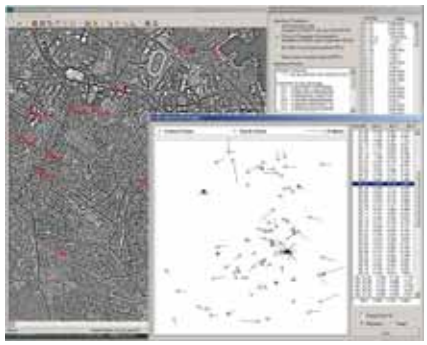
SAT-PP (IGP-ETH Zurich): *High-Resolution **Sat**ellite Imagery **P**recision **P**rocessing Software*



Software for precise processing of high-resolution satellite images (linear array sensors)

Photogrammetric software – SAT-PP

- **Project and Data Management**
  + Multi-sensor data support, including IKONOS, QuickBird, SPOT and other linear sensors
  + Image enhancement with an edge-preserving adaptive smoothing filter



- **Image Orientation**
  + Manual and semi-automated GCP / tie point measurement in multi-image environment
  + Both rigorous sensor models and generalized sensor models such as rational function models (RFM), affine projection model and projective direct linear transformation model (DLT)
  + On-line quality control and error analysis with interaction of graphics elements

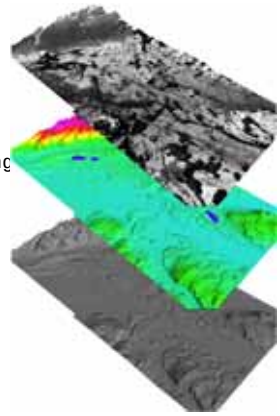
- **Quasi-Epipolar Resampling for Stereoscopic Feature Collection and Automated DSM / DTM Generation**

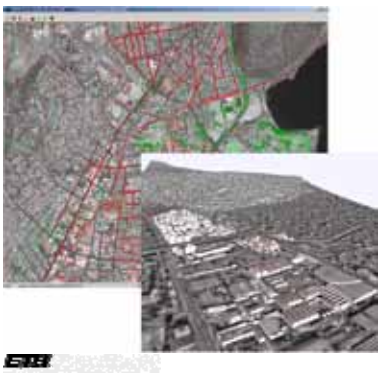
- **Automated DTM / DSM Generation**
  + A hybrid image matching procedure, which exploits the characteristics of linear array imagery and its image geometry, is used to produce dense, precise, and reliable results for DSM / DTM generation

Photogrammetric software – SAT-PP

- **Orthorectification Image Generation**

- **Channel registration**
  + Fully automated sub-pixel image registration between multi-spectral and panchromatic imagery
  + Enhancement of the visual information of multi-spectral imagery by fusing it with the detailed spatial information of panchromatic imagery

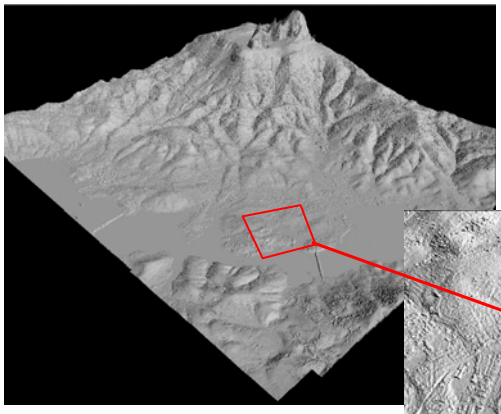




- **Feature Collection and Semi-Automated 3D City Modelling**
  + Works in stereoscopic and multi-image monoscopic mode
  + Features can be collected manually or semi-automatically
  + Mono-plotting with existing terrain data
  + Works with semi-automatic 3D city modeling software CyberCity Modeler™

Photogrammetric software – SAT-PP

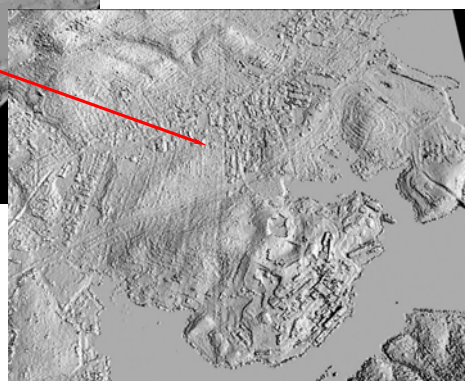
Application Case 1: IKONOS over Hobart, Australia



3D Visualization of 5 m Grid DSM

Automated Extracted DSM by Image Matching

Feature Points + Line Features



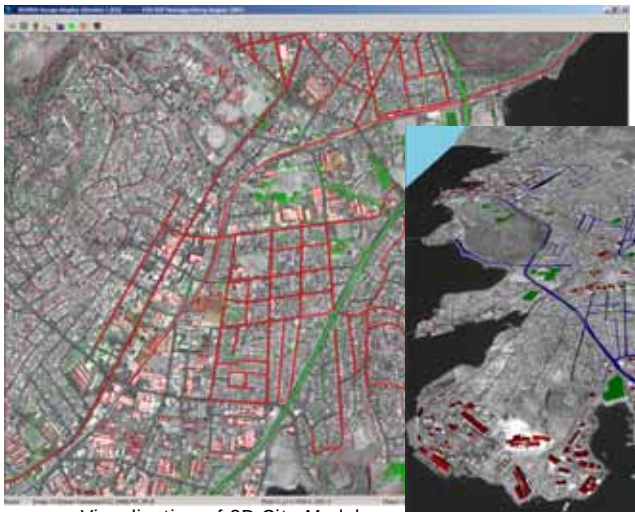
DSM Accuracy Test Results:

(Checked by more than 100 Feature Points)

RMS: 0.9 m

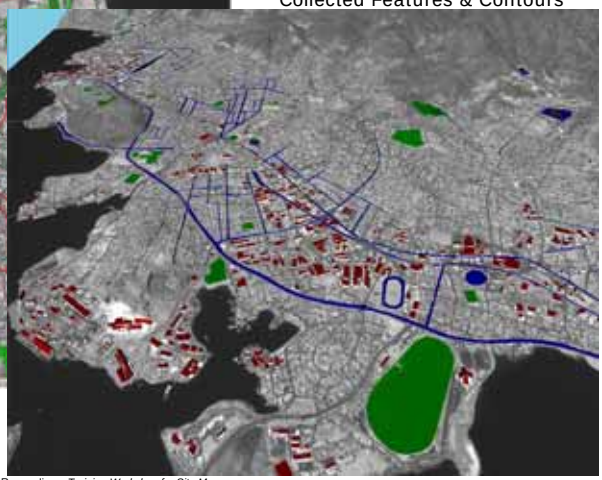
Photogrammetric software – SAT-PP

Application Case 1: IKONOS over Hobart, Australia



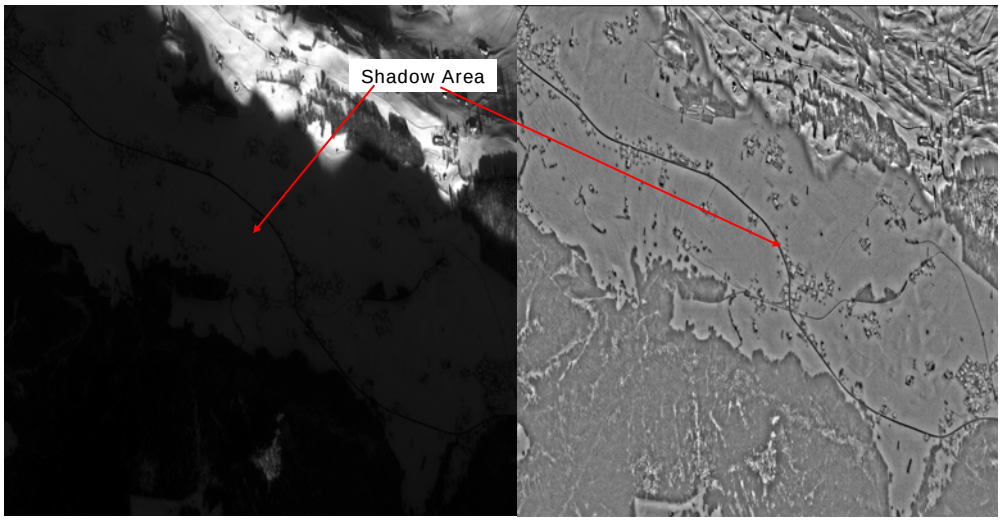
Visualization of 3D City Model

Ortho-Image Overlaid with Collected Features & Contours



Photogrammetric software – SAT-PP

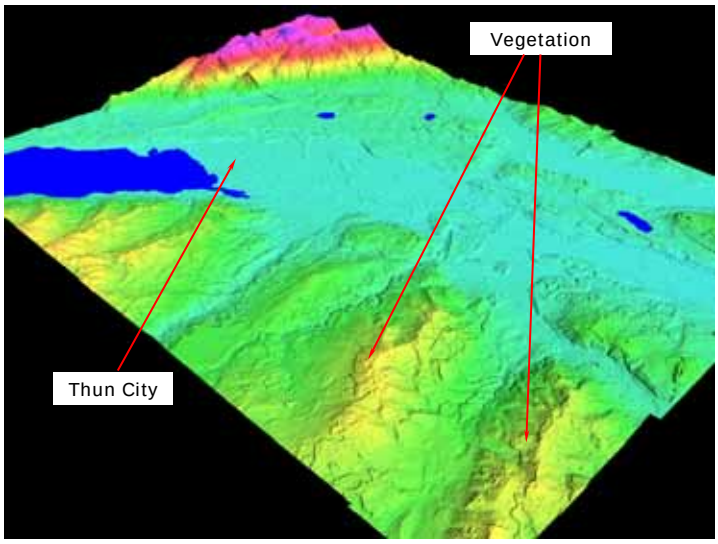
Application Case 2: IKONOS over Thun, Switzerland



