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Sen12Landslides: A Multi-modal, Large-scale, Multi-temporal Benchmark Dataset for satellite-based Landslide Monitoring

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Landslides, with their devastating impact on communities and infrastructure, present a pressing challenge for accurate and timely detection. Effective monitoring is therefore essential, not only to understand the process of landslides, but also to provide comprehensive risk assessments for future planning and to mitigate the consequences of such events. In addition, timely mapping of these hazardous events is essential to gain an overview and coordinate rescue efforts, while also addressing the geoscientific component of how these processes evolve over space and time, including potential acceleration due to climate change. To address this critical need, our study presents a large-scale, multi-temporal dataset that uniquely combines time-series data from the Sentinel-1 and Sentinel-2 satellites to improve landslide monitoring. Our initiative aims to create a globally standardized dataset that will overcome the challenges of transferring existing algorithms and facilitate the development of more effective models. This innovative and still growing dataset, which already includes over 7500 landslides from 16 global regions, offers a unique opportunity to advance machine learning methods for landslide detection. Using time-series analysis of Sentinel-1 radar data, we have successfully identified the onset and end dates of landslide events. Complementing this, Sentinel-2 optical data analyzed by NDVI change provide detailed land cover information critical for accurate landslide labelling. Our methodological approach is rigorously validated by manual expert review to ensure the reliability and accuracy of our results. By incorporating temporal context and combining the cloud-penetrating capabilities of Sentinel-1 with the rich multispectral resolution of Sentinel-2, this research represents a significant advance in the use of satellite data for landslide monitoring and serves as an invaluable resource for both the remote sensing and machine learning communities. It supports both object-based landslide identification and granular pixel-level analysis through semantic segmentation, extending its versatility for various environmental research applications. In our initial benchmarks, we evaluated existing state-of-the-art models such as UNet3D, U-TAE, TSViT and U-ConvLSTM to better understand their individual advantages for landslide monitoring. This process highlights the potential of our dataset to provide a reliable benchmark for future developments in landslide detection research.