Computers & Geosciences 72 (2014) 18–32

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

Using Kinect to analyze pebble to block-sized clasts in sedimentology

G. Moreno Chávez [a,*], D. Sarocchi [b,1], E. Arce Santana [c,2], L. Borselli [b], L.A. Rodríguez-Sedano [d,3]

[a] Doctorado Institucional en Ingeniería y Ciencias de Materiales, c/o Instituto de Geología UASLP, Av. Dr. M. Nava No 5, Zona Universitaria, 78290 San Luis Potosí, Mexico
[b] Instituto de Geología/Fac. de Ingeniería UASLP, Av. Dr. M. Nava No 5, Zona Universitaria, 78290 San Luis Potosí, Mexico
[c] Facultad de Ciencias, UASLP, Diagonal Sur S/N, Zona Universitaria, 78290 San Luis Potosí, Mexico
[d] Posgrado Centro de Geociencias, UNAM, Blvd. Juriquilla No. 3001, 76230 Querétaro, Mexico

ARTICLE INFO

Article history:
Received 18 February 2014
Received in revised form
3 July 2014
Accepted 4 July 2014
Available online 14 July 2014

Keywords:
Kinect device
Depth measurement
Optical granulometry
Fourier transform
Level sets

ABSTRACT

In this paper, we propose a new system for automatically measuring grain sizes in a range from pebbles to blocks. The system is based on use of the Microsoft Kinect device and a novel software developed by the authors which enables a tridimensional digital model of a selected area of an outcrop to be captured. With the tridimensional model, clasts are stacked using new segmentation algorithms based on level sets and Fourier analysis. The resulting binary image (clasts and matrix) is analyzed by means of the Rosiwal stereological method. The granulometric Cumulative Distribution Function (CDF), obtained automatically by this new methodology, was compared to the granulometric CDF, obtained manually by the Rosiwal technique, by means of a Kolmogorov–Smirnov test. The comparison showed good agreement between the methods and demonstrated that this inexpensive system (already used in several scientific fields) with great potential can also be used to obtain fast, automatic and accurate grain size distributions of sedimentary deposits. The software tools used to control the Kinect device, which provide the three-dimensional elevation models of the outcrops and allows its analysis, are freely available from the author.

1. Introduction

Granulometry is an essential tool for the study of sedimentary deposits. Particle size distribution is directly related to the origin, transport and deposition of the particulate materials that constitute a deposit. The statistical study of granulometric distributions reveals key indicators of sedimentary texture and structures which would not be as evident or even impossible to observe by naked eye such as gradation, coarse or finer particles lenses and sedimentary structures (Sarocchi et al., 2005). A study of vertical and longitudinal changes in granulometry along a deposit enables transport and deposition mechanisms to be inferred. Saucedo et al. (2008) and Sarocchi et al. (2011) used this analysis in debris flow and block-and-ash flow deposits.

Granulometric studies are performed by means of different analytical techniques such as image analysis, sieving and laser diffraction (Syvitski, 1991; Sarocchi et al., 2011), because of the wide range of particle sizes contained in the sedimentary deposits. Some sedimentary deposits are so poorly sorted that they may contain particles from a few microns to several meters in size. An analytical method widely used since the early days of sedimentology has been sieving, and until recent decades it was the only method used for granulometric studies (Allan, 2003; Bunte and Abt, 2001). Sieving enables measurement of particles in the range between −5 and +5 phi (32 mm to 0.031 cm); however, if only sieving is used on poor sorted deposits such as pyroclastic and debris flows, debris avalanche or olistostromes (Olgun and Norman, 1993; Saucedo et al., 2008; Roverato et al., 2011; Sarocchi et al., 2011), between others, much of the important information contained in the coarse and fine tails of the distribution is lost. For this reason it becomes necessary to use sieving in conjunction with other analytical methods to also enable the analysis of particles in the fine and coarse distribution tails (Saucedo et al., 2008; Sarocchi et al., 2011). Fine particles are commonly analyzed

* Corresponding author. Tel.: +52 444 817 1039; fax: +52 444 811 1741.
E-mail addresses: gamalielmch@gmail.com (G. Moreno Chávez), sarocchi@gmail.com (D. Sarocchi), arce@fciencias.uaslp.mx (E. Arce Santana), lborselli@gmail.com (L. Borselli), lrodriguez2021@live.com.mx (L.A. Rodríguez-Sedano).
[1] Tel.: +52 444 8171039; fax: +52 444 811 1741.
[2] Tel.: +52 444 8262316.
[3] Tel.: +52 442 238 1104.

http://dx.doi.org/10.1016/j.cageo.2014.07.008
0098-3004/

by means of photo-sedimentation or stream scanning methods (Stein, 1985; Lovell and Rose, 1991; Lewis and McConchie, 1994) while the coarser particles are analyzed by means of optical granulometry techniques based on image analysis (Sahagian and Proussevitch, 1998; Sarocchi et al., 2005, 2011; Jutzeler et al., 2012).

Optical granulometry techniques consist in taking pictures of the outcrops with a scale reference superimposed, segmenting the particles (generally with methods based on grayscale or color selection) and selecting the area of interest to obtain a binary image of the particles to be analyzed. A stereological method (Mouton, 2002; Sahagian and Proussevitch, 1998; Sarocchi et al., 2005, 2011; Jutzeler et al., 2012) is then applied to obtain the volumetric particle size distribution. However, images of natural geological deposits are rarely easy to segment due to the low contrast in gray tones and colors between different granulometric components. For this reason algorithms with smarter and more efficient segmentation criteria are required because the only alternative to optical granulometric analysis is a lengthy, tedious semi-manual method (Sarocchi et al., 2005, 2011).

