Comparison of machine learning and automatic detection software for analysing debris flow deposits

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1. Introduction

Debris flow is a mixture of water and sediments that travels through steep channels at high velocity, posing significant hazards to human life and the environment. These flows can transport a wide range of sediment sizes—from fine mud and silt to large boulders. Sediment distribution along the flow path provides information related to sediment transport, erosion, and deposition processes. This makes particle size analysis of debris flow deposits an important field to research. In recent years, image-based techniques have been in frequent use to analyze surface deposits of sediments, particularly machine learning or automatic detection software. Such studies are mostly focused on the fluvial sediments (such as gravel bars). However, the characteristic of debris flow sediments differs significantly from those of fluvial sediments. Debris flow deposits contain more heterogeneous and broader range of particle shapes and size. Therefore, accuracy on the particle size distribution results from different image-based techniques should be evaluated being specific to debris flow deposits. In this study, we compare two image-based approaches for analyzing surface particle sizes in debris flow deposits: the automatic object detection software BASEGRAIN and a machine learning approach using YOLOv8. We aim to evaluate their effectiveness in detecting and measuring sediment sizes from the UAV photographs of debris flow deposits.

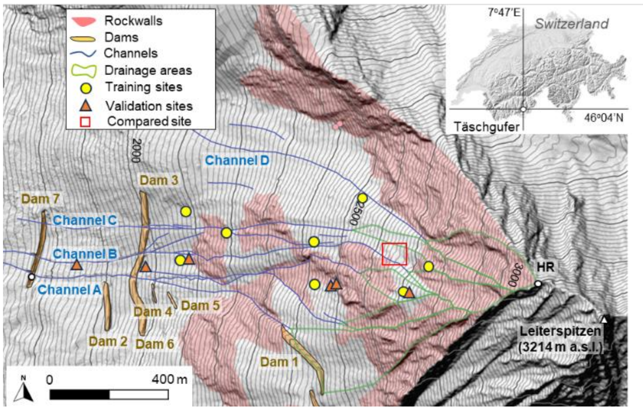

Figure 1. Topographic map of the Täschgufer

2. Methodology

This study was conducted in the debris flow deposit area of Täschgufer (Fig. 1), located in the southern Swiss Alps. The source of the debris flow sediments in Täschgufer is the frequent rockfall activity from heavily disintegrated gneissic outcrops (Stoffel et al., 2005). For this research, we used orthophotos of resolution 0.054 m px^{-1} captured by a DJI Inspire 2 drone in August 2019. Two image-based methods were applied to perform particle size analysis: the automatic object detection software BASEGRAIN and a machine learning model (YOLOv8). BASEGRAIN, a MATLAB-based software tool was designed to automatically detects and analyze top-view photographs of sediment particles in fluvial gravel beds. It allows immediate application without the need for labeled datasets. For the machine learning approach, YOLOv8 (Ultralytics, 2023) was selected due to its flexibility in detecting a wide range of objects. The YOLOv8 model was trained using 20 orthophotos (10 × 10 m each), covering different sediment textures and shapes across the channel deposit. A total of 4,297 sediment instances were manually labeled, and 80% of the data was used for training while 20% (5 images, 1,222 instances) was used for validation. Training was conducted over 245 epochs with an image size of 800 pixels. Validation of prediction result by the YOLOv8 trained model was performed at six 10 × 10 m sites with diverse sediment characteristics. To compare the segmentation results of the two methods, we chose the site just below the rockwalls, which is also the initiation zone of the debris flow. In the compared site, sediments ranged from very fine particles to large boulders exceeding 2 m in diameter (Fig. 2). Visual inspection was performed to compare results between BASEGRAIN and YOLOv8.

3. Result

3.1. Detection by BASEGRAIN

BASEGRAIN segments particles by detecting interstices and applying a watershed segmentation algorithm (Detert and Weitbrecht, 2013). The advantages of BASEGRAIN in performing detection without any training process make it suitable for quick particle size analysis. However, it showed several limitations. In this analysis, BASEGRAIN frequently merged clusters of small adjacent particles into single sediments and often separated larger boulders (mostly greater than a meter) into multiple smaller segments (Figs. 2b, 3). These issues resulted in a high rate of false detections. It excludes particles with an area smaller than 23 pixels, which makes it unsuitable for detecting finer sediments in lower-resolution photographs. While BASEGRAIN performed reasonably well for medium-sized particles (larger than fine grains but smaller than boulders), its performance for extreme sizes (very fine or very big) was limited by image quality and algorithmic constraints. Therefore, manual correction, such as removing false particles or merging dissected sediments, is essential to improve detection accuracy.