Original IKONOS Image | Enhanced IKONOS Image

Photogrammetric software – SAT-PP

Application Case 2: IKONOS over Thun, Switzerland



5 m Grid DSM Generated from 5 IKONOS Images

Image Orientation Accuracy:

RMS-X: 0.48 m

RMS-Y: 0.82 m

RMS-Z: 0.79 m

DSM Accuracy Test Results:

(With 2 m Reference DSM generated from LIDAR)

Whole Area: RMS: 4.8 m

City Area: RMS: 2.9 m

Open Area: RMS: 1.3 m

Photogrammetric software – SAT-PP

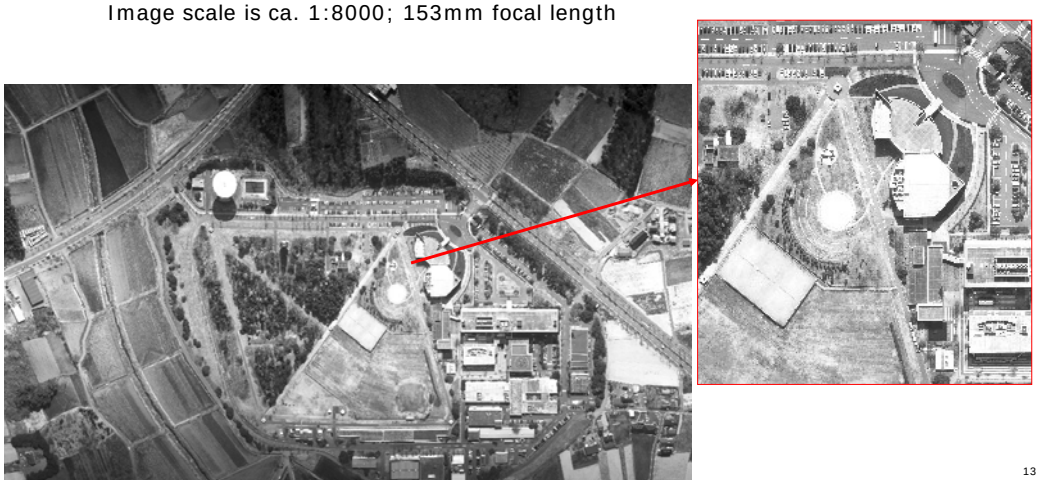
Test area: GSI (Geographical Survey Institute) Test Field, Tokyo

StarImager helicopter camera (TLS)

Footprint: 5.6 cm

Colour aerial photos (2 stereo pairs):

Image scale is ca. 1:8000; 153mm focal length



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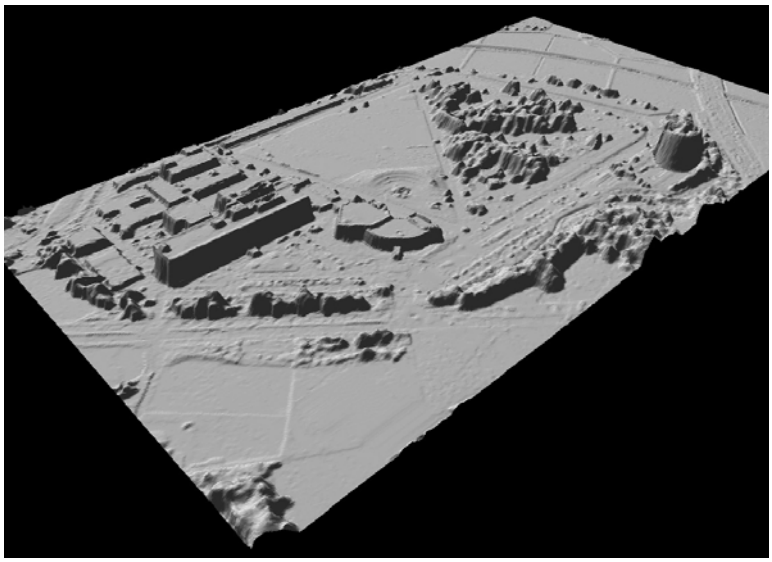
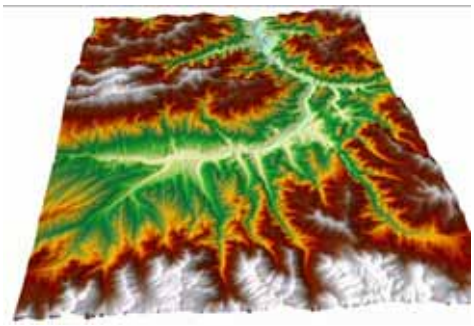
Photogrammetric software – SAT-PP

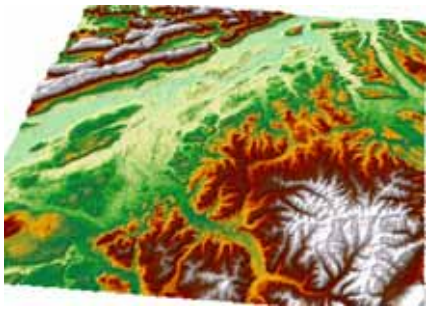


15 cm DSM

Photogrammetric software – SAT-PP



2.5 m SPOT5-HRG

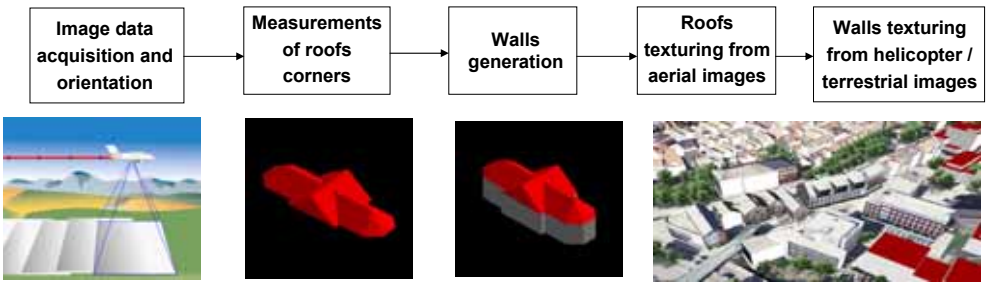


15 m ASTER

Photogrammetric software – CC-Modeler

http://www.cybercity.tv

- Software for precise extraction of buildings from aerial images or high-resolution satellite imagery
- Semi-automated approach to recover all the fine details of the roofs
- Cybercity AG company -> spin off of IGP-ETH Zurich



Photogrammetric software – CC-Modeler

http://www.cybercity.tv

Los Angeles downtown, USA

Photogrammetric software – CC-Modeler

http://www.cybercity.tv

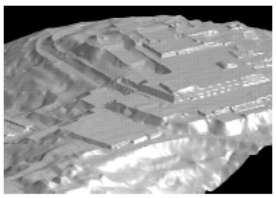
Salzburg, Austria

Photogrammetric software – CC-Modeler

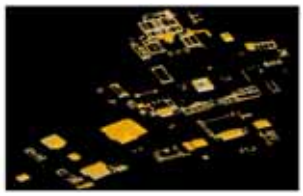
http://www.cybercity.tv

The pre-hispanic site of Xochicalco, Mexico

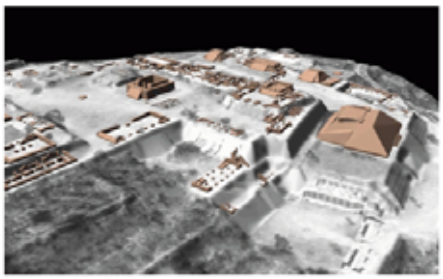
Aerial view
(stereo pair, 1:3000)

