Noise Reduction Algorithm for Mobile LiDAR Data of Sand Ripples in Intertidal Zones of Beaches

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Outline

1. Data acquisition research group projects
2. Mobile LIDAR beach vehicle
3. Classical grid filtering
4. Advanced noise reduction algorithm
5. Conclusion
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Archaeological heritage in the North Sea

http://www.sea-arch.be
The CREST project aims to increase the knowledge of coastal processes near the coast and on land. This project with primarily a social finality is part of the Strategic Basic Research (SBO) programme of the Flanders Innovation & Entrepreneurship and runs from 1 November 2015 to 31 October 2019. There are ten partner institutions involved coming from the academic world, the Flemish government and the private sector.
- Homogeneous coast line
- 300 m between breakwaters
- Very fine sand (0.2 mm)
- 1.5 % slope
Geographic location of Belgium in Europe with detail map focused on the survey region of Raversijde.
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Comparison of several beach data-acquisition techniques

- Aerial LIDAR

- Conventional techniques used for data validation and quality assessment
  - *Global Navigation Satellite System (GNSS) measurements*
  - *Robotic Total Station*
  - *Static Terrestrial Laser Scanning (STLS)*

- Structure from Motion and Multi View Stereo (SfM & MVS) – Kite

- Singlebeam or multibeam echosounding

- Mobile Terrestrial Laser Scanning
Selected technique:

**MTLS (LIDAR)**, several test in cooperation with Prof. Nicolas SEUBE (formerly ENSTA, Brest, France, now CIDCO, Rimouski, CANADA)
Special Service Vehicle (SSV) Kymco UXV 450

Leica HDS 6100 (similar to Z&F 5006)
• Mobile Terrestrial Laser scanning using MTLS
  – Real-time acquisition and processing in QPS Qinsy software
• MTLS (Lidar):
  – Processing = mainly noise filtering
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Classical noise removal based on a grid system:

Removal condition is based on statistical outliers in the height/depth or more complex conditions.
Own PC software development for grid filtering based on H/D and Backscatter

- High precision digital terrain model, up to 8 billion grid cells (or TIN with 50 million points) with 32 Gb RAM.

- Allows:
  - Sub-cm grid intervals (e.g. 300 m by 160 m grid of 2,5 mm cells => ca. 8 billion cells)
  - Visualisation
  - Filtering (outlier removal)
  - Correlation computation
Height/Depth variation Analysis

- Maximal Slope (%)
- Maximal slope direction
- Slope in specified direction
- Slope curvature (second derivative model)
Backscatter Intensity Analysis

- Intensity of the backscatter signal
- Slope direction of maximum intensity
- Slope in specified direction
- Slope curvature (second derivative model)
Outlier elimination

- Local Relief (absolute difference value)
- Standard Deviation (n*SD)
- Boxplot (1.5 * (Q3 - Q1))

Can be applied to:

Geometric model
- Depths
- Slopes
- Curvature

Backscatter model
- Intensity
- Slopes
- Curvature
Correlation Analysis between geometry and backscatter

- Without adequate noise elimination and intensity correction => weak correlation
- Geometric model can be improved by optimal noise filtering
- Backscatter model can be improved by corrections for distance, angle (and humidity ?)
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Backscatter adjustment

\[ I = C \rho \eta_{sys} \frac{\cos \alpha}{r^2} + \varepsilon \]

(Pfeifer et al., 2007)

- \( I \) = intensity
- \( C \) = constant factor
- \( \rho \) = surface properties
- \( \eta_{sys} \) = (non-constant) system transmission factor
- \( \alpha \) = incidence angle
- \( r \) = measured distance
Comparison of the absolute backscatter variability between the exponential and logarithmic models
Intensity map for a track line after intensity adjustment
Overview of the filtering algorithm’s modules
Rotation of strip to eliminate the inclination $\alpha$ of the beach.
• Results:
  – Boxplot-based outlier removal
  – Feature enhancement
Example of a filtered cross-section of the beach
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Conclusion

• Highly accurate intertidal zone modelling of sand beaches requires a specific acquisition technique.

• A SSV equipped with MTLS and a high grade INS and GNSS proved to be the most adequate platform for geomorphological modelling of sand beaches.

• At least equally important is an adequate processing and noise removing filter technique.

• An advanced filtering technique combining the geometry with corrected backscatter values was proposed and proved to yield better results than a classical grid noise filtering technique.
Thank you for your attention

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Questions, Cooperation, Ideas?