CLOUD-BASED TIME SERIES PROCESSING OF VERY-HIGH RESOLUTION OPTICAL IMAGES FOR LANDSLIDE SURFACE DEFORMATION QUANTIFICATION

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IDEX Université de Strasbourg
‘Par delà les frontières de la connaissance’
LANDSLIDE MONITORING WITH VHR OPTICAL IMAGES

Increasing availability of VHR optical satellite images at both higher spatial resolution and revisit time

Methodology to be developed, especially for:

- WV-2/3/4: 0.4 m
- Pléiades: 0.7 m
- Spot-6 & Venúss: 1.5 m
- Sentinel-2: 10 m
LANDSLIDE MONITORING WITH VHR OPTICAL IMAGES

- Recent studies with Pléiades VHR images show that accuracies in the displacement measurements of 10-15 cm are feasible (Stumpf et al., 2014; Lacroix et al., 2015).

Stumpf et al. 2014 – Slow moving landslides driven by hydrological conditions

- Allows area wide monitoring to study interactions between controlling factors

Lacroix et al. 2015 – Slow moving landslides driven by seismic ground shaking.
Limitations: Still many false positive detections and thus not yet suitable for a reliable detection of new / reactivated / unknown unstable slopes

- Existing filtering strategies (e.g. masking of vegetation) are still rather ad hoc
- Spatial filtering
- Yet, no strategies to exploit temporal information (stacks of optical images) from time-series of satellite images
STUDY SITE AND DATASET

Ubaye valley – Southern French Alps – Several slow moving landslides
4 stereo pairs and 1 monoscopic Pléiades image (other acquisition in progress)

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PROCESSING STRATEGY: WORKFLOW

a, b, c > Erdas LPS (commercial software, cloud-based processing)

- Tie points detection
- Bundle adjustment

No ground control required

b

Image Left

Image Right

P

M2

M1

Stereo-photogrammetry

Measured parallax shift

Orthorectification

DSM

Surface reconstruction and landslide displacement measurements with Pléiades satellite images

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PROCESSING STRATEGY: WORKFLOW

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b

Image Left → Image Right

M2 → M1

Measured parallax shift

Stereo-photogrammetry

d, e > open-source implementation (HPC UNISTRA)

d

Post-processing

Image-correlation

Orthorectification

Ortho-rectification
PROCESSING STRATEGY: REDUCTION OF FALSE POSITIVE DETECTIONS

Test of several image correlation techniques: example at S.-Sauze

Robustness

Speed

Runtime scaling

CIAS (Kääb and Vollmer, 2000)
Cosi-Corr (Leprince et al., 2007)
Mic-Mac (Deseilligny et al., 2013)
PROCESSING STRATEGY: REDUCTION OF FALSE POSITIVE DETECTIONS

How to exploit temporal information?

Hypothesis: Errors in the DEM (h) will propagate into ‘false’ displacement measurements ($D_{EO}$)

$D_{EO} = h^*(\tan(\theta_1) - \tan(\theta_2))$

- $h$ is unknown, and highly variable on the scene
- however, if $h$ is constant or normally distributed around zero mean, $D_{EO}$ should approach a mean of zero over time and for multiple pairs
PROCESSING STRATEGY: REDUCTION OF FALSE POSITIVE DETECTIONS

How to exploit temporal information?

b. Multiple pairwise image correlation (MPIC)

2012 2013 2014

Time

- Use of the redundancy of displacement measurements across multiple image pairs
- Multiple-pairwise matching requires high computational load
- Calculation of the vectorial mean ($\mu_D$) for the entire stack (N-S, E-W, NCC)

- Distributed calculation: use of up to 18 nodes (16 CPUs each) reduces processing time from 18 days to 1 day

HPC UNISTRA
PROCESSING STRATEGY: REDUCTION OF FALSE POSITIVE DETECTIONS

How to exploit temporal information?

- Domain knowledge: the direction of the movement is relatively stable over time
- Calculation of a focal PCA (fPCA) to identify the persistent direction of displacement

Stable terrain

![Graph showing stable terrain with PC1 and PC2 axes, variance, and mean ratios.]

Landslide

![Graph showing landslide with PC1 and PC2 axes, variance, and mean ratios.]

for non coherent displacement over time

for coherent displacement over time
RESULTS: EXAMPLE AT LA VALETTE

Vectorial mean $\mu_D$

PCA-based mean $R_D = \frac{\mu_{D^+}}{\mu_{D^-}}$

Ground truth

ROC analysis

Better performance of the proposed technique
RESULTS: REGION SCALE

Detection of numerous small landslides around Super-Sauze
RESULTS: REGION SCALE

Robust detection in vegetated areas
RESULTS: FIELD SURVEYS FOR VALIDATION

Historical image (1904)

2015 07 26

2015 07 26
RESULTS: FIELD SURVEYS FOR VALIDATION
DISCUSSION AND PERSPECTIVES

- The developed methodology allows to exploit redundancy of stereo-acquisitions and temporal persistence of landslides (and other gravitational processes) -> mapping / monitoring

- High computational loads are solved using cloud-based and HPC infrastructure

- To do …

  - Assessment of measured displacement against other displacement time series

  - Test/Validate the methodology on other EO products

  - Use open-source tools for photogrammetry (Mic-Mac) to enable an end-to-end processing chain
