EO-AI4Urban: Earth Observation Big Data and Deep Learning for Sustainable and Resilient Cities

The pace of urbanization has been unprecedented. Rapid urbanization poses significant social and environmental challenges, including sprawling informal settlements, increased pollution and urban heat island effects, loss of biodiversity and ecosystem services, and increased vulnerability to disasters. Therefore, timely and accurate information on urban change patterns is crucial to support sustainable and resilient urban planning and monitoring of the UN 2030 SDGs. Leveraging Earth observation (EO) big data and AI, this project aims to develop innovative, robust and globally applicable methods, for urban land cover mapping and urbanization monitoring to address.

In recent years, deep learning algorithms have shown promise in urban mapping and change detection, especially when integrating various Earth observation data sources. Despite advancements, challenges persist, including cloud interference and the need for labelled data. To address these challenges, the EO-AI4Urban team has developed varous deep learning-based methods for urban mapping and change detection. For urban mapping, a novel Domain Adaptation (DA) approach using semi-supervised learning has been developed for urban extraction. The DA approach jointly exploits Sentinel-1 SAR and Sentinel-2 MSI data to improve across-region generalization for built-up area mapping [1]. Furthermore, we developed a multi-modal urban mapping method that utilizes a reconstruction network to approximate the features of the optical modality when only SAR data is available [2].

For urban change detection, several novel methods have been developed including a dual-stream U-Net [3], a Siamese Difference Dual-Task network with Multi-Modal Consistency Regularization [4], a high-resolution feature difference attention network (HDANet) using the Siamese network structure [5]. Another novel procedure was designed to search for built-up changing patterns with the joint use of temporal and spatial properties, using high-frequency SAR time series [6] [7]. To comprehensively capture the scene-level changes between the bi-temporal VHR images, a novel DAN-CPFS framework that integrates differential aggregation network and class probability-based fusion strategy was proposed [8]. The Double U-Net (W-Net) method, a semi-supervised dual-head approach, was introduced to tackle challenges in change detection such as incomplete buildings and blurred edges. By integrating UNet++ and a superpixel module, W-Net improves spatio-spectral characteristics and corrects edge discrepancies, while employing a self-training method to enhance change detection data volume and reduce labelling costs [9]. Finally, to identify similar urban areas quickly and to reduce the cost of manually labeled data, a multisource data reconstruction-based deep unsupervised hashing method was proposed for unisource remote sensing image retrieval, called MrHash, which consists of a label generation network and a deep hashing network [10]. Furthermore, to address the increasing frequency of extreme heat events due to climate change and urbanization, we proposed a heat health risk assessment framework for Beijing, focusing on hazard, exposure, and vulnerability. It utilizes remote sensing data to analyze the spatial pattern of green infrastructure and its impact on heat health risk.

Using ESA Sentinel-1 SAR, Sentinel-2 MSI, the results showed that the proposed DA approach achieves strong improvements upon fully supervised learning and offers great potential to be adapted to produce easily updateable human settlements maps at a global scale [1] [2]. Using the OSCD dataset, the results showed that the dual-stream U-Net outperformed other U-Net-based approaches with feature level fusion of SAR and optical data [3]. Using bi-temporal SAR and MSI image pairs as input, the Siamese Difference Dual-Task network with Multi-Modal Consistency achieved higher F1 score than that of several supervised models when applied to the sites located outside of the source domain [4]. Using several public building change detection datasets, the experimental results showed that the HDANet can achieve a high building change detection accuracy, compared with the current mainstream methods, with public building change detection datasets [5]. Using Hanyang Scene Change Detection (HY-SCD) dataset, the results show that the proposed DAN-CPFS change detection method outperformed some other state-of-the-art methods [8]. Experimenting on two public datasets and the Shanghai JD large-scene dataset, the W-Net exhibits remarkable performance across datasets. Conducting experiments on Sentinel-2 and GF-1 satellite images, the results showed that MrHash yielded the best performance among all methods [10]. The urban heat study confirms that areas with abundant green infrastructure exhibited a low likelihood of becoming high-risk areas, underscoring the importance of expanding green spaces and water bodies to mitigate heat health risks and offering insights for enhancing urban thermal resilience through nature-based climate adaptation.

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