A Dynamic 3D Reconstruction Technique for Landslide Testing

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Introduction

Experimental studies on granular column collapses in controlled lab environments have helped the geotechnical community to better understand the complex dynamics of landslides and debris flows [1,2].

Conventional experiments captured the granular collapse process with a side-view camera placed perpendicular to a transparent sidewall. Such a method cannot capture the full 3D landsides. Therefore, its application is often limited to 2D phenomenon.

We introduce a novel 3D approach utilizing a high-speed camera array and Structure from Motion (SfM) techniques to capture the 3D landslide phenomena.

Method

A high-speed camera array, consisting of five GoPro Hero cameras, was designed to take photographs of the rapid granular collapse process at 60 fps with a 1/960 s shutter speed. The granular materials were modelled with ABS plastic pellets, whose diameter is 3mm and which were painted in various colors. A mixture of colors helped increase the structural features of the grain assembly. The granular column was first kept in a rectangular compartment and then released into a channel by rapidly lifting a gate.

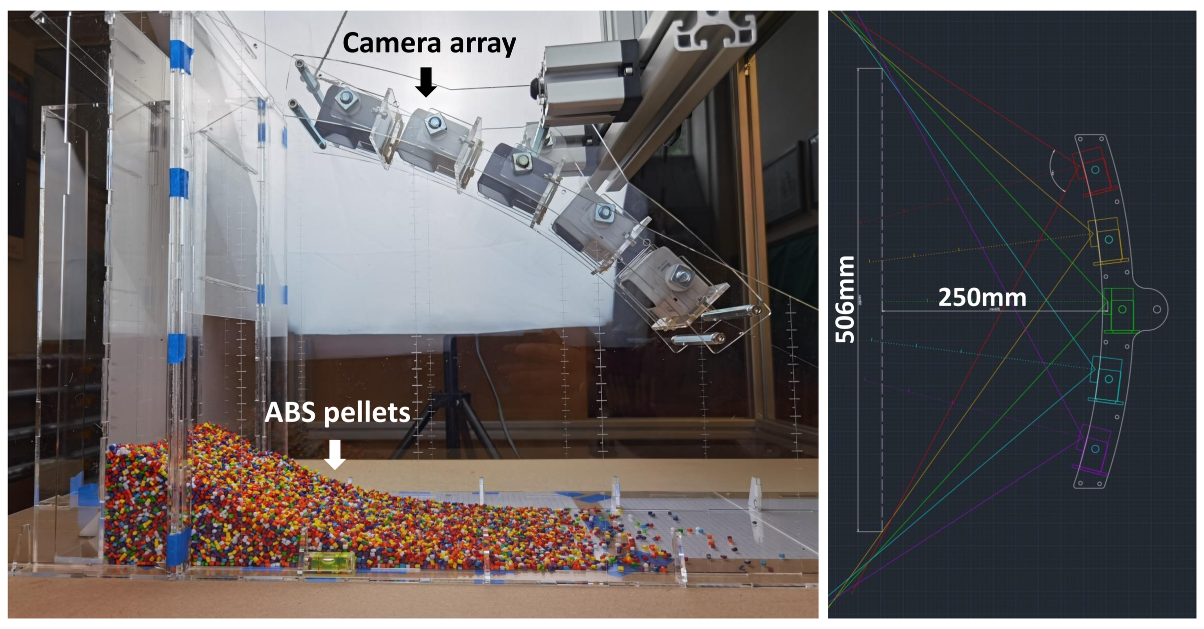


Figure 1. Setup of the experiment. Left: the granules were released into a channel with a width of 15mm. The initial granular column has dimensions of 140mm X 50mm X 15mm (height, basal length, width). Right: the camera array is configured to ensure a 100% FoV overlap. The equivalent vertical FoV of the camera array is approx. 90°, covering 502mm of view (in length) at the cameras' minimum focus distance of 250mm.

3D dynamic reconstruction of the landslide outer surface was achieved using commercial SfM software Pix4Dmapper[3]. Post-processing was carried out using 3D point cloud processing software CloudCompare[4].

