Landslides: 3D reconstruction with smartphone images

Christoph Mertz

https://orcid.org/0000-0001-7540-5211

Final Report – August 2025

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, under [grant number 69A3552344811 / 69A3552348316] from the U.S. Department of Transportation's University Transportation Centers Program. The U.S. Government assumes no liability for the contents or use thereof.

Technical Report Documentation Page

<table>
<tr><td>1. Report No.</td><td>2. Government Accession No.</td><td>3. Recipient’s Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Landslides: 3D reconstruction with smartphone images</td><td>5. Report Date
August 2025</td></tr>
<tr><td>6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
Christoph Mertz, Ph.D.
https://orcid.org/0000-0001-7540-5211</td><td>8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Carnegie Mellon University
5000 Forbes Ave, Pittsburgh PA, 15213</td><td>10. Work Unit No.</td></tr>
<tr><td>11. Contract or Grant No.
Federal Grant # 69A3552344811 / 69A3552348316</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address</td><td>13. Type of Report and Period Covered
Final Report (July 1, 2024 – June 30, 2025)</td></tr>
<tr><td>14. Sponsoring Agency Code
USDOT</td></tr>
<tr><td colspan="3">15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.</td></tr>
</table>

16. Abstract

In this project we explore the usage of 3D reconstruction to monitor and measure landslides. We took images of a landslide prone area in late Fall 2024 and late Spring 2025. We used COLMAP to make a 3D point cloud out of the images and with CloudCompare we measure the difference between the two point clouds and thereby detect changes. In our experiment we are able to detect a rock that was dislodged, vegetation growth and accumulation of rocks.

17. Key Words	**18. Distribution Statement**
Landslides, 3D reconstruction, COLMAP	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	11	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Introduction

Landslides can be very disruptive and dangerous for highway traffic. It is important to monitor areas that are prone to landslides. Adding sensors to the environment can be tedious and expensive. One method we want to explore in this project is using the camera of a smartphone as our sensor and analyzing the data with 3D software.

Location

As a test site we choose a stretch of I68 in Cumberland, MD. It has the GPS location of (39.64339, -78.79495). Figure 1 shows a satellite view and the view from across the interstate.

Figure 1: Landslide area next to I68 at Cumberland. On the left is a satellite view (Google Maps). The middle picture shows the area from across the interstate along the landslide. On the right is a direct view of the area we will analyze in detail (red arrow).

Before we took any pictures, we placed two levels on the ground (see Figure 2) which define the horizontal plane and an absolute scale.

Figure 2: Two levels that will allow the 3D reconstruction to be scaled and leveled.

COLMAP

COLMAP[1] is widely used in the computer vision community to do 3D reconstruction form set of images. It is a well-maintained software package that can be used with a GUI[2] or with command lines[3]. To make the reconstruction a one step command, we wrote a script that executes the commands up to the dense pointcloud creation. The GUI is good for visualizing the results and to interactively remove images that are miss-aligned.

1 https://colmap.github.io/

2 https://colmap.github.io/gui.html

3 https://colmap.github.io/cli.html

Figure 3: 3D reconstruction (bottom) of a hill side (top). The insert shows the 3D point cloud of the levels. Notice that the orange level has a faint double. This is a sign of misalignment.

At first we did a reconstruction of a large part of the hill side. The point cloud shown in Figure 3 was made from 324 images. Unfortunately, some of the images were misaligned. The evidence for the misalignment can be seen in the bottom insert of Figure 3. There is a faint double of the orange level.

Misaligned images and their corresponding points in the point cloud can be removed with the help of the COLMAP GUI. Clicking on a misaligned point will show the corresponding images. Clicking on one of those images brings up a menu where on can delete this image from the reconstruction.