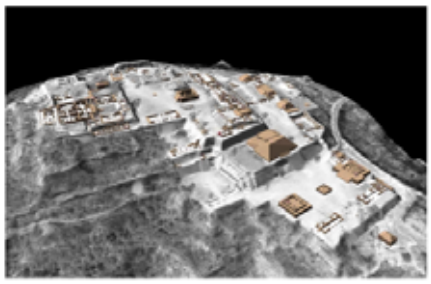


Produced Digital Terrain Model



Extracted buildings



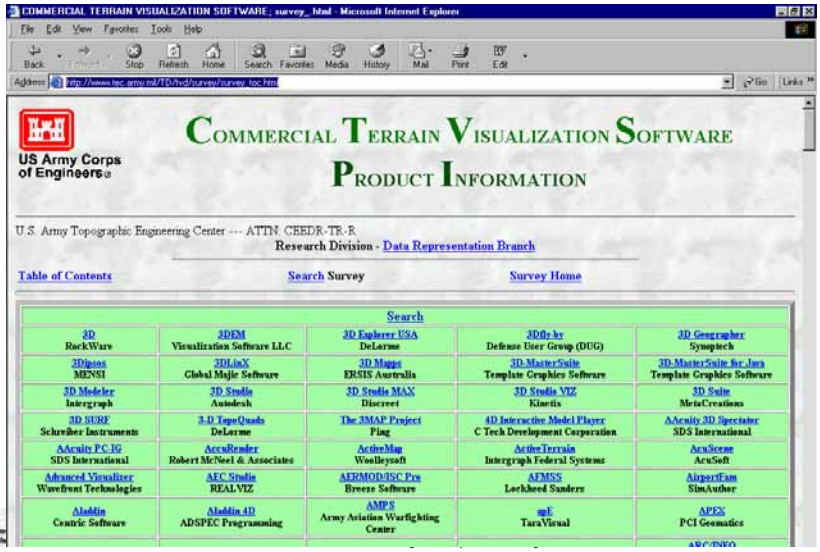


Textured DTM with overlaid buildings

DTM / DSM Visualization

http://www.tec.army.mil/TD/tvd/survey/survey_toc.html

more than 550 software for terrain visualization



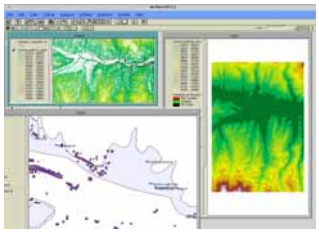
Visualization & GIS software

- ArcGIS
- ArcView

- Maya
- 3D Studio Max

- VirtualGIS
- Skyline
- TerrainView

DEMO



Photogrammetric data & (3D) Engine

3D ENGINE:

- software that combine earth 3D model, images and vector data ('geodata')
- data coming from different space agency (EuroImage, DigitalGlobe, NASA, WorldSAT)
- 3D (in reality 2.5D) or 2D viewer
- streaming technology

Free tools:

- Google Earth
- NASA Wind
- EarthSlot / Skyline
- GeoFusion
- Virtual Earth
- Yawaha
- ...

TerrainGlobe (Viewtec)

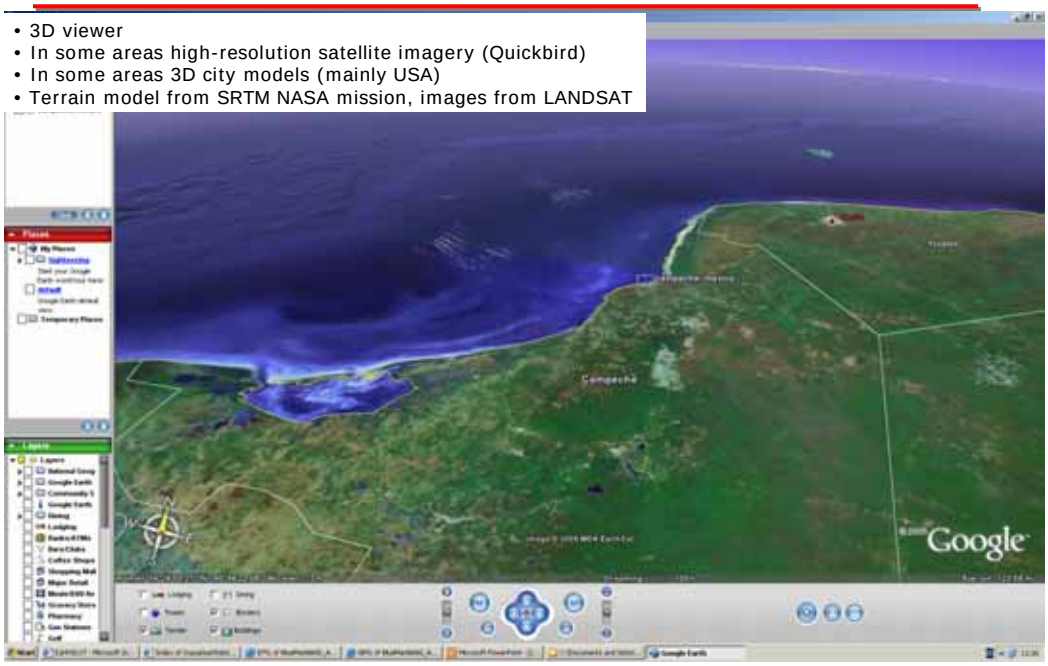
Other commercial tools where it is possible to import your own data (e.g. city models, vector layers, etc.):

- ArcGlobe (ESRI)
- TerrainGlobe (Viewtec)
- GoogleEarth Pro
- ...

Google Earth

http://earth.google.com/

- 3D viewer
- In some areas high-resolution satellite imagery (Quickbird)
- In some areas 3D city models (mainly USA)
- Terrain model from SRTM NASA mission, images from LANDSAT

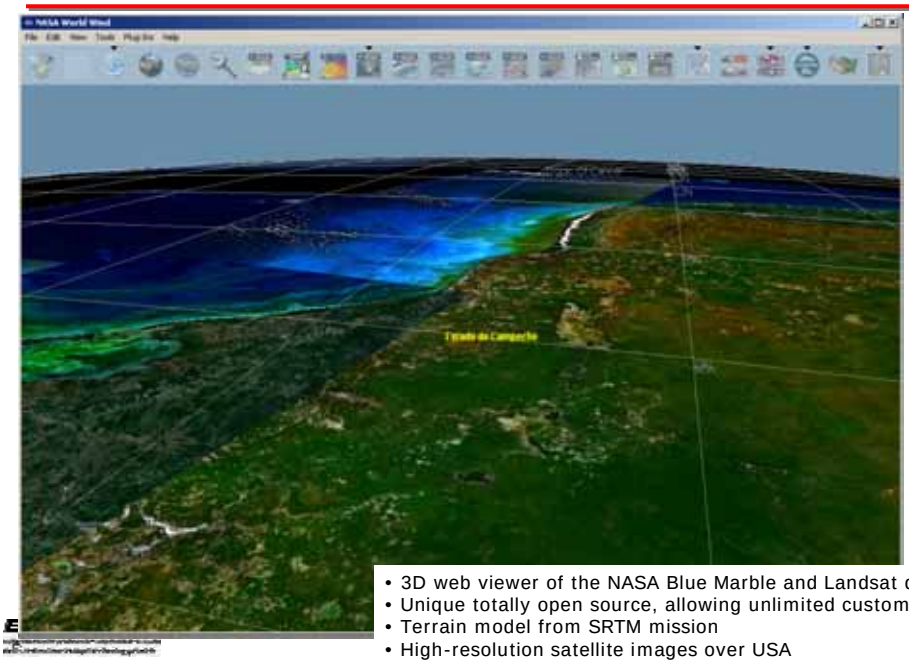


Google Earth

- 3D city models of some cities
- Google Earth Pro allow you to import your own data

NASA Wind

http://worldwind.arc.nasa.gov/

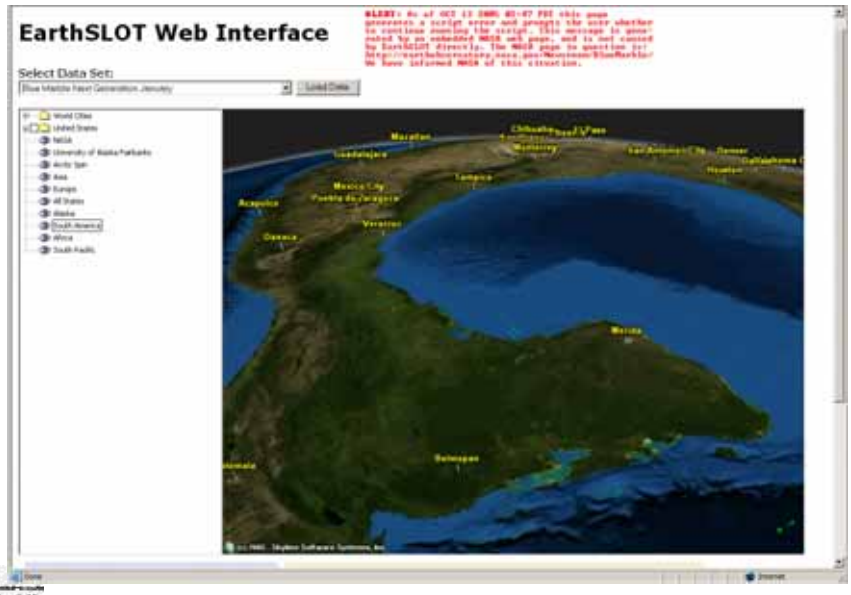


- 3D web viewer of the NASA Blue Marble and Landsat data
- Unique totally open source, allowing unlimited customization
- Terrain model from SRTM mission
- High-resolution satellite images over USA

