Final Project Report – John Hillier J.Hillier@lboro.ac.uk

Automated gorge detection for a global catalogue and insights into climate and tectonics

Background: Bedrock gorges are unusually steep sided valleys, likely sculpted by a river that is strongly incising down in response to change driven by tectonics, climate, or drainage organization. As such, they potentially provide insight into the process of bedrock erosion and once better understood may usefully record the drivers of change (e.g., climatic forcing). Despite this the characteristic morphology of gorges as it relates to and records their evolution has not been explored in any systematic way. Currently, no systematic compilation of gorge location and morphology exists. Existing studies either focus on single gorges [e.g., Cook, 2013], on several gorges from a single region [e.g., Montgomery, 2011], or on gorges formed from a single process [e.g., Ouimet, 2008], but do not compare and contrast gorges in a more general way.

Overarching aim: The proposed collaboration will integrate the expertise of Hillier (landform quantification), Cook and Turowski (gorges) to create and exploit a global gorge database with the aim to i) field-validate competing models of bedrock channel formation [e.g., Turowski, 2009], ii) extract information about a region's climatic and tectonic history from gorge morphology or preservation, and iii) identify special sites that may yield detailed insights into fundamental processes.

Specific objectives achieved by the BGS funded pilot:

- Field visit to Switzerland, including collecting DEMs of key transects (e.g., initiation zone) using structure through motion (STM).
    - Gorges are difficult test cases for STM, as their elongate, narrow geometry with overhangs confounds typical strategies (e.g., photos using unmanned aerial vehicles - UAVs). John's test of an *ad-hoc* ground-based sampling strategy took 597 photos in ~45 mins of a key gorge initiation zone that is currently also instrumented for monitoring bedrock erosion. A DEM has been successfully produced (Fig. 1). It will be used for comparison with existing laser scans in its centre, and as a high-resolution (< 1m resolution) test case for the algorithm. Thus, this substitutes for the Swiss Lidar data which has proven unfeasible to obtain.
- Quantify morphological characteristics that distinctively typify gorges.
    - This was the subject of intense discussion in the field, which contributed invaluably to John's understanding to allow the design of the algorithm, but also moved forward the views of all parties on the trip. A journal paper on the typology and generating mechanisms of gorges in the Valais region is planned.
- Design robust computational procedures to extract gorges, and implement them in profiles.
    - Successful initial implementation this was done in Potsdam, thanks to the interaction this GFZ funded visit afforded, and has recently been ground-truthed (Fig. 2). Having just missed the 2015 deadline, we intend to first present this use of the method at the EGU conference in 2016, leading to an *ESPL* paper in due course.
- Devise and implement multi-profile, 3D processing procedure, considering problematic areas such as confluences.
    - This has been done conceptually, and the intention is to obtain support to fully implement this.

JH and his collaborators thank BSG for the support that they have provided in the pilot study, which will lead to a journal publication, but has also provided the kernel of work to seed attempt to obtain funding for the larger global project.

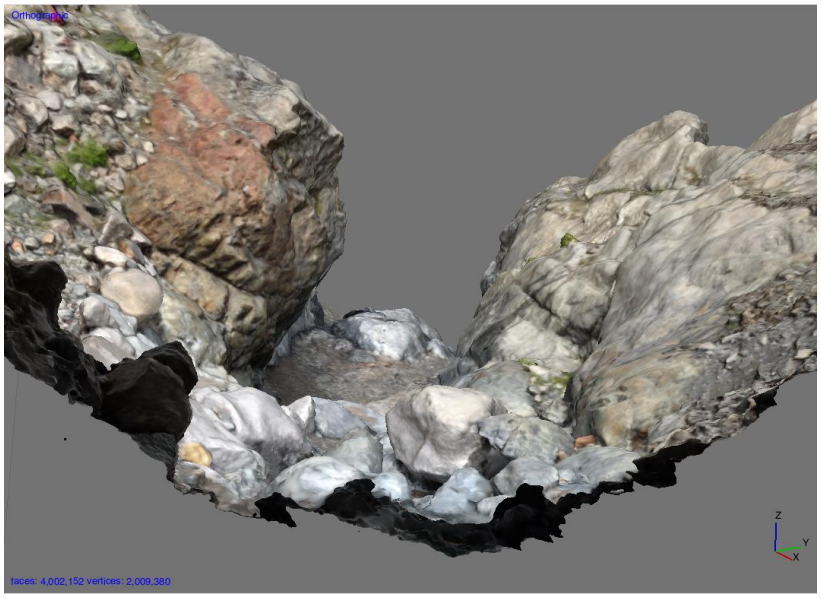

Fig. 1: DEM of a Swiss gorge generated with and overlain by photos. Structure through motion (STM) techniques in PhotoScanPro were used. The 'inner' gorge shown is being intensively studied, and is shown for purely because nicely displays its geometry. The DEM continues, both to encompass the wider valley and the downstream part of the inner gorge. Scale of inner gorge: ~5m high and 2-3 m wide.