Noticing misalignment is fairly straightforward if there is an object that stands out like the orange level. However, it is very difficult when the areas are covered with similar looking loose rocks. We therefore concentrated our effort on a smaller area with a mix of loose and solid rocks. Figure 4 shows two images of that area, one taken 12/17/2024 and the other taken 6/19/2025. In the next section we will make 3D point clouds of this area from the two dates and compare them.

Figure 4: Left and right pictures were taken in late Fall and late Spring respectively

3D point cloud construction and comparison

We took 22 images from the late Fall dataset and 44 images from the late Spring dataset and did a 3D reconstruction of each respectively. We did the usual steps of feature extraction, feature matching, sparse reconstruction and finally dense reconstruction. Figure 5 shows the resulting point clouds.

From the levels in the large point cloud (Figure 3) we know the absolute scale of the hillside. Next we need to align the two dense point clouds. At first we tried to use COLMAP to align the two sets of images. This can be done by combining the two sets into one dataset and letting COLMAP match all the images with each other. Unfortunately, this did not work with our images. Alternatively, can do this the alignment with the help of the program CloudCompare[4]. It is a two step process. First we do a coarse alignment by picking four corresponding point pairs “Align (point pair picking)”. The second

4 https://www.cloudcompare.org/

step, the fine alignment, is an iterative closest point method “Fine registration (ICP)”.

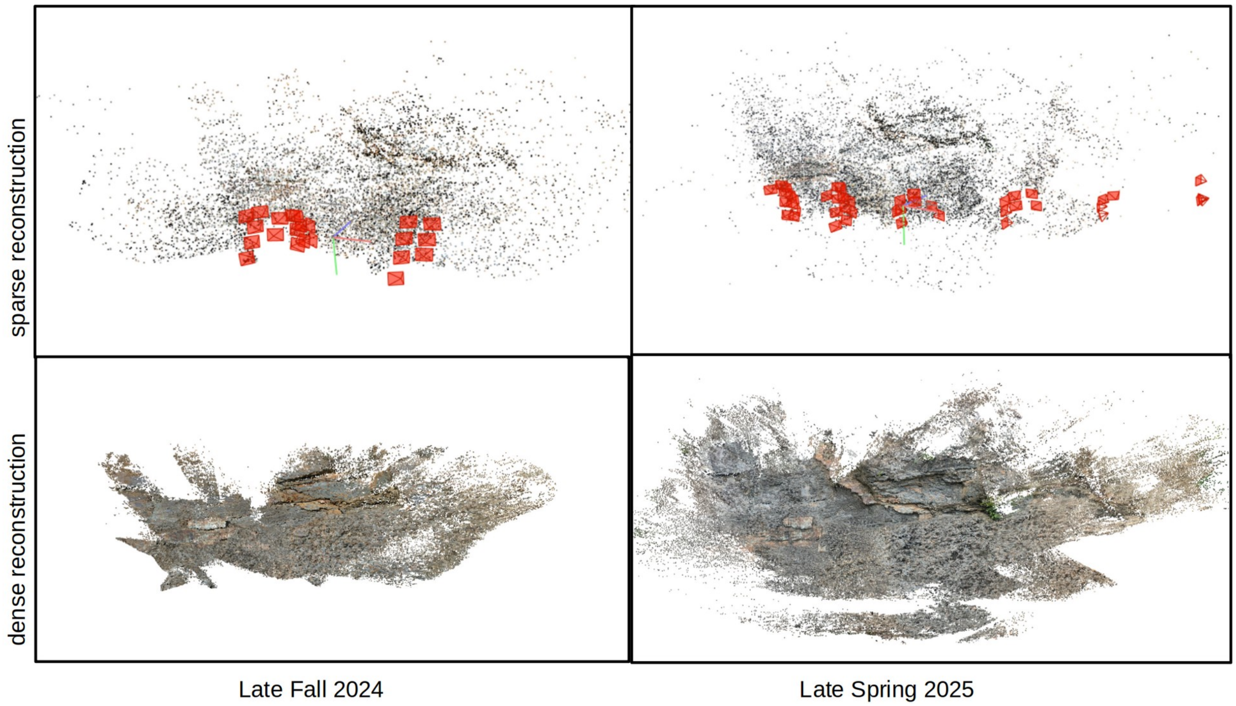

Figure 5: Sparse (top) and dense (bottom) point clouds from the images taken 12/17/2024 and 6/19/2025 respectively. The sparse point cloud and the camera positions (red pyramids) are displayed by the COLMAP GUI. The dense point clouds are displayed by the program CloudCompare. They are scaled and aligned to each other.