EarthSLOT Web Interface

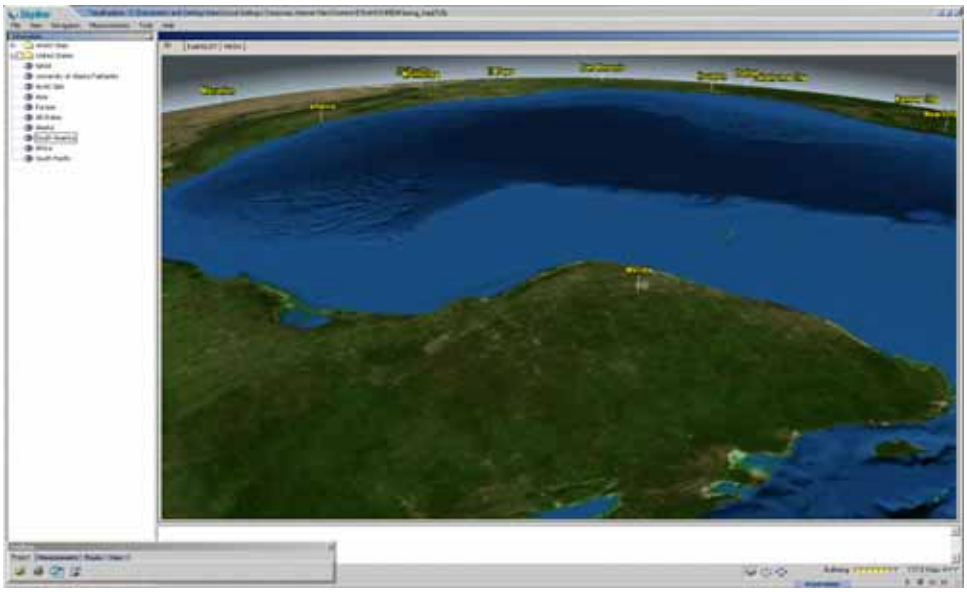
http://eslot.engr.uaf.edu:8181/eslot_web_interface.html

- 3D web viewer of the NASA monthly data using Skyline 3D engine



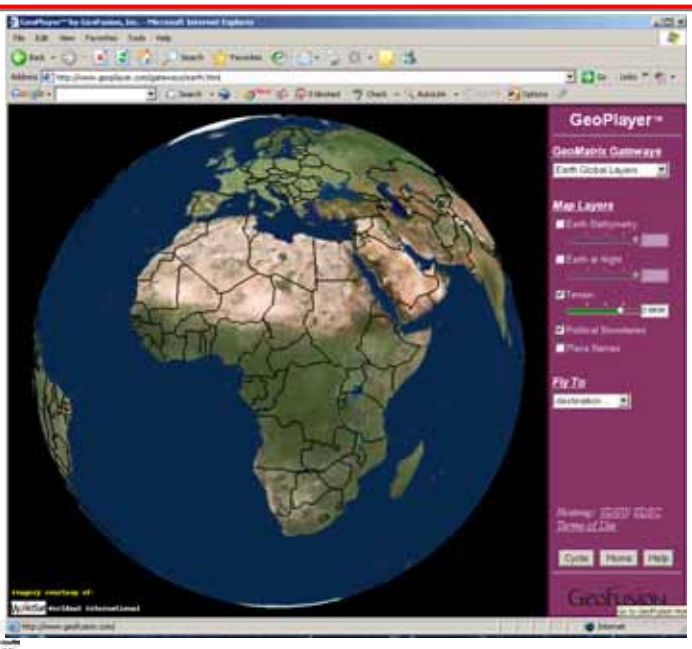
Skyline – Terra Explorer

http://www.skylinesoft.com



GeoFusion

http://www.geoplayer.com

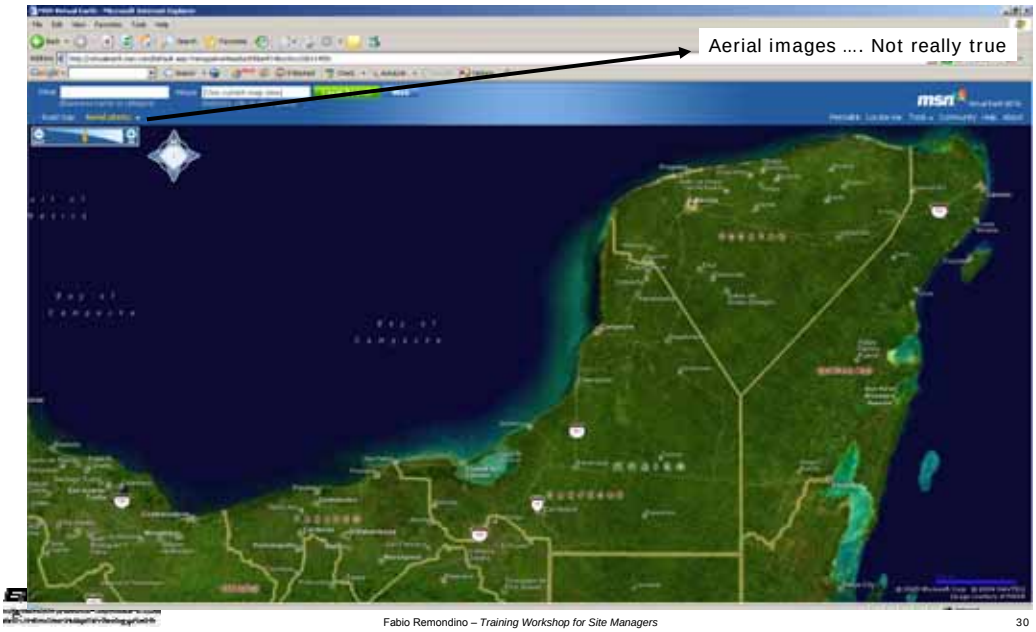


VirtualEarth

http://www.virtualearth.msn.com

- 2D view
- Satellite data
- Aerial images over USA

VirtualEarth



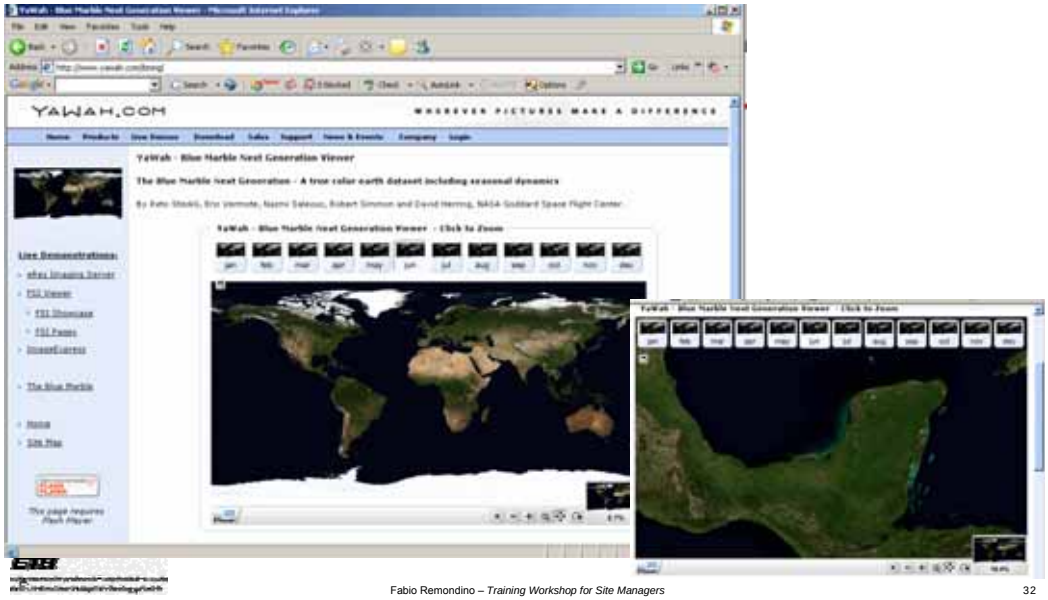
VirtualEarth

- Aerial images …. over US

Yawaha

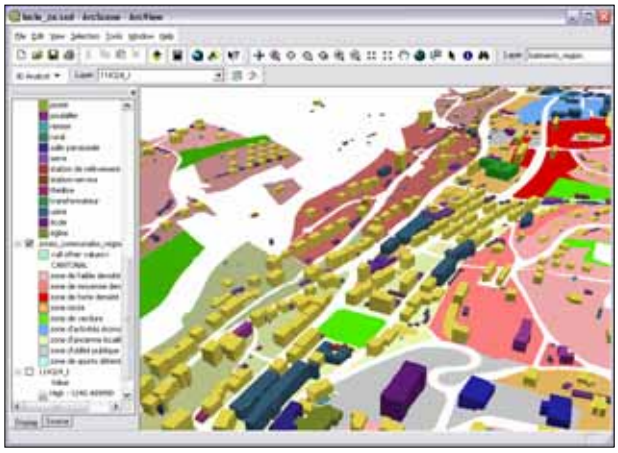
http://www.yawah.com/bmng/

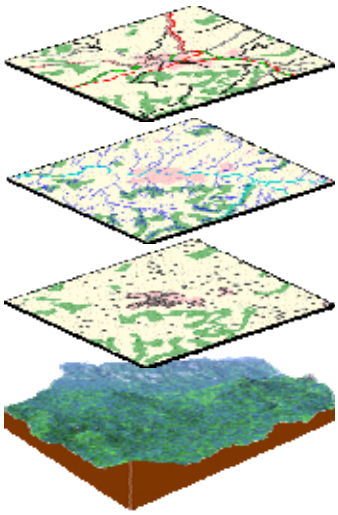
• Monthly 2D viewer of the NASA data (Blue Marble, 500 m)