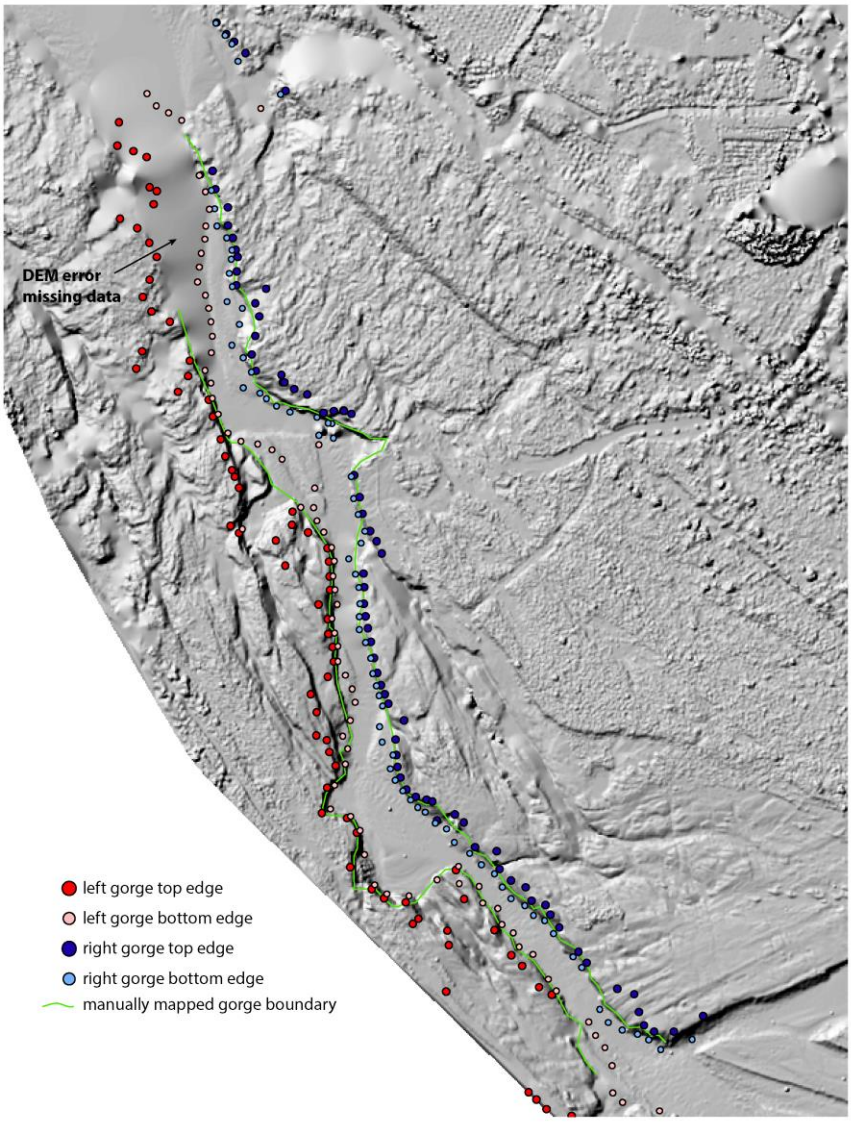

Fig 2: The Daan gorge in Taiwan: width ~50-100m, depth ~10-15m. This test case assesses that ability of the algorithm (coloured dots). The algorithm robustly (i.e., with relatively few outliers) determines the location and scale of the gorge and its first-order variations downstream, and classifies the main elements of the gorge in profile (i.e., bottom and sides). Deviations from a close match between the automated and manual mapping are explicable i.e., where i) DEM data are missing, ii) the DEM edge is near (south), or iii) a sensible manual interpolation has been done across side gorges.