Automated extraction of talus surfaces for natural disasters management

Society for Conservation GIS Conference
Pacific Grove / Asilomar
27 July 2015

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Motivation

1. Natural and cultural landscape conservation – talus cone

2. Natural hazard risk management – talus cone

3. Developing spatial models and datasets for applications in conservation (of natural resources and cultural heritage)
Talus surface
scree, debris cones, talus cones, talus slopes, fans

**Geomorphological form** – collection of material, partly sorted; at the base of mountains

The **existence** of the talus cones indicates the (previously) unbalanced topography → loose material

Different **geomorphological characteristics** of talus surfaces and individual parts
Settlements threats on talus surfaces ➔ risk management, natural hazards

Natural and cultural landscape conservation

Impact

Podobnikar 1998

Posočje, Slovenia

Transforming talus surfaces after the Easter earthquake (1998) in Posočje

Upper Sava Valley, Slovenia
Debris flow after the heavy rain (2000)

Log pod Mangartom, Posočje, Slovenia
Talus – universality

Atacama: Valles Marineris

Similar environmental conditions

Earth: talus cones (sand)
Atacama = Mars-like landscape

Mars: talus cones (sand)
East Candor Chasma
Earth ... Mars

Different environmental conditions:
- Gravitation
- Wide availability of loose material (often windblown)
- Absence of fluvial erosion
Study areas: Slovenia, Austria
Study areas: Mars

West Candor Chasma
- deep, elongated, steep-sided depression
- 6° S, 77° W

Nanedi Valles
- valleys Nanedi
- 7° N, 48° W

Most probably talus surface
Datasets

Geomorphometry ... using only DTM!

DTM data of different: resolution, sensors, purposes, landform, etc.

Sources of different quality: global DTM, national, regional, local DTM, LIDAR

Gallenkirch, Montafon Valley, Austria
Talus surface shape parameterization

Angle of repose  (different top to the bottom)
Cone transversal radius
Talus is positioned on the base (relative to the mountain)
Edges of talus are sharp
Particular pattern (high resolution LIDAR)
etc.
Methodology

Specific geomorphometry

Identifying specific, **hardly describable** landforms

Reconstruction of the entire talus cone surface with regard to **identification of parts** talus cone

Two options

**Highest data quality**, or

**Robust indicators** that define and model talus (that tolerate existing inaccuracies of DTM)
Selection and definition of the indicator variables

Selection of variables (indicators = 1):
They describe different characteristics typical for talus

Expectation:
Each indicator must encompass talus surface in its entirety

Selection of threshold:
It is needed to find the following values: Exclude as much as possible a large surface area, with the use of extreme limits which allow to keep the total area of talus surface

A number of variables were analyzed, finally were selected 2 to 7 as a statistically significant (No. depended on DTM quality, Earth/Mars)
Variables for LIDAR DTM 1

- Relative relief
- Concave convex
- Slope 5-20°
- Relief above
- Relief below
- A+B+C+D+E=5

Gallenkirch, Montafon Valley, Austria
Methods for outline the talus surfaces

Applied approaches based on:

(Exploratory: ISOcluster
  Goal: provide an unbiased result of talus surfaces)

Progressive Boolean overlay
  Goal: detect the actual areas of talus surfaces

Both approaches can be robust to allow for a confrontation with any appropriate data quality
Exploratory approach: ISOcluster
unsupervised classification

Two variables to characterize the talus:
- **Slope angle**
- **STD of the slope angle** (measure of variability)

Result:
- Talus surface is outlined
- No vallis bottom included

Nanedi Vallis, Mars
Progressive Boolean overlay

Progressive (step-by-step) overlay (uses binary indicator variables to detect patterns in geospace)

Begins with the **roughest estimations** of the talus cones (initial approximation)

Continues using increasingly fine, but less significant variables that improve the quality of the analysis

... until the changes are within a **certain threshold**
Talus – model for DTM 50 m (Mars) (very low quality DTM)

Sum of all 7 variables
A+B+C+D+E+F+G = 7  
(red in both illustrations)

Sum of 7 variables (at least 6):
A+B+C+D+E+F+G ≥ 6 (yellow)

Yellow areas show areas that might be talus

Possible uncertainties:
1. Bad estimation (algorithm problem)
2. DTM errors (!)
Talus – model for DTM 12.5 m (intermediate quality DTM)

Upper Sava Valley, Slovenia
(area of Mojstrana: 7.9 x 5.8 km)

For all four points of the compass
yellow – south
blue – north
green – east
pink – west
Talus – models for LIDAR DTM 1 m
(high quality DTM)

Upper Sava Valley,
Slovenia

large slopes

small slopes
Talus – model for LIDAR DTM 1 m (high quality DTM)

In most areas the method is suitable
Smaller talus cones are also detected

Gallenkirch, Montafon Valley, Austria
Verification of the model (for LIDAR DTM 1 m, with DOP)

Upper Sava Valley, Slovenia
Comparison of DTMs

LIDAR DTM, resampled to 12.5 m (Flycom)

LIDAR DTM 1 m (Flycom)

DTM 12.5 (GURS)

Upper Sava Valley, Slovenia
DTM errors?!