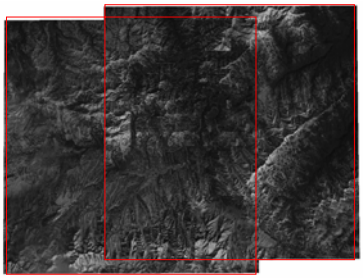
From 2D data to 3D models and GIS

Data acquisition: satellite, aerial (terrestrial) imagery
Data processing: DTM generation, features extraction, …
GIS creation: DTM, isolines, features, …



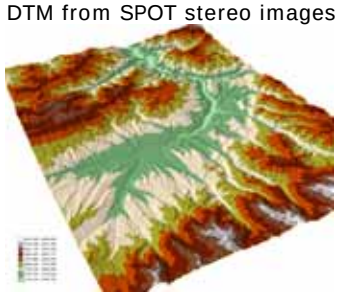


From 2D data to 3D models and GIS – The Bamiyan Project



SPOT5 stereo scene

DTM from SPOT stereo images

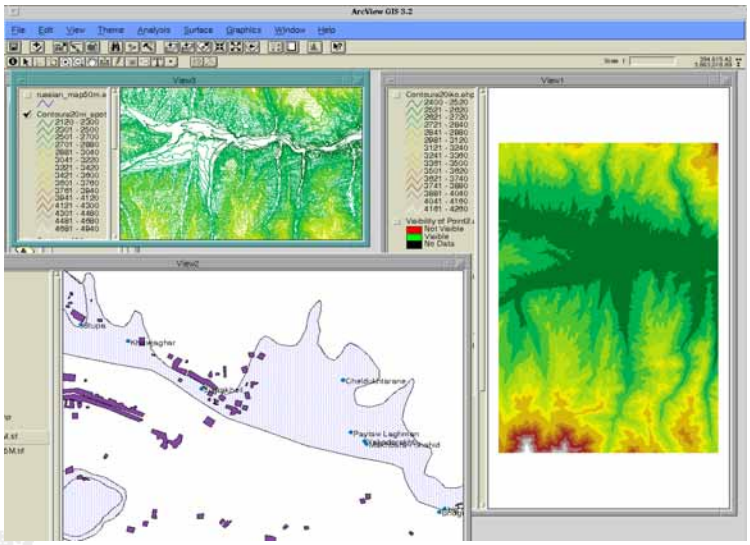


IKONOS mosaic

Textured DTM with IKONOS imagery

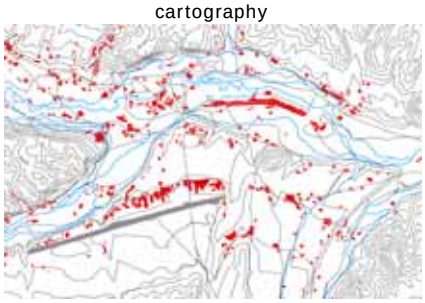
From 2D data to 3D models and GIS – The Bamiyan Project

The recovered 3D photogrammetric data are imported in GIS software for further documentation, classification, etc.



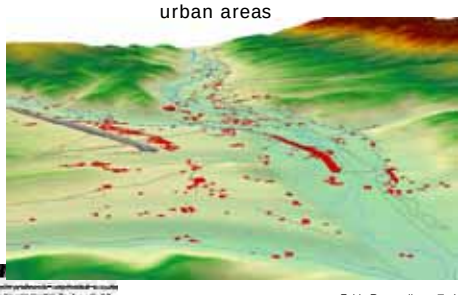
From 2D data to 3D models and GIS – The Bamiyan Project

cartography



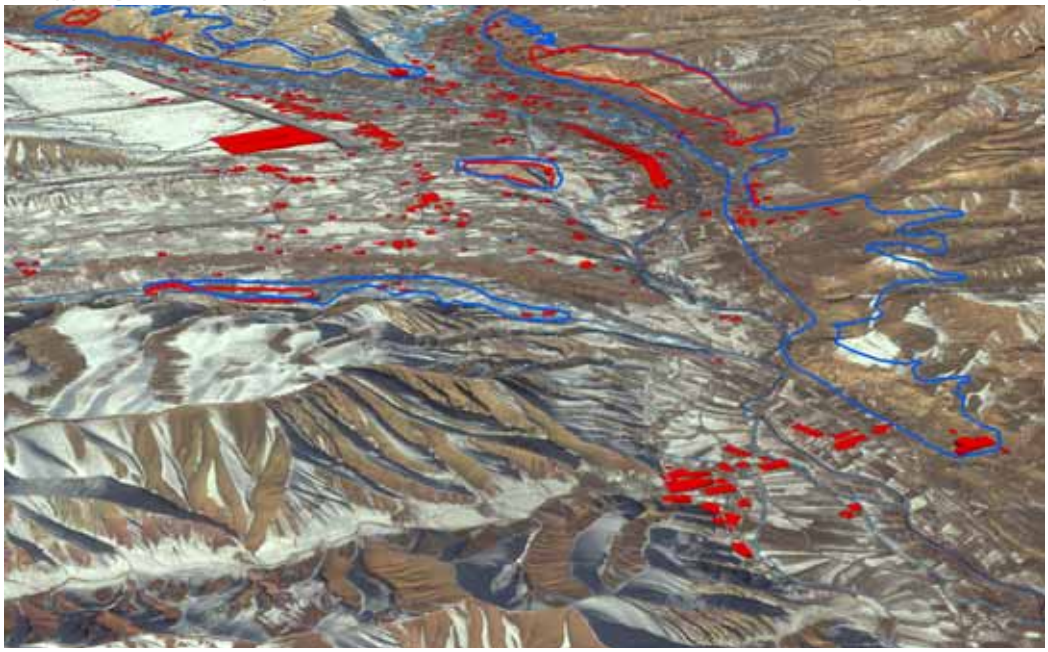
UNESCO protected zones

urban areas



3D buildings, streets, rivers

Bamiyan, Afghanistan –
Mapping UNESCO protected areas, urban and natural vector layers



Bamiyan, Afghanistan –
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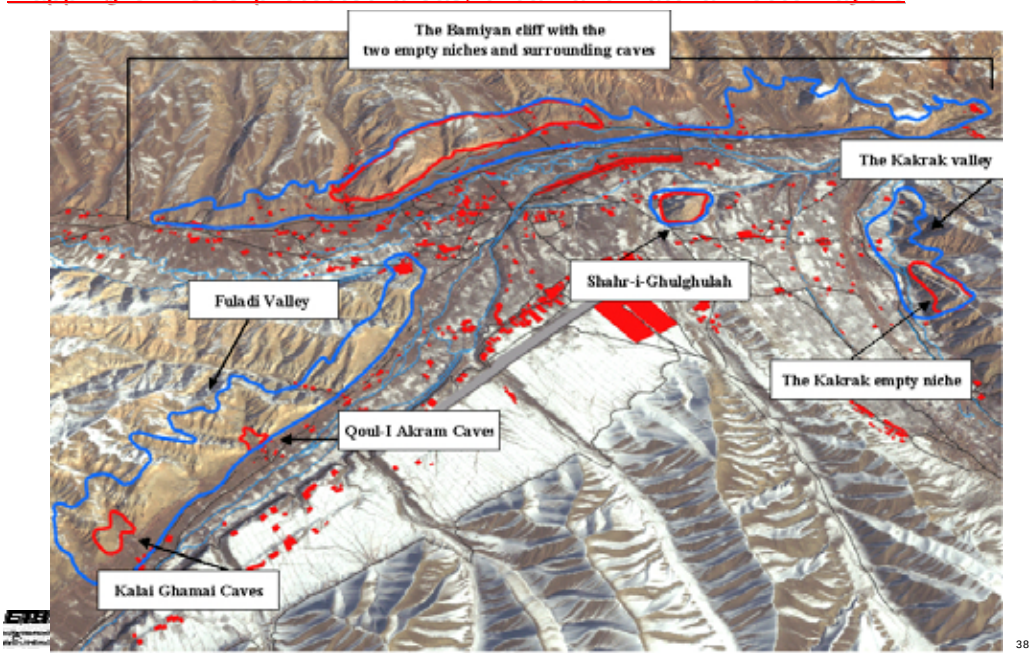