Now that the two point clouds are aligned, we can measure the distance between them. For each point in one point cloud we measure the shortest distance to the other point cloud. This results in a distance plot as seen in Figure 6 where the color of a point indicates distance to the other point cloud. Most of the area is colored in blue, i.e. the distance between the two point clouds is small (~1 cm). Some areas are green, indicating differences of about 10 cm. The largest distance we found is about 37 cm. Two arrows point to two locations which we look at in more detail.

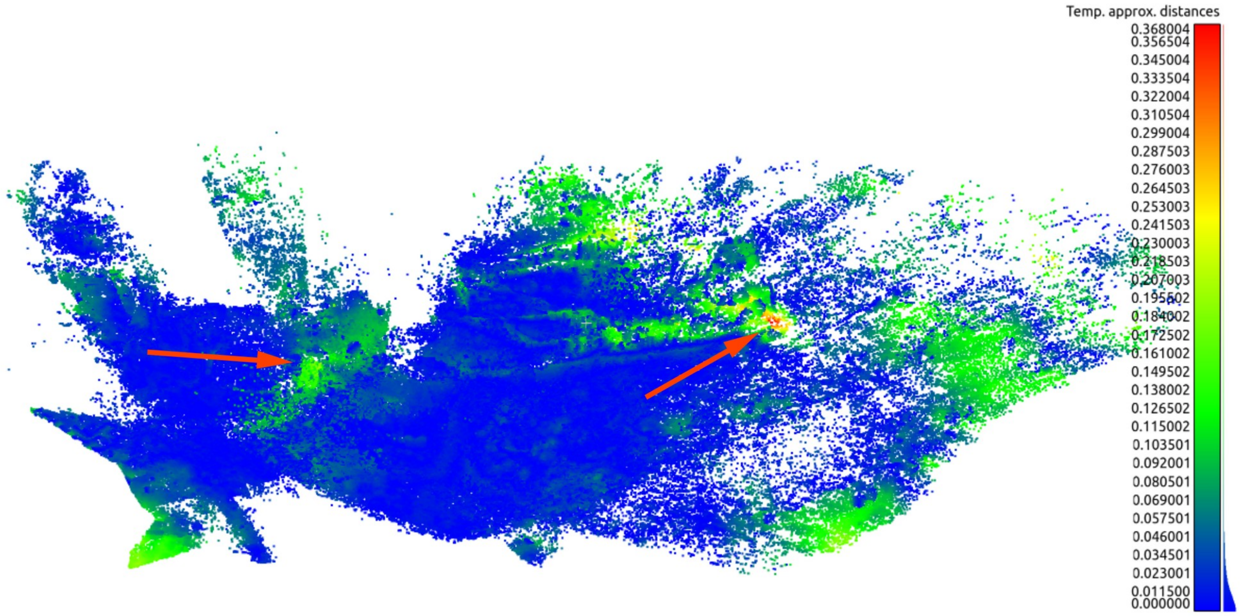

Figure 6: Point cloud difference. The color of each point indicates the distance of this point to the other point cloud. The distance values are in meter. The red arrows point to two significant locations.

In the first area (Figure 7 top) a piece of rock broke off from a rock formation and slid down the hill. The right top image shows the rock that broke off, but it is not directly visible in the distance plot, it got buried among the loose stones. However, the location where it used to be is clearly marked as green.