Results

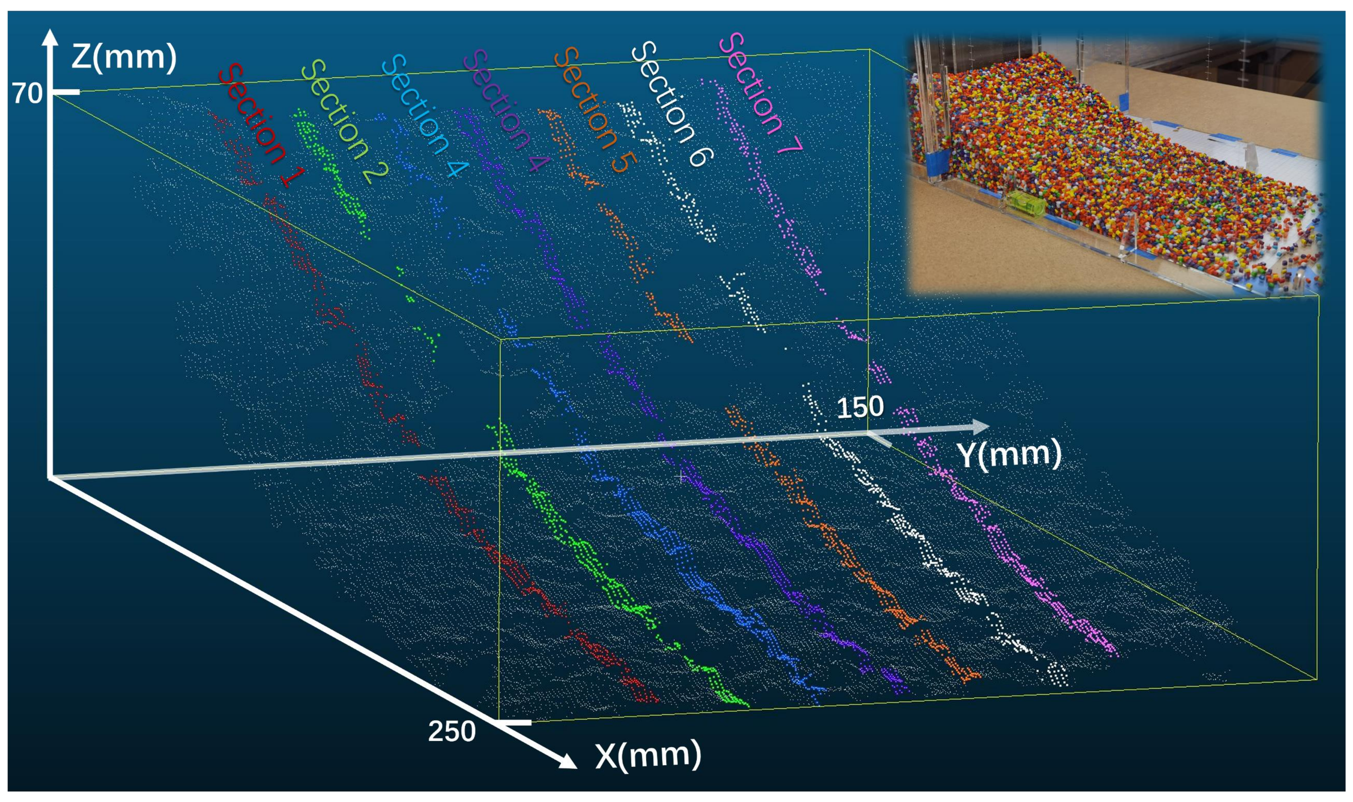


Figure 2. A point cloud showing the final deposit shape in a granular column collapse test. Seven longitudinal sections (width=3mm, interval=12mm) were sampled to depict the final deposit profile.

The maximum runout distance, d_∞, indicates the influencing area of the landslide. Meanwhile, the shape of the landslide mass and the front propagation speed are the most important parameters to quantify the landslide characteristics and verify the numerical models. These information can be easily extracted from the reconstructed 3D surfaces which are made of a set of point clouds.