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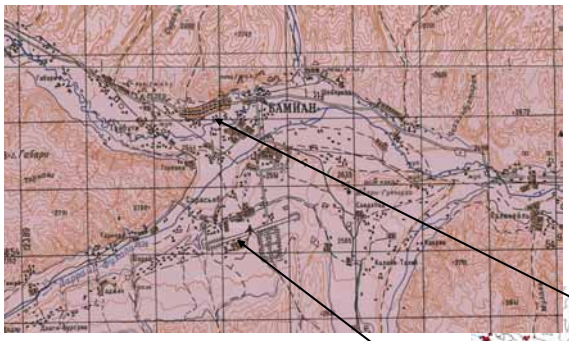
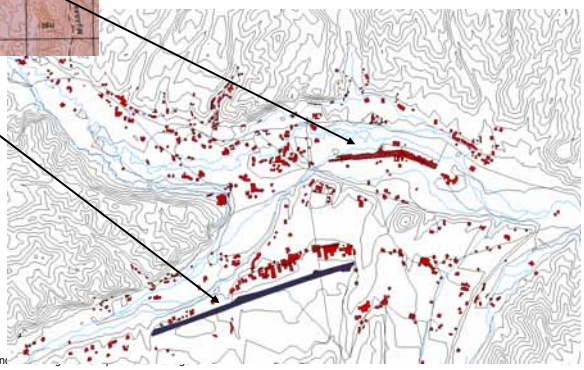
Bamiyan, Afghanistan



Russian Map (1970's)

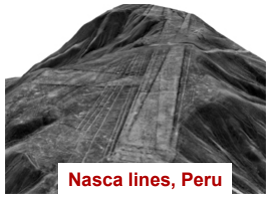
New cartography (2003)



Photogrammetric 3D modeling of natural & C.H. areas

- Bamiyan, Afghanistan
- Nasca, Peru
- Machu Picchu, Peru
- Angkor Wat, Cambodia
- Tucume, Peru
- Everest
- La Libella, Ethiopia


Mount Everest


Nasca lines, Peru


Ayers Rock, Australia


Lalibella, Ethiopia


Bamiyan Buddha, Afghanistan

Bamiyan, Afghanistan

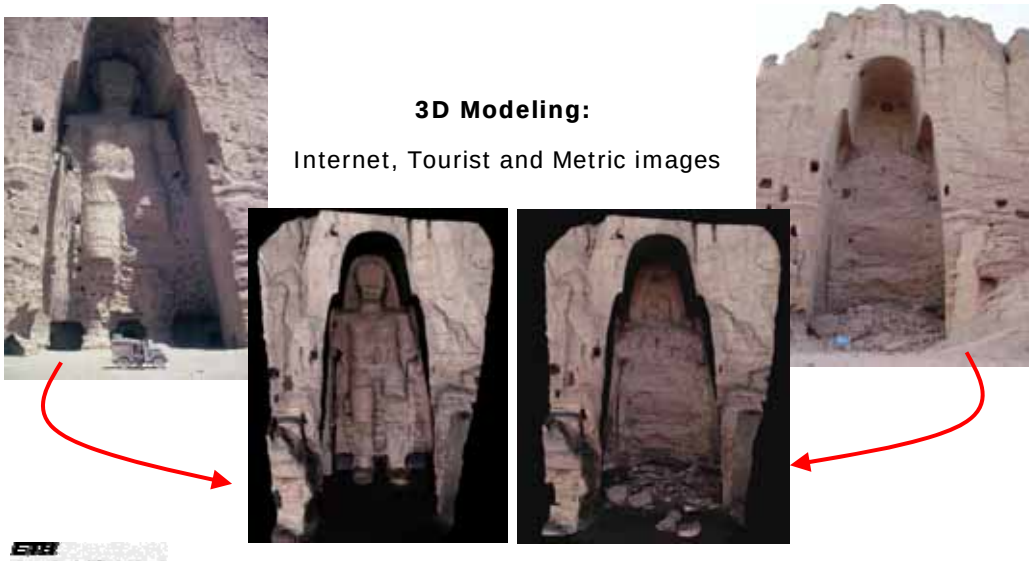
- Bamiyan, 200 km N-O di Kabul
- Area rich of Buddhist monuments, in the middle of the 'Silk Road'
- Destruction in 2000/2001
- Included in UNESCO World Heritage List since 2003 [http://whc.unesco.org]

Bamiyan, Afghanistan - The Great Buddha and its empty niche

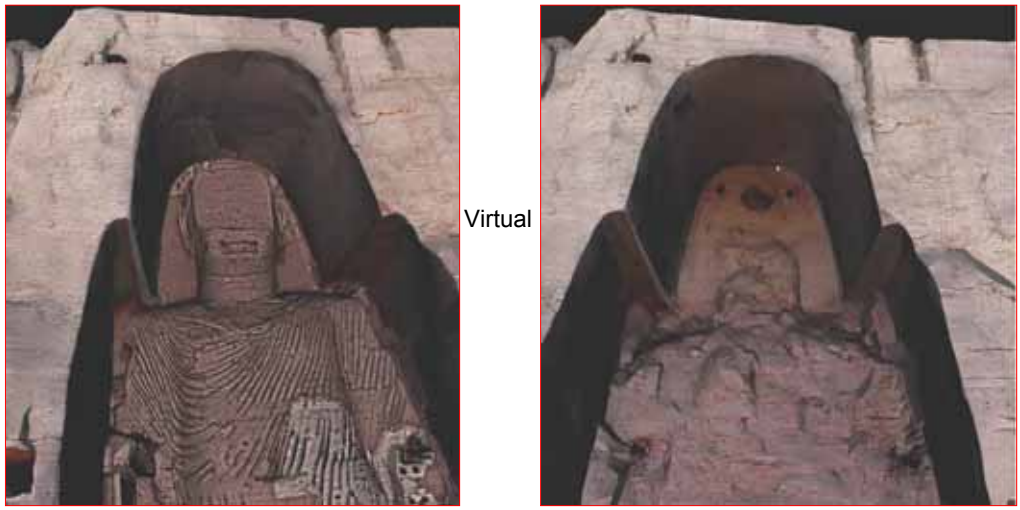
Before March 2001:
- 53 m high
- tallest representation of a standing Buddha
- niche full of frescos

After March 2001:
- empty niche
- no more frescos
- risk of collapse

Bamiyan, Afghanistan - The Great Buddha and its empty niche



Bamiyan, Afghanistan - The Great Buddha and its empty niche



Before March 2001 After March 2001

Bamiyan, Afghanistan - The Great Buddha and its empty niche

Bamiyan, Afghanistan - The Great Buddha and its empty niche

Bamiyan, Afghanistan - The Great Buddha and its empty niche

Bamiyan, Afghanistan

The Great Buddha and its empty niche

Bamiyan, Afghanistan - The Great Buddha and its empty niche

Archeology:
- Great Buddha statue of Bamiyan: is ANASTYLOSIS possible?

The leftover of the statue after the explosion are ca 60% of the original
→ **Anastylosis not really possible**

Bamiyan, Afghanistan - The Great Buddha and its empty niche

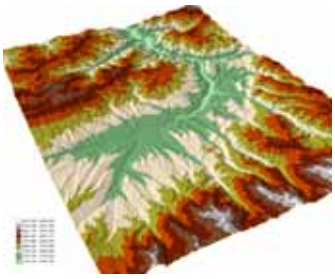
August 2003 | Virtual Reality

Film production
and
virtual reality

The Giant Buddhas movie:
http://www.giant-buddhas.com

Bamiyan, Afghanistan

More to come in the workshop's presentation on Wed. 30.11.2005

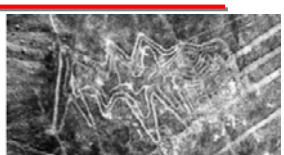


Nasca & Palpa, Peru

- Lines and figures drawn in the desert (geoglyphs)
- Unknown motivation, many hypotheses (astronomy, religion, water)

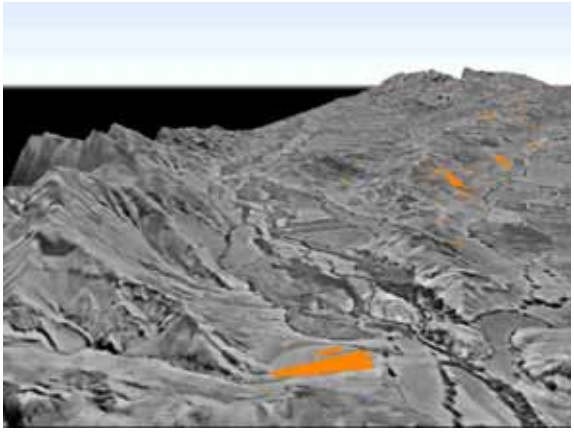
Project @ ETH:
→ ca 400 aerial images, 1:7000 scale
→ Mapping and archaeological analysis of the geoglyphs
→ Digital preservation as of 1998