3.2. Detection by YOLOv8

The YOLOv8 model, trained on orthophotos from Täschgufer, demonstrated high adaptability to local size ranges (Fig. 2c). It successfully identified most visually detectable surface particles with strong accuracy, achieving over 86% precision and over 76% recall during validation. While, like BASEGRAIN, it could not detect fine sediments due to resolution limitations, YOLOv8 effectively segmented larger particles without dissecting them into multiple fragments and avoided merging clusters of smaller sediments into single sediments. Although some detections were missed, it produced more reliable results with fewer false positives and better performance on large boulders. Although initial model training requires time and labeled data, once trained, YOLOv8 can be deployed efficiently across multiple UAV surveys, enabling consistent and scalable sediment monitoring across larger debris flow regions.

4. Conclusion

The sediment detection pattern between BASEGRAIN and YOLOv8 on UAV photographs of debris flow deposits was different. YOLOv8 showed higher adaptability for detecting debris flow sediments compared to BASEGRAIN, especially for larger particles. While BASEGRAIN offers faster results, many manual corrections are essential to get accurate results.

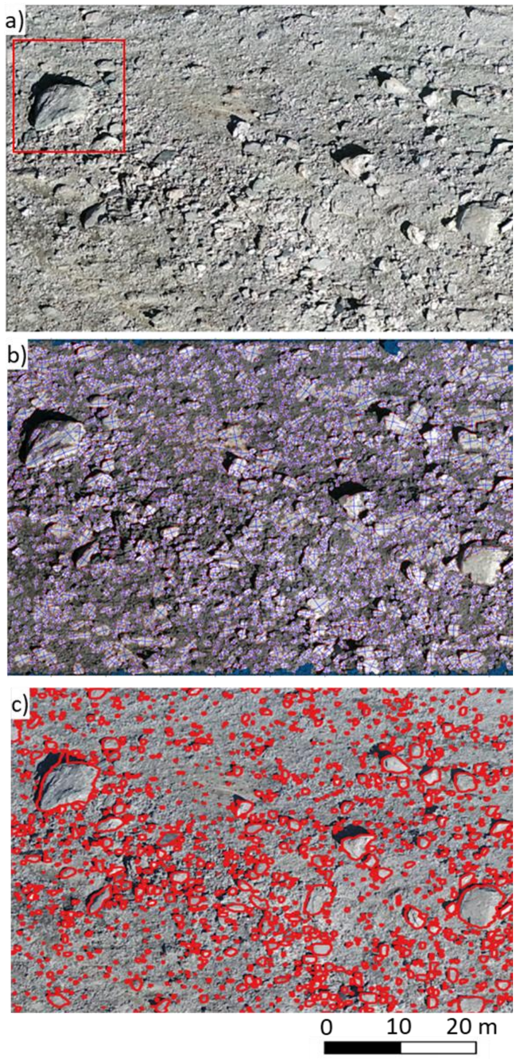

Figure 2. Comparison of sediment detection: a) Original orthophotograph b) Detection by BASEGRAIN c) Detection by YOLOv8. Red box indicates the section in Figure 3.

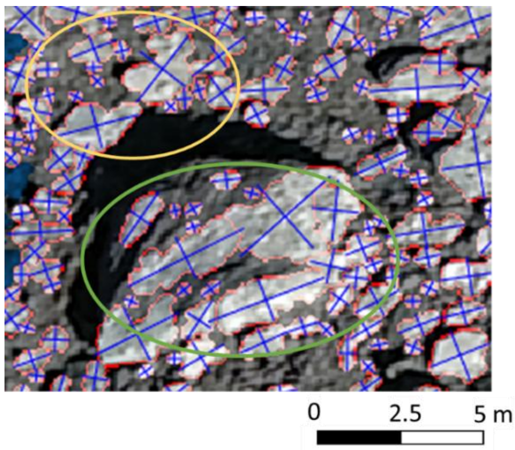

Figure 3. BASEGRAIN detection. Green: over-segmentation of large sediment. Yellow: merging of small sediments.

References

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