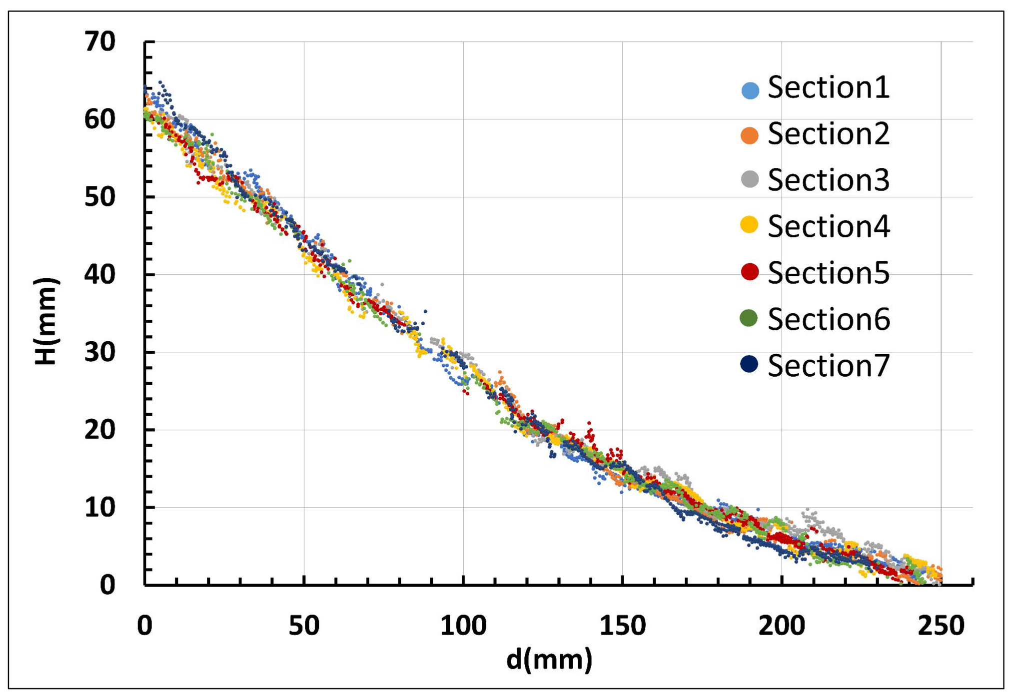


Figure 3. Seven representations of the final deposit profile. The x-intercepts correspond to the maximum runout distance $d\infty$. The y-intercepts correspond to the final deposit height $h\infty$.

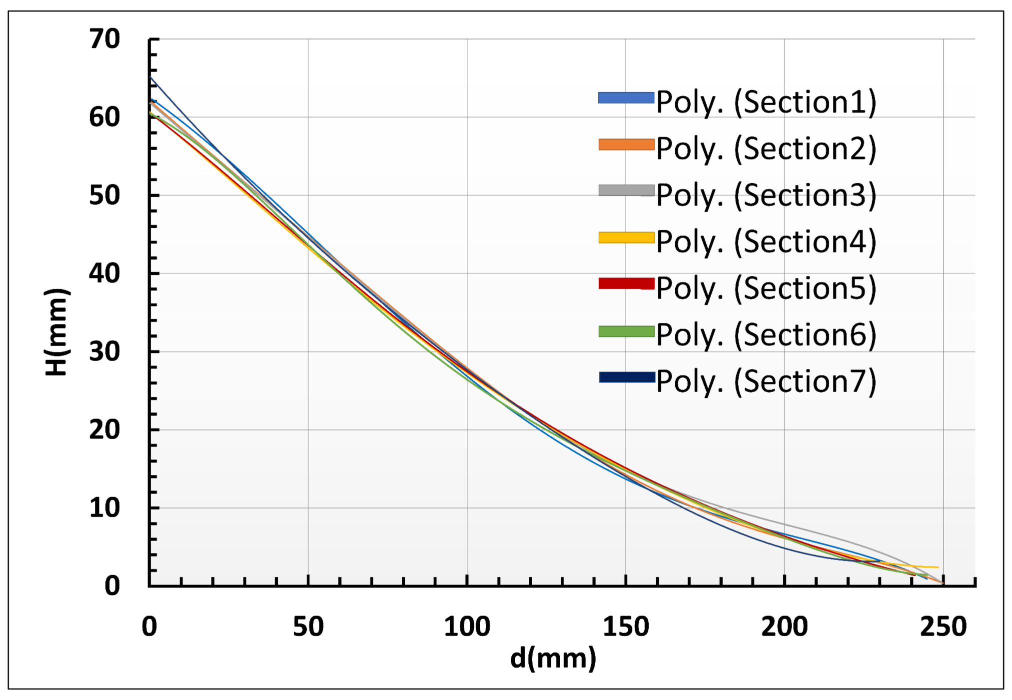
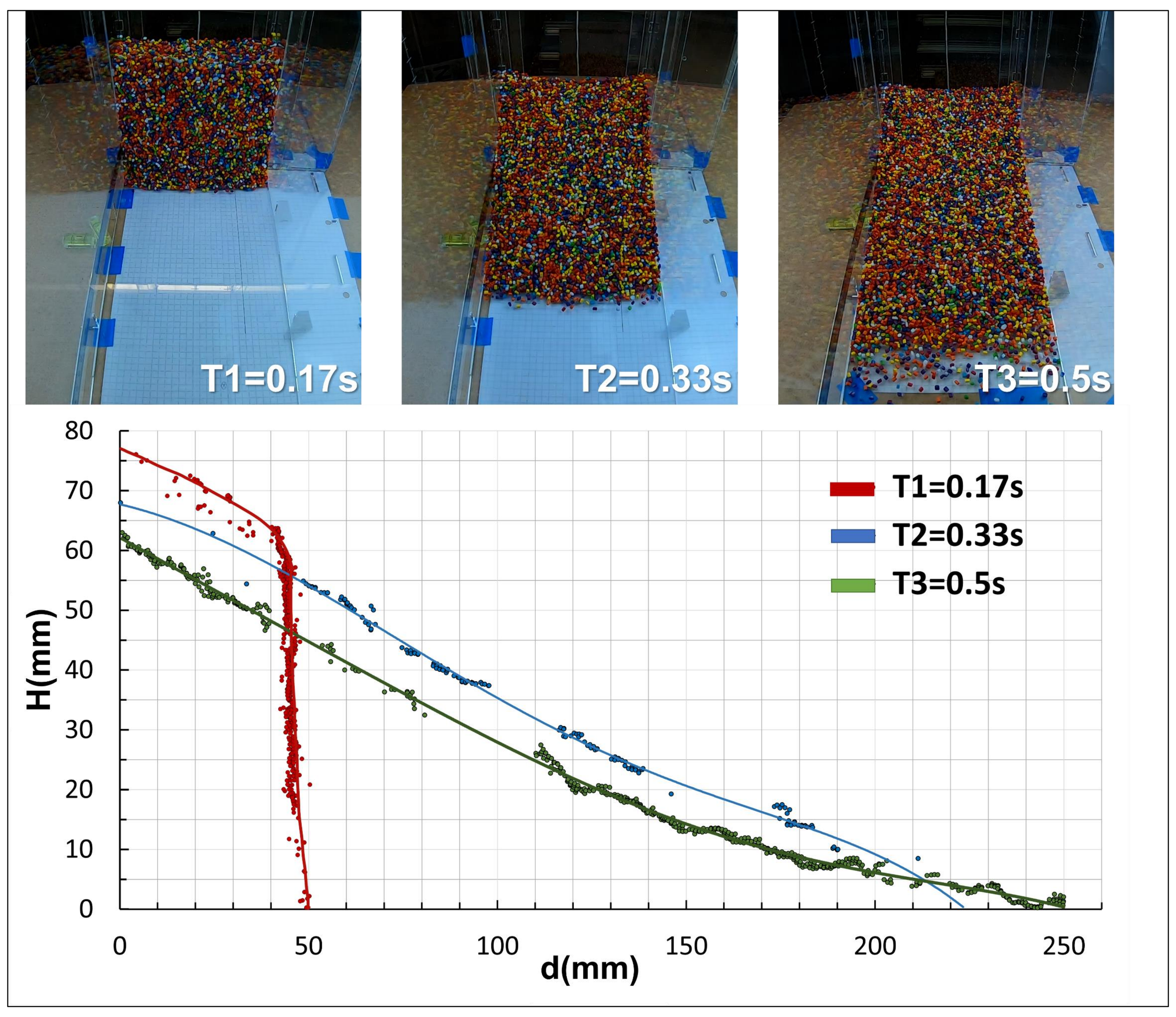