So far, ca 700 geoglyphs mapped / documented

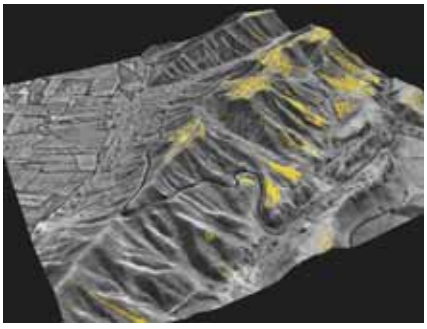


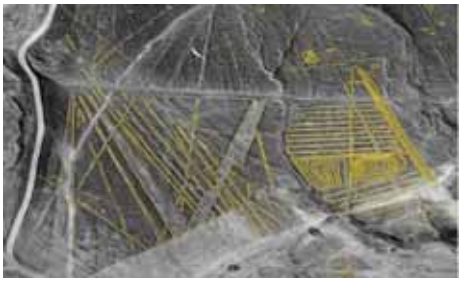
Nasca & Palpa, Peru

3D Modeling and Visualization



Virtual flight over the geoglyphs





Nasca & Palpa, Peru

GIS Visibility Analysis

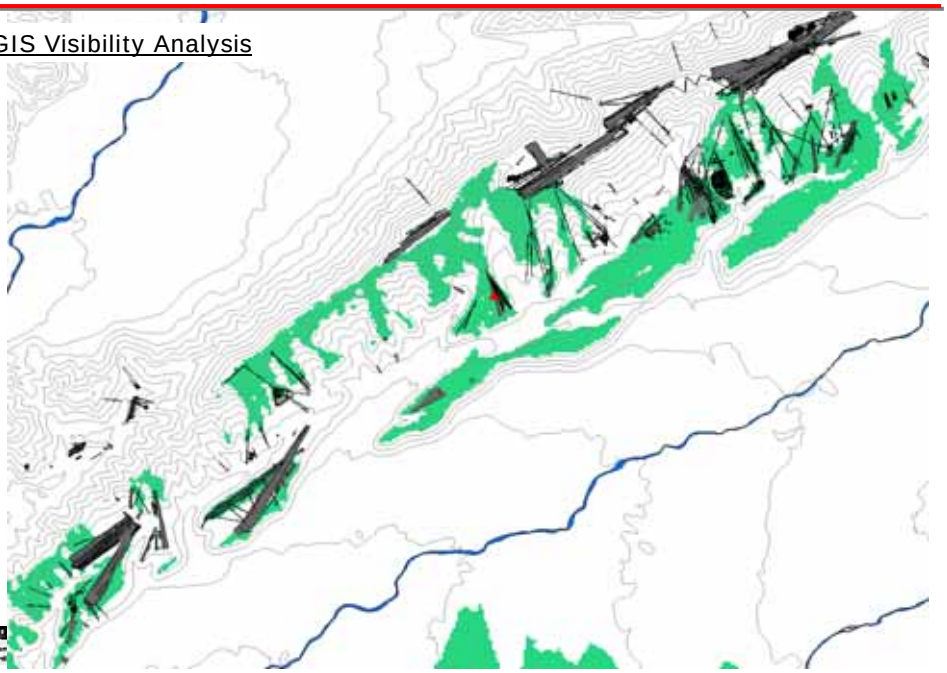
- Are geoglyphs really only visible from air?
- Is intervisibility between geoglyphs higher than between arbitrary points?

- Visibility analysis -

GREEN AREA = areas from where it's possible to see the RED DOT (e.g. the geoglyph)

Nasca & Palpa, Peru

GIS Visibility Analysis

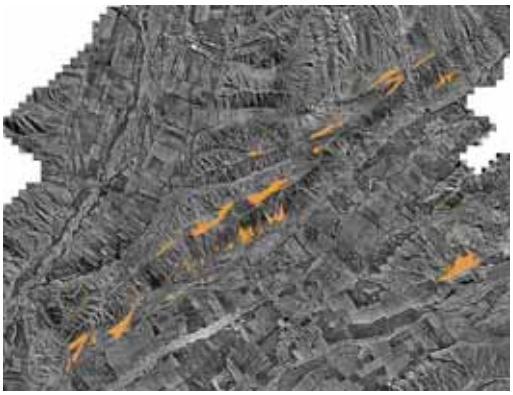


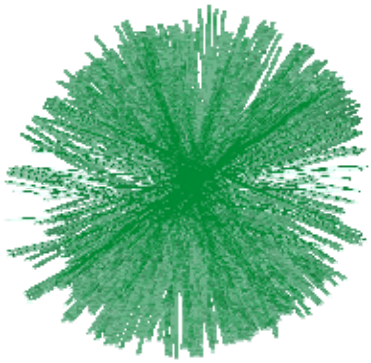
Nasca & Palpa, Peru

GIS Orientation Analysis

- Is there a relation between geoglyphs and topographic elements (e.g. mountains)?

Calculation of the center of gravity and main axis for 337 trapezoidal, linear, triangular and rectangular geoglyphs. Main lines are oriented in direction of the plateau and Perpendicular to it, directions towards the mountains could not be observed



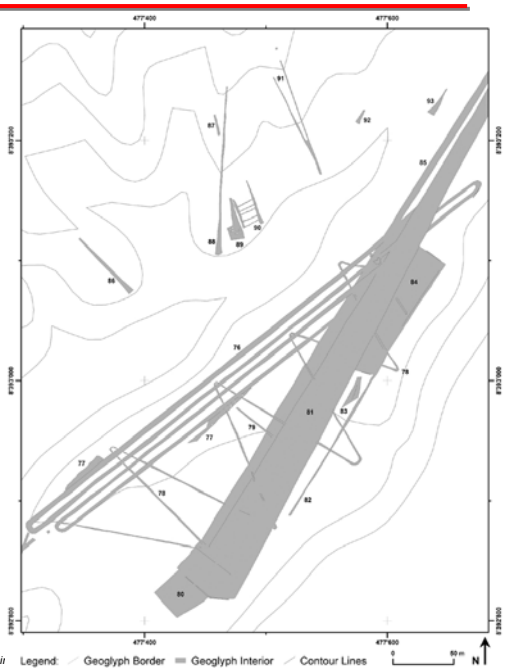


Nasca & Palpa, Peru

Photogrammetric Products

- First complete map of the region including the geoglyphs
- Supports the archaeological fieldwork
- Physical 3D model, shown in museum of Palpa
- Virtual 3D model, used for archaeological analysis and prospection

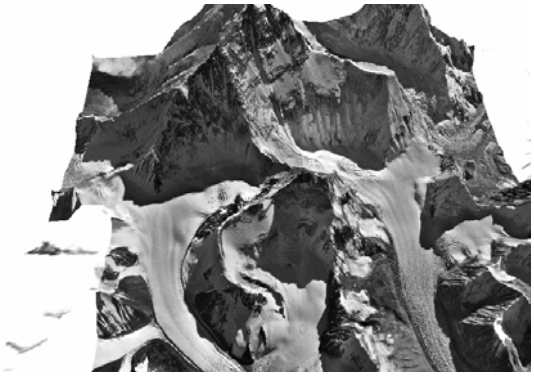
GIS Example



Mount Everest

- aerial images
- area around ‘Hilary Step’

→ 3D modeling & cartography
→ Animation (Discovery Channel)



Mount Everest

Real or Virtual?

Lalibella Church, Ethiopia

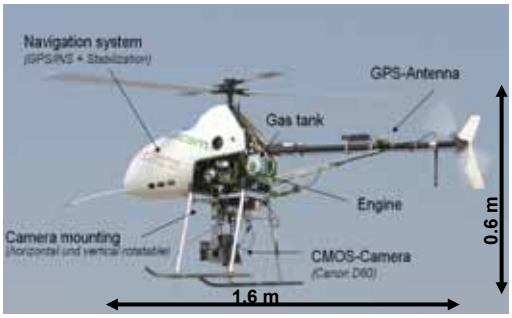
• old underground church
→ 3D virtual reconstruction for documentation & visulization using terrestrial images

Bayon Buddha, Angkor Wat, Cambodia

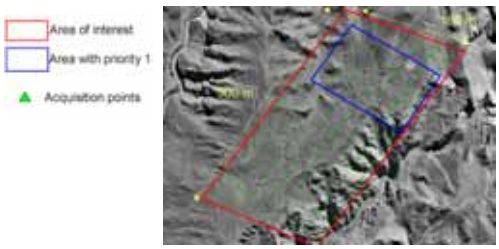
• UNESCO archaelogical area with ca 70 buddhist towers
• different temples covered by vegetation
→ 3D virtual reconstruction for documentation & visulization

Pinchango Alto, Peru

– Settlement and miner's workshop, close to Palpa
– Area of 200 x 300 m2
– Well preserved stone architecture abundant surface finds, and richly furnished graves dating to the Late Intermediate Period (AD 1000-1400)
– Defensive location high above the valley



