Application of High-resolution LiDAR-derived DEM in Landslide Volume Estimation

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- TAIWAN
Optech and Leica run demo flights

- **Optech ALTM 2033**
  - March 20~April 03, 2002
  - Beach Super King Air 350

- **Leica ALS40**
  - April 10~April 16, 2002
  - Beach Super King Air 200
MOI (Ministry of Interior) LiDAR Program in 2004-2005

- Conducted by
  - Industrial Technology Research Institute
- Point density > 1 point/m²
- 4000 Km²: DEM and DSM of 1m Grid
Geological structures and Hazards Survey of Taipei Metropolitan Area (2005-2007)

- 2,490 Km²: DEM and DSM of 2m Grid
- Point density > 1 point/m²
- Drainage analysis
- Active structure analysis
- Analysis of Volcanic Topography
- Supported by Geological Survey of Taiwan
An Example of Geological Research
Fomosat-2 image taken after Typhoon Morakot (Aug., 2009)
National LiDAR Mapping Project (2010-2015)

- Expecting to finish a complete coverage of Taiwan
- National LiDAR Mapping is launched
  - 2010-2012 LiDAR Mapping for Morakot hazard area
  - 2012~2015 The rest of Taiwan will be surveyed

- Optech ALTM-Orion
  - Optech ALTM-Gemini
  - Optech ALTM-Pegasus
  - Leica ALS60
  - RIEGL LMS-Q680i
    - 2004 Optech ALTM 3070
    - 2004 Leica ALS50
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TAIWAN
Background

- On a regional scale, it is difficult and time consuming to measure the sediments induced by landslides for an extremely rainfall or catastrophic earthquake event.

- How much sediments induced by landslides is crucial in sediments yielding of a catchment, debris flow forecasting, and related hazards’ assessment.

- Using multi-temporal LiDAR derived high-resolution DEM to examine the area-volume relation of landslides become possible.
Study area

- Namasha District, Kaosiung City: 38.46 km²
- Baolai District, Kaosiung City: 74.78 km²

Taiwan Strait
Pacific Ocean
LiDAR-derived 2m DEM of the study area I

The error bar of elevation is within 20-30 cm.
LiDAR-derived 2m DEM of the study area II
LiDAR-derived DEM & DSM

2010: LiDAR DEM 2m

2010: LiDAR DSM 2m
Flow chart of data processing

1. Interpreted Typhoon Morakot-induced landslides in aerial photos
2. Define individual landslide boundary in DEM
3. Co-registration of two DEM and calculate volume of individual landslide
4. Regression of landslide volume and landslide area $V = aA^b$
Landslides recognized from aerial photos took before and after Typhoon Morakot.
Landslide interpreted in study area I: 286 landslides

Landslide interpreted in study area II: 127 landslides

Well cemented SS & Sh

slate
Defined individual Landslide boundary
3D DEM Variation with landslide boundary
Defined individual Landslide boundary

Profile along center axis of landslide zone

Undisturbed area  Depletion zone (landslide area)  Undisturbed area
Estimation of individual landslide volume

\[ V = A \left( \sum_{i=1}^{n} h_i \right) \]

\[ A = \text{cell area (m}^2\text{)} \]

\[ h_i = \text{elevation difference (m)} \]
Landslide volume analysis

Baolai District (Study area I: slate): 286 landslides

\[ V = 0.736A^{1.155}, \quad r^2 = 0.856 \]
Landslide volume analysis

Namasha District (Study area II, well cemented SS and Sh): 127 landslides

\[ V = 1.5804^{\frac{A}{10^4}}, r^2 = 0.896 \]
Comparison of different empirical formulas

Well cemented sandstone and shale

V = 1.58A^{1.122} (proposed by the present study)
V = 0.736A^{1.158} (proposed by the present study)
V = 0.0844A^{1.4234} (Guzzetti et al., 2008)
V = 0.024A^{1.368} (Siminett, 1967)
V = 0.05A^{1.5} (Hovius et al., 1997)
Conclusions

● Using two-temporal LiDAR-derived DEM can accurately obtain the debris volume induced by landslides.
● Empirical formula links failure area and debris volume for well cemented sandstone and shale, and slate are obtained in this study.
● Empirical formular for different lithology will be obtained in our National LiDAR Mapping Project.
Thanks for your attention