In many cases, useful information for segmenting large clasts from sedimentary deposits can be derived from 3D scans of the clasts protruding from the base level of a Digital Elevation Model (DEM). In this paper we propose a new optical method which is based on the use of a DEM of outcrops obtained by means of a Microsoft Kinect device. The equipment utilized is an Xbox 360™ console accessory, with moderate spatial (2–20 mm) and depth resolution (1–75 mm), working in real time (30 fps). The equipment is inexpensive, small in size, lightweight, and can be used with a simple laptop equipped with an USB port. Kinect applications are growing in diverse scientific and educational areas such as computational graphics, image processing, computational vision, and human–machine interfaces (Cruz et al., 2012; Liying et al., 2012). Mankoff and Russo (2012) demonstrated that this device can be usefully employed in many earth science disciplines.

We propose the use of the Kinect for automatic analysis of coarse clasts (pebbles to blocks) as a complement to data obtained using other methods for a complete granulometric analysis of sedimentary deposits. Specific software has been developed to manage the device, capture color images and construct a DEM of the outcrop, perform image segmentation (which is based on level

Fig. 1. Kinect device.

Table 1
Infrared camera area and resolution with respect to distance.

Kinect–plane distance (m)	Area (m^2)	Depth resolution (mm)
0.5	~0.7	1
1	~1.4	3
5	~7	75

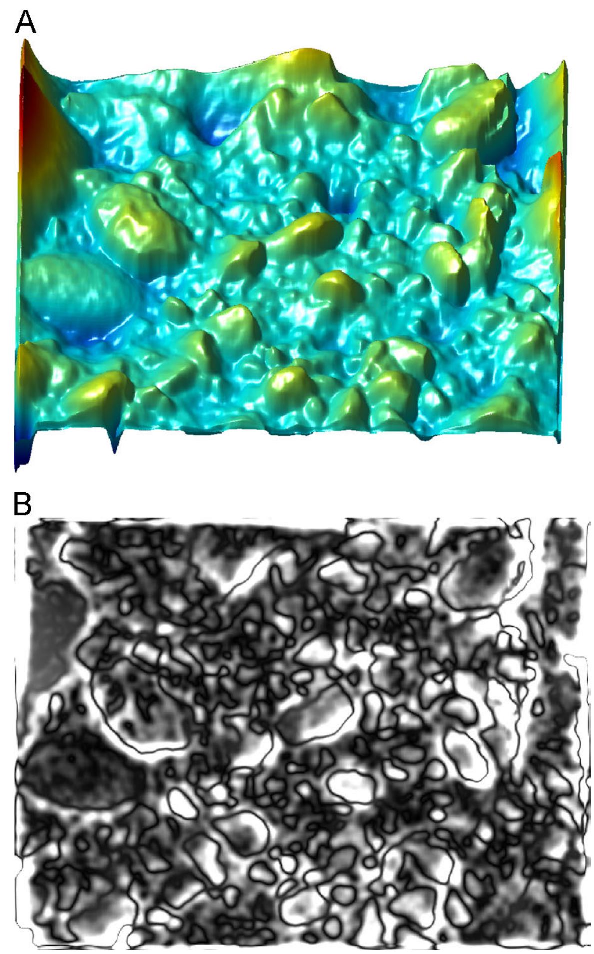

Fig. 3. (A) The depth image of area 4 and (B) its filtering by a Gaussian low-pass filter in the frequency domain.

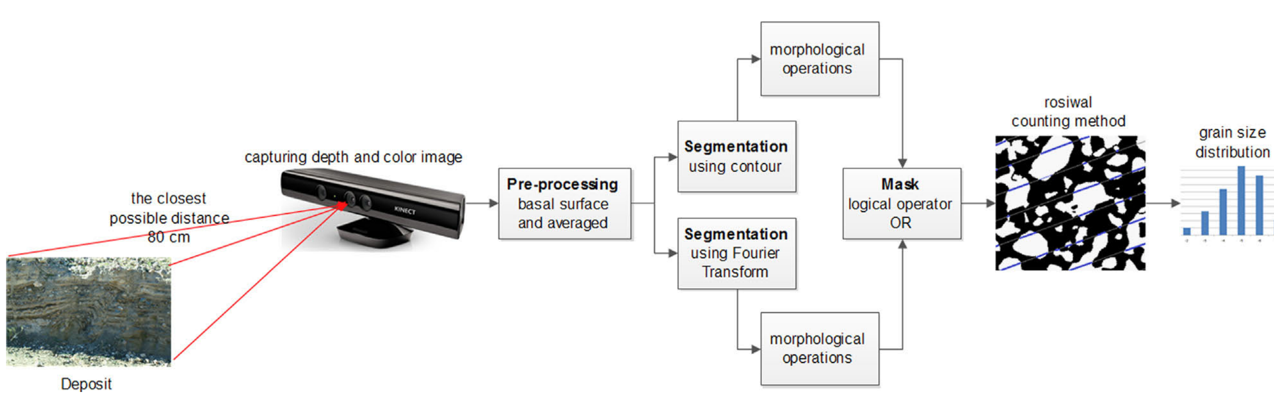

Fig. 2. Schematic diagram of the capture of the DEM of the outcrop, DEM processing and Rosiwal analysis.