Deep Learning from Space: Methods & Applications in High-Resolution Satellite Imagery Analysis

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Abstract

Satellite imagery analysis using deep learning methods, specifically convolutional neural networks (CNNs), has grown in popularity since 2012, with uses extending into the estimation of population, wealth, poverty, conflict, land use classification, education, and infrastructure, among other applications. This dissertation contributes to this body of literature in three parts. First, I explore the use of deep learning to overcome the sparsity, or complete lack, of accurate information regarding existing road infrastructure across much of the world. Using a novel labeled dataset generated by a custom-coded Android application, I show that a transfer learning approach can estimate road quality based on high-resolution satellite imagery with an accuracy of up to 80%. In the second chapter, I illustrate the vulnerability of this and related models to cyber intrusions (data poisoning) and propose a new technique to mitigate these vulnerabilities. The third chapter applies the lessons learned to propose a novel model architecture for spatiotemporal monitoring of industrial sites in inaccessible regions around the world, integrating high-resolution satellite imagery, a segmentation algorithm, and a pretrained CNN-LSTM (long short-term memory) framework to automatically detect and monitor individual industrial sites within the People's Republic of China. These three chapters advance our understanding of many of the challenges unique to computer vision in the context of satellite data and provide some guidance on fruitful future directions.