AI and time-series for detecting landslides from optical imagery (Ref IAP2-18-183)

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In partnership with Newcastle University

Supervisory Team

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Key Words
landslide, artificial intelligence; remote sensing; disaster response

Overview

Fig 1: Landslides and debris flows further caused extensive damage and hampered relief efforts in the days after the Wenchuan earthquake. This image from Beichuan County shows the bare rock and soil exposed by co-seismic landslides on the slopes above the town and the destruction caused by landslide debris (Source: David Wald, USGS).

Earthquakes in mountainous areas can trigger thousands of (co-seismic) landslides causing significant damage, hampering relief efforts, and rapidly redistributing sediment across the landscape (Fig 1). Efforts to understand the controls on these landslides rely heavily on manually mapped landslide inventories but collecting these inventories is time consuming and relies heavily on costly high-resolution imagery (e.g. Roback et al., 2018). Lower spatial resolution (e.g. Landsat) imagery offers near global coverage, extending over multiple decades with high temporal resolution (Fig 2). Conversely, recent private endeavors such as Planet.com offer free high-resolution 3 metre imagery with a high, sub-weekly, revisit frequency to the academic community that can be leveraged to identify small landslides.

Fig 2: False colour Landsat 8 images of the Langtang valley before and after the Gorkha earthquake. Landslides can be identified as areas where vegetation (in red) has been removed to expose soil and rock (in grey) (Source: http://mountainhydrology.org)

If an effective approach could be found to take advantage of these lower resolution datasets this could considerably increase the archive of landslide inventories. It might also improve the speed and accuracy with which landslide information could be provided to those responding to an earthquake.
Over the last decade, computer vision and artificial intelligence has made rapid progress in identifying everything from cars to cats. This has been enabled by progress in deep learning using a type of neural network dubbed a ‘Convolutional Neural Network’ which closely mimics human vision (e.g. Fig 3). Whilst these types of networks are now abundantly used by tech giants such as Google and Facebook, their application in a geographic context is extremely sparse.

This project will examine two alternative approaches to landslide detection: 1) a multi-temporal approach that harnesses the rich time series of available medium resolution imagery and that can be implemented within cloud computing infrastructure (e.g. Google earth engine, Gorelick, 2017); and 2) an neural network driven approach that will approach the human ability for generalized feature detection but without having the range of cognitive biases that affect human pattern matching.

Specific objectives are:
O1: Develop a suite of new classification tools for use with widely available medium resolution imagery.
O2: Tailor a subset of these classification tools to generate rapid landslide maps following large earthquakes.
O3: establish the performance of the new classification methods using existing co-seismic landslide inventories from a diverse range of environments.
O4: Demonstrate the impact of extending the set of mapped landslide inventories by applying the new methods to several landslide triggering earthquakes where landslide inventories have not been made widely available.

Methodology

Time-series methods: using Landsat and Sentinel time series within Google Earth Engine [Gorelick et al., 2017], building on recently developed pixel-wise NDVI differencing methods (Fig 3) and exploring more refined object based methods within the constraints of GEE.

Neural Network methods: Convolutional Neural Networks (CNN) will be implemented in the Keras API using the TensorFlow libraries as a backend. These are the open-source tools released by Google Inc. These networks will be trained from existing landslide inventories. The objective of the approach is to develop an AI capable of recognizing an image region where a landslide is present. From there, class activation maps will be used to delineate the landslide in the same manner that a human operator would.

Testing against observed landslide inventories: classifiers will be tested against hand-mapped landslide inventories collected by the project team and supplemented by existing open-access inventories. From these two sources the project team already has >6 inventories each containing >5000 landslides (e.g. Fig 3). Testing will include not only standard pixel and object based classification metrics but also metrics specifically developed for landslides such as: size distributions, spatial density maps, and impact on the quality of derived products (e.g. susceptibility maps).

Application to historic earthquakes: the new classifiers will be applied to a set of existing landslide triggering earthquakes where landslide inventories have not previously been widely available. The new inventories will be used to test existing theory and models in these new settings. Example applications might include: The relationship between earthquake magnitude and landslide response of Marc et al. (2016); the statistical and mechanistic susceptibility models of Parker et al., (2017) and Gallen et al., (2017); and the method of Meunier et al. (2013) to use landslide distributions to reveal seismic source characteristics.

Timeline

Year 1: familiarizing with AI and traditional classification methods and selecting a suitable initial approach drawing on in house expertise; familiarizing with landslide characteristics and the requirements of
the research and disaster response communities; first iteration of time series and AI classifiers.

**Year 2:** refinement and testing of time series and training of AI classifiers using existing landslide inventories.

**Year 3/3.5:** application to multiple historic earthquakes where medium resolution imagery exists.

### Training & Skills
Departmental training in (a) research skills and techniques and (b) research environment are provided through four mechanisms: (i) a programme of taught modules; (ii) internal training ‘workshops’ that focus on key geographical research skills and techniques; (iii) input from supervisors; and (iv) departmental seminars by visiting and internal speakers and presentations by postgraduate students themselves.

Physical geography research postgraduates normally take the taught departmental module ‘Implementing Research Design’ during their first year. The aim of this module is to help students put University training in research design into practice specifically in relation to physical geography research both generally and with regard to the student’s own project work.

Students receive instruction in data collection and the scientific method, contextualizing and problematizing research in physical geography, planning for field- and laboratory work, and team and group working in physical geography. Assessment of students in this module is formative. In addition to generic training offered by the University, the Department also provides training through a series of in-house ‘workshops’. These workshops offer the opportunity to gain both experience and knowledge with a number of tools in a specifically geographical disciplinary context and to gain an understanding of some of the wider structures and practices which make up academic life. This programme has been developed in response to postgraduate requests and is open to ALL postgraduate students irrespective of degree or year of study.

Research training continues through the second and third years, and is based around a number of themes: (i) Recognition and validation of problems; (ii) Demonstration of original, independent and critical thinking, and the ability to develop theoretical concepts; (iii) Knowledge of recent advances within the research field and in related areas; (iv) Understanding relevant research methodologies and techniques and their appropriate application within the research field; (v) Ability to analyse and critically evaluate findings and those of others; and (vi) Summarising, documenting, reporting and reflecting on progress. The candidate will receive training from supervisors on python coding (used for the CNN scripts). The candidate will also be funded for attendance at the conference of the British Machine Vision Association in year 2 and 3 in order to further develop their machine vision skills.

### References & Further Reading


### Further Information
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