Figure 4. Fitted curves of the final deposit profile. The lines represent the surface profile of the settled granular assembly. Fitted with 5th order polynomial function.



A granular column collapse usually lasts for 0.2-0.7s, depending on the column's initial aspect ratio. With the cameras recording at 60fps, around thirty instantaneous shapes of the landslide mass can be retrieved. Then, the evolution of the landslide profile and propagation of the landslide front can be further obtained from this time series 3D surfaces.

Figure 5. Surface profiles at 0.17s, 0.22s and 0.5s. The flow front propagation speed can be calculated as the ratio of the front displacement to the time interval. Expansion of volume was observed before granules underwent significant movement, which manifested the dilatancy of the granular material.

Discussions and Future Work

The measured maximum runout distance $d\infty$ and final deposit height $h\infty$ are in good agreement with the theoretical values, yielding an error of 4.6% (*250mm vs. 239mm*) and 2.7% (*73mm vs. 75mm*), respectively. The experimental system has shown its ability to achieve reliable measurements.

We are interested to further develop methods to extract the velocities of individual grains. With the velocities of many surface grains, the surface velocity field can be obtained. A few challenges were encountered, e.g., blind spots, lack of structural features of grains, matching difficulties in consecutive frames. We will explore modern photogrammetry and computer vision technologies to overcome these issues. The measured velocity fields will be compared with the numerical modelling results in the next stage of work.

[1]G. Lube, H. Huppert, R. Sparks and A. Freundt, "Collapses of two-dimensional granular columns", Physical Review E, vol. 72, no. 4, 2005. Available: 10.1103/physreve.72.041301.

[2]E. Lajeunesse, A. Mangeney-Castelnau and J. Vilotte, "Spreading of a granular mass on a horizontal plane", Physics of Fluids, vol. 16, no. 7, pp. 2371-2381, 2004. Available: 10.1063/1.1736611.

[3]Pix4Dmapper. Pix4D SA, 2021. https://www.pix4d.com

[4]CloudCompare. EDF R&D, 2021. https://www.danielgm.net/cc/

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