Incidental terrestrial imagery for post disaster spatial data capture of debris flows

Rene Wackrow, Jim Chandler, Tom Dijkstra

Department of Civil and Building Engineering
Loughborough University
Loughborough, UK
r.wackrow@lboro.ac.uk

Enoc Sanz-Ablanedo

Department of Cartography, Geodesy and Photogrammetry
University of León
Ponferrada, Spain
enocsanz@unileon.es

Meng Xingmin

Research School of Arid Environment and Climate Change
Lanzhou University
Lanzhou, China

Abstract— **Consumer-grade digital imagery captured by non-experts has a great potential for DEM extraction. The portability of the equipment creates opportunities for data collection in difficult and inaccessible mountainous terrain. In this context it provides an important tool enabling rapid response post-disaster planning in regions affected by large scale natural hazard events. The potential of this methodology is illustrated by a case study of the large scale debris flow that killed several thousand people in the town of Zhouqu, China in August 2010. The case study briefly introduces the pertinent details of the debris flow event. Data collection, processing and representations are highlighted. It is concluded that the methodology can be beneficial for post-disaster planning, and that the relatively cheap instrument requirements and simple methodologies also provide an opportunity to involve local residents and municipal authorities for landscape monitoring in active terrains.**

I.   INTRODUCTION

This article reports on a component of a research programme in response to the large debris flow that devastated the town of Zhouqu (Gansu province, China) during the night of 7/8 August 2011. Fig. 1 represents an image sequence of the area before and after the catastrophic event. The trigger for this disaster was a rainfall event which delivered an more than 70 mm in approximately one hour (in a region where average annual precipitation ranges from 400 to 800 mm). This single cloudburst represents a severe anomaly (a return interval of more than 200 years is estimated) [1,2]. The sudden discharge of water, confined in narrow, steep-sided valleys resulted in large scale entrainment of valley floor deposits, particularly where large vertical steps in the longitudinal profile of the valley floor exit. The resultant devastating debris flow caused significant loss of life with more than thousand people killed.

This region is characterized by a seismically active mountainous terrain, an extension zone of the Tibetan uplift. The local erosion base at Zhouqu is formed by the Bailong River at approximately 1300 m with surrounding peaks reaching heights from 3500 to 3800 m. The debris flow catchment area is approximately 25 square kilometers and is characterized by a very high relative relief. Vegetation cover in the catchment mainly comprises brushes and sparse forest, above the tree line alpine pastures exist.

An understanding of the debris flow formation mechanism and its role in landscape evolution can have significant implications for risk management in these active terrains [3]. As with all landslide events, it is vitally important to collect data rapidly to understand the local geological structure, drainage and geotechnical parameters, which are essential in building a robust model describing the landslide event. Dimensions of instability need to be mapped, including their position in the catchments, the transport zone characteristics   and the lower depositional environments. This would enable the construct of mass balance assessment and mapping out of the pre-disposition of the catchment for different types of geohazards.

