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Weathered Rock Surface Classification with Unpiloted Aerial Vehicle Imagery and Machine Learning

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Introduction and Motivation for the Research

Weathering of rocks is a critical process that significantly influences the stability and response of rocks under dynamic conditions. Weathering is the primary process by which the strength of rocks is adversely affected. Traditional methods of determining the degree of weathering such as Schmidt rebound, penetration-obstruction, hardness tester, and ultrasonic methods require more workforce and lead to time consuming and difficult field monitoring tasks. Frequently, they either give incomplete field data or put the working staff in danger because of the difficult terrains with potentially hazardous conditions despite the safety measures and time-consuming efforts. The advancement of technology, tools, data-gathering platforms, and data-processing techniques provide attractive alternatives for traditional time-consuming methods while demanding rigorous evaluation prior to usage as acceptable replacements for the existing. In light of this, aerial or satellite images for such operations are the preferred choice at present besides, the major drawbacks in spatial and temporal resolution. Unpiloted aerial vehicles (UAVs) or drones have become a popular and successful remote sensing tool for many disciplines due to their high spatial range, resolution, and flexibility in handling.

Objectives of the Research and Procedures

Objective: Using the UAVs to assess the possibilities of identifying the rock weathering patterns aiming to replace the laborious tasks involved in the traditional field works.

Procedures: The constructed benches of an abandoned quarry site having different weathering grades and abnormally weathered regions were imaged using a DJI Multi-spectral Phantom 4 UAV and processed with DJI GS Pro software. The UAV flew at the height of 120 m with a front overlap of 80% and a side overlap of 60% while covering an area of 0.33 km^2 with a whisk broom flight path for image acquisition. The captured images were processed using Pix4D Mapper, and mosaic maps of each band were created and georeferenced using ground-control points (GCPs). The GCP coordinate measurements were taken from a Stonex DGPS unit and were used to increase the georeferencing accuracy. The UAV images consisting different shades of features, including soil, various stages of weathering (complete, moderate, and slight), fresh rocks, wet rocks, and vegetation were converted into unique classes for classification purposes using 800 × 500-pixel region and subject to undergo supervised machine learning techniques. The obtained multispectral images having five spectral bands were initially prepared with natural colour composites and sixty false-colour composites. Experts performed ground-truth labelling for the selected study area through on-site observations and high-resolution UAV images. Fifty-eight critical features were extracted from each false-colour composite using different filters. The performance of the 18 machine learning algorithms for this specific classification study was assessed using the Pycaret library's "compare_models()" function. Algorithms that performed equally well, based on overall accuracy and F1 score were selected to assess other false-colour composites. A preliminary assessment was performed to determine the best combination of false-colour composites and selected ML algorithms. The algorithms were employed with default parameter settings and their overall accuracy and F1 scores were used to assess their performance. To further support our findings, we analysed the confusion matrix, receiver operating characteristic (ROC) curve, area under the curve (AUC), and contrast of spectral values between the selected bands. Finally, a high-performance model and promising band combinations were recommended for further analysis.

Results

Depending on the overall accuracy and F1 score of the high-performance ML algorithms measured for the natural colour composite image, the Random Forest (RF) classifier and Extreme Gradient Boosting Machine (XGB) performed well, with an overall accuracy of 0.65 and an F1 score of 0.6, respectively. Therefore, RF and XGB were chosen for further evaluation of the other false colour composite images. XGB performed slightly better than RF in classifying most classes, such as discoloured rock, completely weathered rock, moderately weathered rock, fresh rock, wet rock, and vegetation cover. However, both algorithms performed similarly in classifying soil and slightly weathered rocks. Among these, the weathered rock class (comprising completely, moderately, and slightly weathered rocks) achieved an F1 score of 0.88 using the RE-NIR-R (RE- Red-edge, NIR- Near infrared, R- Red) band combination with a 96% correct prediction rate.

Conclusions

This study highlights the potential of utilising UAVs with multiple ML algorithms to classify weathered rock surfaces. The RE-NIR-R band combination with the XGB algorithm yielded an impressive F1 score of 0.88 for classifying weathered rocks in general. However, the subclassification of different weathering classes yielded a range of F1 scores (i.e., 0.4 to 0.71), mainly owing to restrictions, such as the spatial resolution, enforced by the multispectral sensors. However, this combination of bands enabled the identification of a clear distinction between vegetation and discoloured rocks. Despite these limitations, our study serves as a promising first step in demonstrating the potential of combining images acquired from UAVs and ML algorithms to identify and classify rock-weathering patterns on exposed rock surfaces.