Problem of matching on area without many topographic features

Problem of shadows

HRSC (ESA), Mars
Geomorphometrical applications

Variables for different purposes → generic methods
Analytical shading (geovisualizations)
Image processing

Towards better DTM quality
Different DTMs conflation
Different methods conflation

High DTM quality for sea level rising application
Relief map in scale 1:250,000 from 2005 (see the link)

Analytical shading (standard and basic hill-shading)

Advanced analytical shading (global shading, enhanced topographic edges, lighter flat areas, multi-scale and isotropic appearance)

Advanced analytical shading with hypsometry (global shading, enhanced topographic edges, lighter flat areas, multi-scale and isotropic appearance)
Multidirectional Visibility Index – MVI (multi-applicative)
(enhanced photograph – applicable in image processing)

Podobnikar 2012 (The Cartographic Journal), 2012 (Remote Sensing)

Many very small features and prominent structures are more recognizable.
DTM modelling with datasets conflation

[weighted sum of sources with geomorph. enhance]

Spatial data integrator facility ... similar philosophy to talus surfaces extraction ... error reduction
Partly conflated DTM
Final conflated DTM
Different filters applied to LIDAR DTM conflation

HRI

MCC

LAStools

the best one
Sea level rise (climate changes) → sensitivity to DTM quality (!)
+60 m (melted all the ice on Earth)
+80 m (melted all the ice + possible expansion of water due to the higher volume)
Further development – what to do next?

Results

**Robust** and **generic** methods for spatial analysis

**Overall better DTM quality**

Geomorphometry related analysis is planned to be used for

Improved natural hazard risk management in Alpine areas

A number of other **conservation GIS** applications

Elevational range shifts (forest, animals) due to climate changes

Coral reef resilience study due to climate changes

Archaeological predictive modelling

Geolinguistics applications
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Society for Conservation GIS
Exploratory approach: ISOcluster

Two main variables to characterize the talus slopes:

Slope angle

STD of the slope angle (measure of variability)
Study areas

Upper Sava Valley (Slovenia)
Montafon (Austria)
West Candor Chasma (Mars)
Nanedi Valles (Mars)
Geomorphomertical applications

Applied approaches based on:

(Exploratory): ISOcluster
  Goal: provide an unbiased result of talus surfaces

Progressive Boolean overlay
  Goal: detect the actual areas of talus surfaces

Both approaches are robust to allow for a confrontation with any appropriate data quality
analytical shading (standard solution)

MVI-quasi slope

global shading
enhanced topographic edges
lighter flat areas
multi-scale & isotropic appearance

MVI-relative relief

cartographic visualization

MVI (advanced solution)
Sea level rise? (6 m)
Discussion

Variables:

- Appropriate variables? Better variables (indexes)? Appropriate thresholds?
- Variables and parameters for specific environments?

Models:

1st method = simple classification, 2nd method tries to describe parts of the talus feature in different scales

Definition of the object (objective) – could be define what do we want to find and the impact?
  → the relation between the model and the reality should be explained

Assessing every phenomena separately in order to understand it and include it to the mathematical model

To know the properties of the variables it is possible to include them with special think over (ponder);
  → The same to the my philosophy of DTM from various data sources,
    where is necessary to find best properties of the each dataset

Common properties for all DTMs different quality of data? (general part) vs. special properties that are important for particular type of data, quality, sensors ....
  → robust model ... sensitivity analysis, reliable decision making, homogeneity

Verification, testing inquiry:

- Experience, knowledge, objectivity of operator, objectivity of the system
- Data for verification → possibility of many other kinds visualization?
  → We need a good previous knowledge or/and a comprehensive exploratory analysis and simulations
Conflated DTM
Overview: from data to applications

Data
"raw material of the 21st century"
Sensors: photo, SAR, lidar, human eye;
Other data: Web, geodetic, indicators, cartographic, etc.

Signals (Geospace)

Understanding of the studied phenomena

Spatial Data Analysis
- What to search in data?
  - Analysis of: patterns, shapes, structures, trends, abnormalities, significant features, etc.

Problems?
- missing data
- too low quality and uncertainty
- too complex problem
- etc.

Understanding Data Properties
- assessment
- interpretation

Abstract, Synthesis
- numerical, statistical
- descriptive, visual
- better semantics

Solutions
- alternatives
- optimisation

Processing (Predictions)
- universal DEM
- specific DEMs
- other products

Applications
- intelligent territories
- Smart Cities
- etc.

Ethics
- use for good purposes
Results

Talus surfaces can be automatically detected on Earth and Mars.

Methods seem to be robust: they are often able to overcome problems with different aspects of data quality.

Suggested variables can be used to outline other characteristics of the terrain (generic).
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