Acquiring spatial information necessary for a high quality DEM soon after the event can be challenging. However, as demonstrated in [5], photogrammetric data acquisition can now
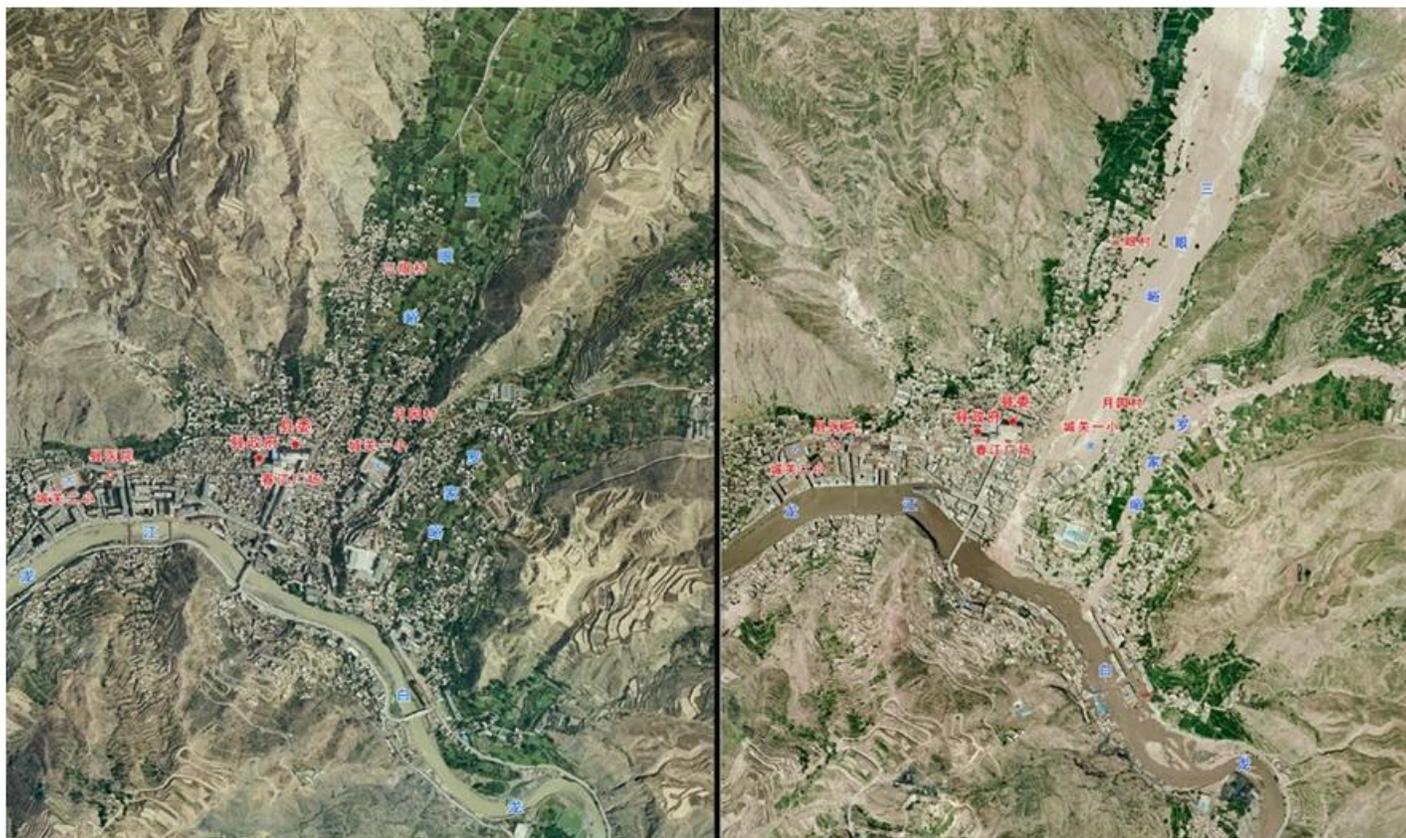
Figure 1.   A sequence of satellite images showing Zhouqu before (left July 2008) and after the landslide (right August 2010) [4].

involve non-specialists using cheap consumer-grade digital cameras. This methodology provided the opportunity to acquire stereo-pairs shortly after the Zhouqu event, and these were used for both DEM generation and orthophoto rectification.

II.   DATA COLLECTION AND PROCESSING

DEM extraction of the lower depositional environment of the Zhouqu event (Fig. 2) used a stereo-image pair acquired using a Nikon D80[1] consumer-grade digital camera. The field work was conducted by a non-photogrammetric expert, whilst data were processed and compared using two different photogrammetric software packages available at Loughborough University (Leica Photogrammetry System (LPS) 9.3 software and PhotoModeler Scanner 2010). Additionally, an ortho-rectified image was superimposed over the extracted DEM for mapping purposes and to create fly-thru representations.

---

[1] http://www.dpreview.com/reviews/specs/Nikon/nikon_d80.asp

A. Image acquisition

The mountainous environment and absence of roads required highly transportable and lightweight equipment for recording suitable imagery for DEM extraction in the period immediately following the geohazard occurrence. This was achieved by the acquisition of a mildly convergent but highly oblique stereoscopic image pair of the lower depositional environment in Zhouqu. The images were acquired from the opposite hill side using an approximate camera baseline of 50 meter and a camera to object distance of approximately 200 meter. The camera used to capture these imagery was a handheld ten Mega-pixel Nikon D80 digital camera with an 85 mm fixed lens. The lens was fixed on infinity focus setting using electrical tape. Using this method, the inner camera geometry could be accurately recovered using a calibration process [6] upon return to the UK. The potential of consumer-grade digital cameras for spatial measurement application has been demonstrated in previous work [6,7]. Additionally, 3D coordinates (longitude, latitude, height in WGS84) of both camera stations were recorded using a wrist

Figure 2.   Image of the lower depositional environment in Zhouqu after the landslide event

watch (Garmin Forerunner 405) capable of recording GPS data. These recorded 3D WGS84 coordinates were transformed into XYZ coordinates and used for image processing.