The second area (Figure 7 bottom) has two contributions. The largest difference (red in the distance plot) comes from newly formed vegetation. But there is also an extra accumulation of stones that is marked as green in the distance plot. These probably came from weathering of the rock formation above it.

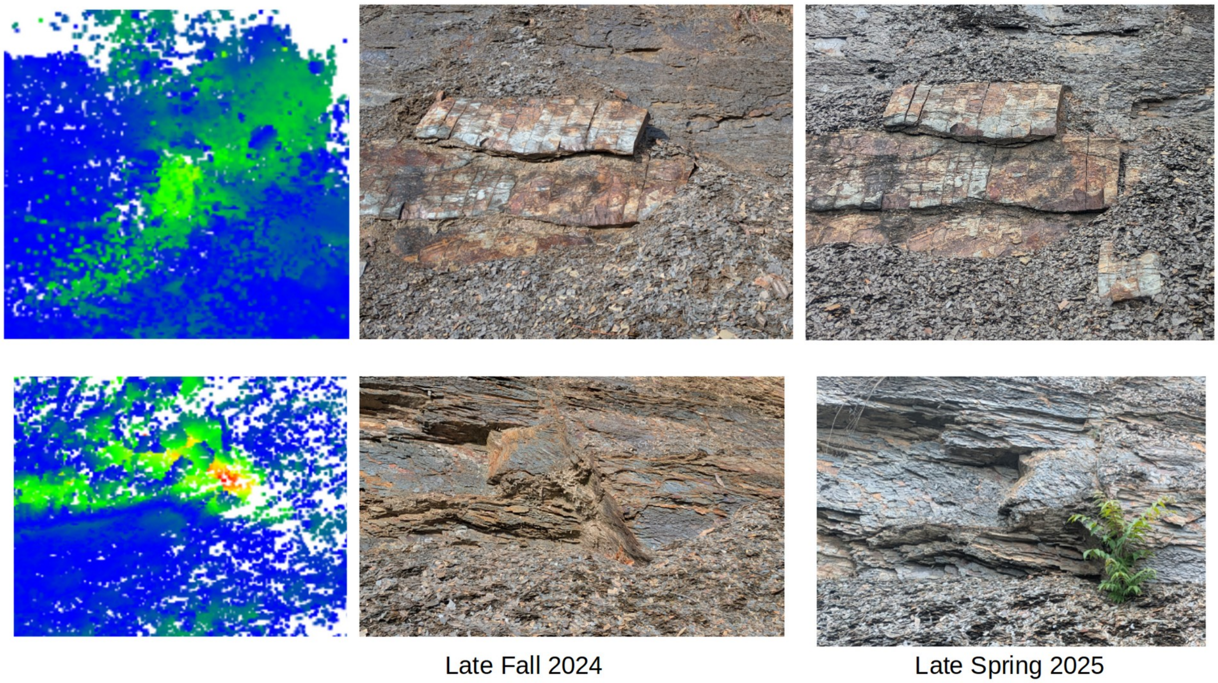

Figure 7: The distance plots (left) and the corresponding images of late Fall 2024 (middle) and late Spring 2025 (right). In the upper sequence one can see that a piece of a rock formation dislodged and slid down the hill. In the lower sequence the difference is caused by a plant and by the accumulation of loose rocks.

Lessons learned and conclusion

Creating 3D models form landslide prone areas in different seasons turned out to be more challenging than anticipated. It was expected that it is difficult to do 3D reconstruction where there is a lot of vegetation. Much less expected was that it was a problem to do 3D reconstruction in areas where there is a lot of loose stones. It would have been helpful if we would have added markers to the areas of interest.

Nevertheless, after some manual corrections, we were able to create 3D point clouds for the two different dates and compare them with each other through a distance map. This map helps to identify areas of change, e.g. a dislodged rock, vegetation growth, and accumulation of rocks. With some improvements of the data taking method, this is a promising technology to inexpensively monitor landslide areas.