3D glacier monitoring with historical aerial images - from 1954 to today

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Geoprocessing and Archiving of historical aerial images, Paris, 3-4 June, 2019
Outline

- Partners & Project aims
- Data analysis
- Approaches for 2D/3D
- Results
- Remarks & Conclusions
3D Glacier monitoring with historical aerial images - from 1953 to today. Paris, 3rd June, 2019

Portrait AVT

- Vermessung **AVT-ZT GmbH**
  - Mapping company founded in **1970**
  - HQ in **Imst**, Tyrol / Austria
  - About 100 employees
  - Active in all branches of surveying

- Since 2019: **AVT Airborne Sensing**
  - Former Terra Messflug GmbH and Weser
  - 25 people
  - Various **sensors** and **platforms**
  - Broad range of **projects**
    - Photo flights in **Europe** (2-22 cm GSD)
    - Country-wide orthophotos
    - Historical aerial data processing
    - High-resolution surveying
    - Lidar mapping with detailed classification
    - Terrestrial and indoor mapping
• **MUSE** is the Science Museum of Trento, Italy, an auxiliary body of the Autonomous Province of Trento.
Glaciology activities @MUSE

- Glaciers monitoring:

Cadastre of Italian glaciers

Mass balance «direct» method

Mass balance Geodetic method

Glaciers perimeters From orthophotos and RS

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Current situation in Trentino:
- 128 glaciers
- Size 77 km²
- Adamello, largest in Italy

Monitoring of:
- Perimeters (2D):
- Volumes (3D):
  - 1954/2015

Inclusion of 2D/3D data from 1954
Photograms on Province of Trento:
- About 300 photograms, 23 cm x 23 cm
- Cameras: XF311 with f=153.16, XF353 with f=153.89, KF7660, with f=153.34

Acquisition:
- August / October 1954 by US Aviation
- Mean scale 1:55.000, overlap 60%-30%
- Coverage: Province of Trento, 150 – 3.500m

Scanned by IGM at 2.400 dpi
- GSD 58,8 cm
Photograms quality

Scanning errors

Scratches
Photograms quality

Expected errors
Not dramatic for:
- IO/EO estimation
- Orthophoto production

Masks

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• Additional crucial errors for the glacier project!
  • Low radiometric quality

Saturation

Dark shadows
Other data

- Technical maps, edition 1998
  - DTM 10m x 10m generated from 1998 technical maps
- DTM 5m x 5m from LiDAR, edition 2009
- Technical maps, edition 2013
- Historical maps from IGM:
  - scale 1:25,000
  - From flights in 1954, 1959 and 1961
AVT Aerial flight 2015

- Photogrammetric flight on the glaciers, 21/09/2015
  - GSD 8 cm, 80/60, 116 km²

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Aerial flight 2015

• 3D glacier modelling by DIM, grid 10 cm for DSM and TrueOP

Adamello glacier, 2015
• Manual measurement of fiducial marks

---------------------------------------------
Interior Orientation
Done by: FB
Date: 06:02:12 21/11/2018
Image: 10_3255
File: R:\Projekte\31854_HDOP_Trentino\30_Bilder\10_3255.tif
Type: Manual
---------------------------------------------

Image coordinates
Fiducial from camera file Residuals Measured pixel coord.
Mark x [mm] y [mm] vx [mm] vy [mm] column [pix] row [pix]
1 -119.0000 0.0000 -0.1903 -0.0060 22568.0000 11326.0000
3 117.0000 0.0000 -0.1949 -0.0061 250.0000 11300.0000
4 0.0000 -116.0000 0.1926 0.0061 11290.0000 318.0000
2 0.0000 116.0000 0.1926 0.0061 11266.0000 22310.0000

---------------------------------------------
Transformation 6 Parameter (2 rot., 2 scale)
Origin [mm] 119.5791 -119.2099
Scale 0.0106 0.0105
Rotation of Axes [grad] -199.9261 0.0696
Sigma0 [mm] 0.2725
r.m.s. [mm] 0.1363
---------------------------------------------
• Ground points collection from:
  • Previous projects (few)
  • Public database of fiducial points from Province (mainly churches)

• AT with 13 GCPs, RMSE: 1.49 m (X), 1.18 m (Y), 1.40 m (Z)

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• All Province of Trento, ~6.230 km², GSD 1m

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## 2D Perimeter Temporal Analysis – Adamello Glacier

### Year | Surface
--- | ---
1850 | 30.00 km²
1954 | 19.04 km²
1983 | 18.16 km²
2003 | 16.30 km²
2015 | 15.24 km²
Historical 3D glacier modelling

Classical stereo photogrammetry
- Stereo measurements of mass points and breaklines + Interpolation
- Manual, expertise required

Historical maps digitalization
- 2D digitalization in GIS environment + Interpolation
- Manual, precision depends on maps, training required

Image Matching
- Good AT and overlap required
- Automatic

Test on Caseres

Test on Busazza
Glaciers outlines in 1954 (~ 5 km$^2$) and 2015 (1,63 km$^2$)
3D & Image quality: test on Caseres

Digitized contour lines, 2 sets of stereo measurements with same operator
3D & Image quality: test on Caseres

- Generation of 3 independent DEMs
- Significant differences in manual stereo models!
  - overexposed areas, higher elevations with low structure and very homogeneous surface
• Test on Dense Image Matching
  • 3 images
  • AT accuracy around 1 m
  • Two commercial softwares

• Unsatisfactory results:
  • Noise
  • Not reliable estimated coordinates

• Possible reasons:
  • Insufficient overlap
  • Low radiometric quality

• Successful approach in 2015 flight
3D Temporal comparisons

• Comparisons between 1954 (stereo) and 2015
3D Temporal comparisons

- Comparisons between 1954 (contour lines) and 2015
3D information extraction

Unique approach not possible with low resolution aerial images

Manual measurements
- Image quality acceptable in small distinct regions
- Historical maps not available

Dense Image Matching
- Image quality acceptable in large regions

Contour line digitalization
- Image quality not acceptable
• Glaciers classification according to data availability and quality

• Method definition for each area
Remarks & Conclusions

• Photogrammetry as a useful tool for glaciologists for historical (and current) glacier monitoring:
  • Larger extent, reduced field work, continuous (vs punctual) information

• Glacier delimitation:
  • 3D stereo measurements improve the information from 2D orthophoto digitalization in several critical situations
  • Topographic maps do not always agree with the source aerial images, in case of Careser below 2.800 m

• 3D (height, volume) analysis:
  • Very high value information from historical images!
  • No other comparable source
Remarks & Conclusions

- Historical aerial images
  - Standard processing feasible (i.e. AT, OP, stereo plotting)
  - Main shortcoming: low radiometry on glaciers
  - DIM might be successful on other datasets

- Heterogeneous approach for 3D data extraction, according to data quality and availability

- Future steps:
  - completion of the modelling on the other glaciers
  - DIM tests on other historical flights

Thank you for your attention!