B. Data processing

Data processing was carried out using both the Leica Photogrammetry System (LPS) 9.3 software and PhotoModeler Scanner 2010. The use of non-metric imagery necessitated calibrating the Nikon D80 camera using a calibration field at Loughborough University. The parameters describing the inner camera geometry could be imported into the photogrammetric software packages. GPS data recorded using the wrist watch served two purposes: firstly, XYZ coordinates of the camera stations were used as initial estimates for exterior orientation in a bundle adjustment and secondly, data could be oriented to the WGS84 reference datum. However, a limit number of control points were still needed to achieve satisfactory exterior orientation for the stereo pair. The availability of an ortho-rectified SPOT satellite image upon the WGS84 reference datum, provided the opportunity to identify and measure nine control points, which were also clearly identifiable in the image pair. The nine points provided sufficient control and the exterior orientation for the stereo pair could be achieved using a bundle adjustment within both LPS and PhotoModeler Scanner.

After a satisfactory restitution of the stereo pair had been achieved, tie points could be extracted using the automatic tie point generation routine of LPS, as well as the "Smart Point" method implemented in PhotoModeler Scanner. Sets of tie points were used to create DEMs, orthophotographs and fly-thru models.

Figure 3.   DEM/orthophotograph of the lower depositional environment in Zhouqu after the landslide event

III.   RESULTS AND DISCUSSION

DEMs and orthophotographs were both extracted from image pairs to represent the lower depositional environment at a resolution of 2 meter (Fig. 3). Unfortunately, sufficient data to independently assess the accuracy of extracted DEMs are currently not available. In addition, a fly-thru representation[2] was generated to improve visualization of the spatial character of the area. Initially, it was hoped that these data would have been used to assess depositional displacements and displacement velocities, by comparing the DEMs with remote sensing data representing the area before the event. Unfortunately, currently available remote sensing data are characterized by poor resolutions (20 meter) which is not suitable to identify deposits with dimensions of just a few meters. However, information provided in this work significantly improved the elevation resolution of this study area. These data are important to characterize the spatial, geological and geotechnical parameters of this failure and also assists in identifying threshold slopes and short term hill slope channel interactions.

A second image pair (Fig. 4) was acquired further up the debris flow. This imagery represents sediment storage and can be

---

[2] http://www-staff.lboro.ac.uk/~cvrw5/movies/movie_4.avi (25 MB)

REFERENCES

[1]   MA Dong-tao 2010 Some Suggestions on Controlling Catastrophic Debris Flows on Aug. 8th, 2010 in Zhouqu, Gansu. Internal report Key Laboratory of Mountain Hazards and Earth Surface Processes, Chinese Academy of Sciences, Chengdu, 610041 (in Chinese).

[2]   MA Dong-tao and Qi Long 1997. Study on comprehensive controlling of debris flow hazard in Sanyanyu gully. Bulletin of Soil and Water Conservation, 17(4), 26-31 (in Chinese).

[3]   Roering, J.J, Kirchner, J.W, and Dietrich, W.E., 2010. "Characterizing structural and lithologic controls on deep-seated landsliding: Implications for topographic relief and landscape evolution on the Oregon Coast Range, USA". GSA Bulletin, 117, 654-668

[4]   State Bureau of Surveying and Mapping 2010. "A handout photo showing a combo of satellite images of Zhouqu before and after the recent landslide". AFP/Getty images, 11th August 2010.

[5]   Bryan, P., and Chandler, J.H., 2008. "Cost-effective rock-art recording within a non-specialist environment". International Archives of Photogrammetry, Remote Sensing and spatial Information Sciences, 37(B5), 259-264.

[6]   Chandler, J.H., Fryer, J.G., and Jack, A., 2005. "Metric capabilities of low-cost digital cameras for close range surface measurement". Photogrammetric Record, 22(117), 10-21.

[7]   Wackrow, R., Chandler, J.H., and Bryan, P., 2007."Geometric consistency and stability of consumer-grade digital cameras for accurate spatial measurement". Photogrammetric Record, 22(118), 121-134.

Figure 4.   Sediment storage

processed using the method described previously. A DEM can be generated and used for estimating sediment storage. Additionally, morphology change can be assessed including computing volumetric change. These information can be used to compute the displacement velocity of the debris flow.

IV.   SUMMARY

This paper demonstrates that valuable spatial information of landslide events can be recorded by non-experts using consumer-grade digital cameras. This provides the opportunity for a cost effective and fast response to a landslide event which can also assist in identifying and monitoring potential landslide slopes. Mobilizing local residents and municipal authorities is feasible but requires the use of both cheap instrumentation and simple methodologies. The portability of the equipment also provides the possibility to gather data in areas with difficult and limited access (e.g. the upper catchment area in mountainous terrains). These data can be used to further improve geohazard process models and risk management strategies and vulnerability reduction strategies.

ACKNOWLEDGEMENTS