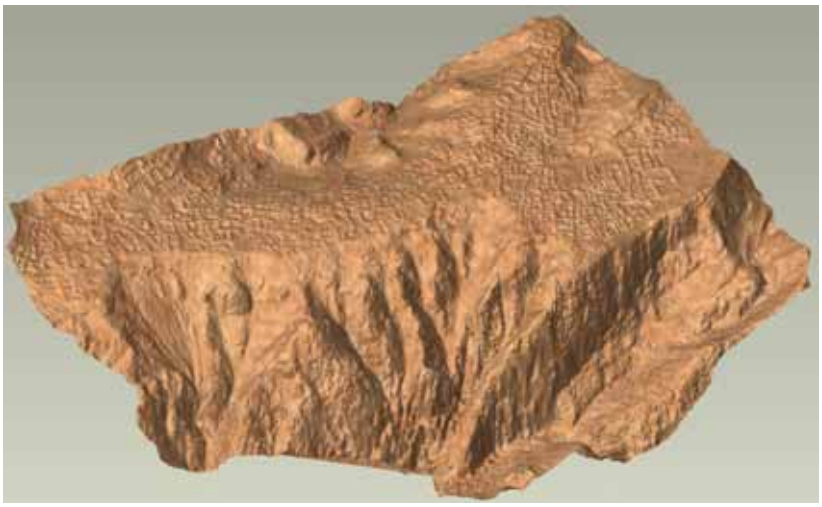
Pinchango Alto, Peru



- wePilot1000 system (a flight control system for UAVs from weControl)
  - Consists of GPS/INS system, altimeter & stabilizer
- Laptop with monitoring software (weGCS from weControl)
  - Ground support and control equipment
  - Handling, storage
- Camera (Canon D60), different lenses (14, 28-200 and 50 mm)
- Communication links
- Power supply
- Transport equipment

Pinchango Alto, Peru

Detailed 3D model of the area

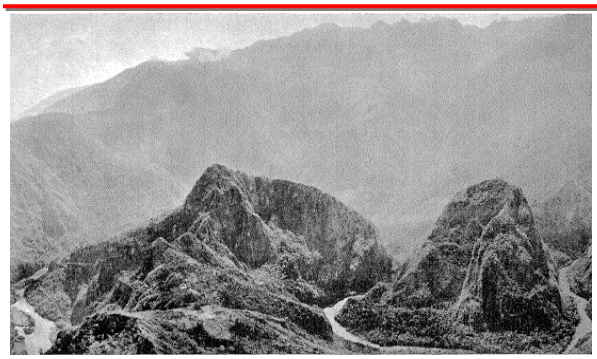


Machu Picchu, Peru

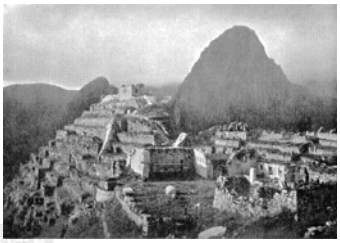
• archaelogical area of the Inca, unique survived to Spanisch invasion “Lost City of the Incas” (2430 m above sea level)
• build at the end of the fourteenth century, the city was still functioning in the middle of the sixteenth century.
• discovered by Hiram Bingham on 24.7.1911 and UNESCO World Heritage List since 1983
• in danger due to the high number of tourists
• modeling from aerial images; planned model helicopter flight
→ 3D virtual reconstruction for documentation & visulization

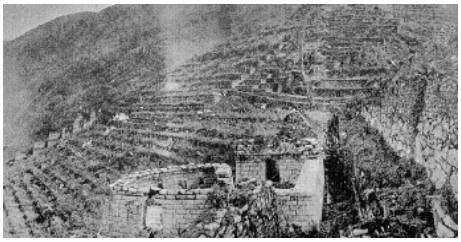
Machu Picchu (The old pick)

Machu Picchu, Peru

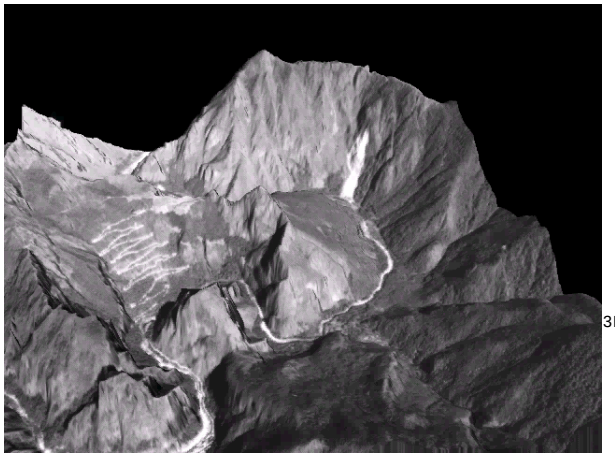


Source: Peruvian expedition 1912 - Machu Picchu and vicinity (Hiram Bingham)





Machu Picchu, Peru



3D model from aerial images (1:25000)

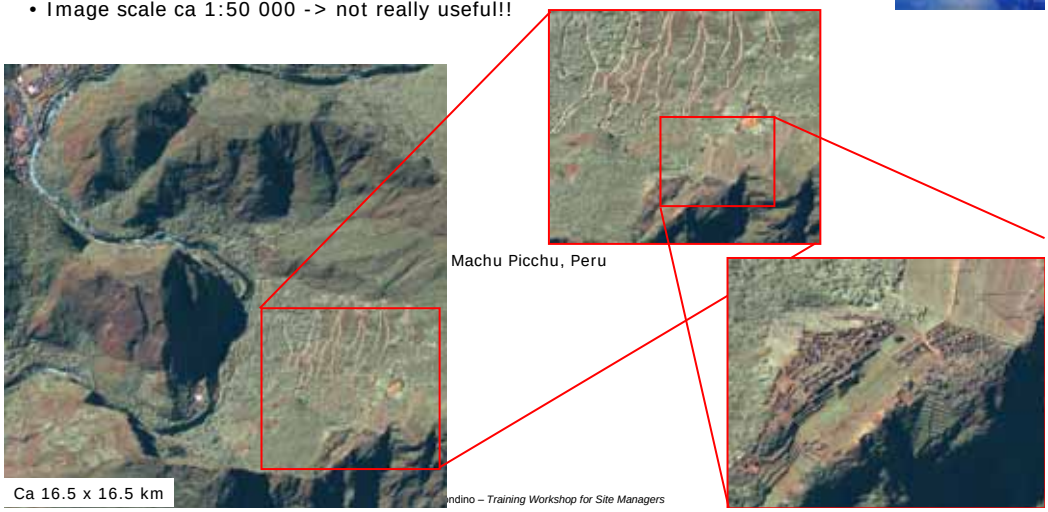
Virtual flight

Machu Picchu, Peru

http://www.digitalglobe.com/

What about using satellite images? Ex. Quickbird:

- Altitude: ca 450 km
- Revolution period: 93 min
- Revisit frequency: 1-3.5 days
- Sensors: 61 cm nadir Pan (up to 86 cm) + 2.4m multispectral
- Image scale ca 1:50 000 -> not really useful!!



Machu Picchu, Peru

Why should we use a model unmanned helicopter in Machu Picchu?

- Aerial images resolution not enough for detailed modeling and documentation of the buildings
- Large size and a high building density => occlusions
- The applied acquisition technique should provide high resolution images from various viewing directions
- Airplanes, Helicopters and Balloons are limited in maneuverability
- Autonomous model helicopter can operate close to the object, are highly flexible in navigation and can provide arbitrary viewing directions

Machu Picchu, Peru

Flight planning with unmanned helicopter:

• Scale:	1:4000
• Focal length:	28 [mm]
• Flying height:	112 [m] above ground
• Side and end lap:	75 % x 75 %
• Image resolution:	4k x4k
• Baseline:	36 [m]
• Distance between stripes:	24 [m]
• Exposure interval:	7.2 [s] between images
• Numbers of images:	8 stripes with 11 images/stripe
• Flying time:	1.5-2 hours

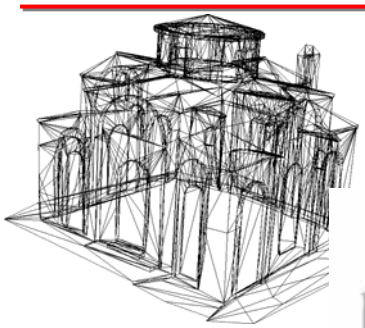
- Costs ca 1500 US $ / day (only hardware)
- To be added: pilot + operator + transport + gas + insurance

Ayers Rock, Australia

Tucume, Peru

- Area rich of adobe structures
- Use of aerial images of the 40's

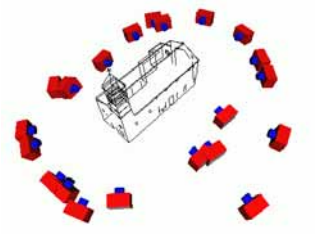
3D Modeling of terrestrial objects



16 images,
2 days of work

Courtesy of Sabry El-Hakim, NRC Canada

3D Modeling of terrestrial objects



21 images,
1.5 day of work

Conclusions

• Need of preservation and documentation of cultural heritage has become more and more important
• Adoption of modern and efficient technologies for data acquisition and processing
• P & RS well-suited technologies for (large) mapping and modeling
• Reality-based 3D virtual reconstruction
• Derived data as basis for:
- ✓ animation & visualization
- ✓ archaeological analysis
- ✓ GIS application
- ✓ map production
- ✓ site maintenance and reconstruction
- ✓ etc.

http://www.photogrammetry.ethz.ch
fabio@geod.baug.ethz.ch