Automating National Mapping & Cadastre with GeoAI

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SUMMARY

National Mapping & Cadastral Authorities (NMCAs) are continually looking at ways in which they can be more efficient and effective in maintaining and delivering authoritative, timely, land and geographic information to their users. Advances in GIS technology, and adoption of new capabilities such as Artificial Intelligence (AI), can make a significant contribution to meeting these needs.

AI is not a new topic. However, with advances in computing power, availability of large (big) data, and its incorporation in GIS (GeoAI), AI is now a highly relevant and timely capability that can be applied today to automate, amongst other things, change detection and feature extraction. This will help reduce costs and the time taken between change happening on the ground (in the 'real world') and being reflected in the topographic maps and cadastre (the 'digital world') improving the quality (currency) of the products and services available from the NMCAs.

The paper and presentation will highlight these new GeoAI capabilities and illustrate how they have been applied to support change detection and feature extraction in a number of case studies from the European NMCAs.

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1. Introduction

National Mapping & Cadastral Authorities (NMCAs) are continually looking at ways in which they can be more efficient and effective in maintaining and delivering authoritative, timely, land and geographic information to their users. Advances in GIS technology, and adoption of new capabilities such as Artificial Intelligence (AI), can make a significant contribution to meeting these needs. In particular, GeoAI (incorporating AI in GIS) can be used to automate the process of change detection and feature extraction, reducing the time it takes between change happening on the ground – in the 'real world' – and being reflected in the topographic and cadastral databases – the 'digital world'.

This paper describes some of these GeoAI capabilities and how they have been successfully implemented in a number of different use cases in NMCAs.

2. Why use GeoAI?

One of the key challenges for NMCAs, whether it's maintaining topographic or cadastral data, is to deliver more up-to-date (current) data to their users, and to do this as cost effectively as possible often with reducing budgets. Anything that can be done to automate this process will help deliver quality improvements and costs efficiencies.

This has been successfully demonstrated in the generalization process for topographic mapping – creating multi-scale mapping products from a single national database. NMCAs such as Dutch Kadaster, Ordnance Survey GB, Ordnance Survey Ireland, IGN France and several others have implemented fully automated generalization workflows that deliver significant cost savings and more up-to-date topographic mapping products.

Using the GeoAI capabilities in GIS we can now look to implement automation to the data capture and maintenance workflows.

3. GeoAI capabilities

The field of artificial intelligence (AI) has progressed rapidly in recent years, matching or, in some cases, even surpassing human accuracy at tasks such as image recognition, reading comprehension, and translating text. The intersection of AI and GIS – GeoAI - is creating massive opportunities.

Broadly speaking, **AI** is the ability of computers to perform tasks that typically require some level of human intelligence. Machine learning is one type of engine that makes this possible. It uses data driven algorithms that learn from data to give you the answers that you need. One type of machine learning that has emerged is deep learning. Deep learning uses computer-generated neural networks, which are inspired by and loosely resemble the human brain, to solve problems and make predictions.

Machine learning has been a core component of spatial analysis in GIS. Its tools and algorithms have been applied to geoprocessing tools to solve problems in three broad categories: classification, clustering, and prediction. With classification, you can use vector machine algorithms to create land-cover classification layers. Clustering lets you process large quantities of input point data, identify the meaningful clusters within this data, and separate meaningful clusters from the sparse noise. Prediction algorithms, such as geographically weighted regression, give you the ability to model spatially varying relationships. These methods work well in several areas. Their results are interpretable, but they need experts to identify or include those factors (or features) that affect the outcome being predicted.

Deep Learning allows us to use the machine rather than the human to analyse what those factors/ features should be just by looking at the data. In a deep neural network, there are neurons that respond to stimuli and are connected to each other in layers. Neural networks have been around for decades, but it has been a challenge to train them. The advent of deep learning can be attributed to three primary developments in recent years—availability of data, fast computing, and algorithmic improvements:

- Data: We now have vast quantities of data, thanks to the Internet, the sensors all around us, and the numerous satellites that are imaging the whole world every day.
- Computing: With cloud computing, we have powerful computational resources. Graphics processing units (GPUs) have become more powerful than ever and gone down in price, thanks to the gaming industry.
- Algorithmic Improvements: Finally, researchers have now cracked some of the most challenging aspects of training deep neural networks through algorithmic improvements and network architectures

One area of AI where deep learning has done exceedingly well is computer vision, or the ability for computers to see. This is particularly useful for GIS because satellite, aerial, and drone imagery is being produced at a rate that makes it impossible to analyze and derive insight through traditional means. Image classification, object detection, semantic segmentation, and instance segmentation are some of the most important computer vision tasks that can be applied to GIS.

With object detection, the computer needs to find the objects within an image as well as their location. This is a very important task in GIS because it finds what is in a satellite, aerial, or drone image, locates it, and plots it on a map. This is highly relevant for NMCAs interested in change detection and feature extraction.

Using semantic segmentation each pixel of an image is classified as belonging to a specific class. In GIS, semantic segmentation can be used for land-cover classification or the extraction of road networks from satellite imagery. Another type of segmentation is instance segmentation. You can think of this as a more precise object detection in which the precise boundary of each object instance is marked out. Instance segmentation can be used for tasks like improving base maps. This can be done by adding building footprints or reconstructing 3D buildings from lidar data.

These AI (Deep Learning) capabilities are now integrated in GIS, embracing the complete workflow from imagery management, through *deep learning*, to final sharing of the products:

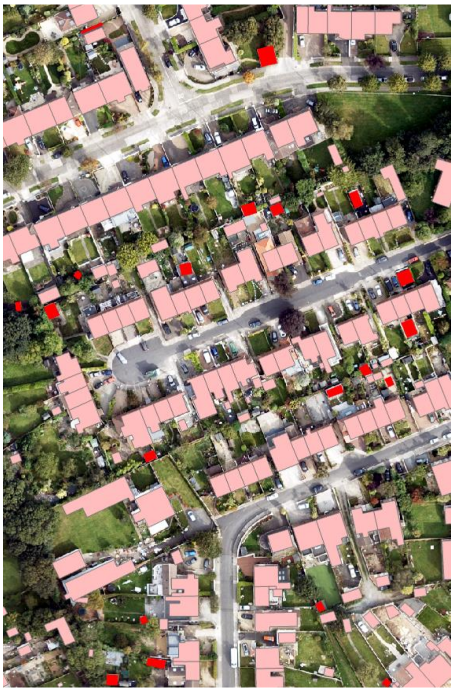
Imagery Management > *Labelling: Data Prep: Model Training: Inferencing* > Post Processing > Sharing

Esri has worked on the process of streamlining this workflow by creating a number of pre-trained DL models, including for buildings, roads, land cover. These provide an excellent starting point that can be further trained to suit specific geographies.

4. Case Studies

Over the last 12 – 24 months Esri has worked on several Proof of Concepts (PoCs) with the NMCAs to assess the application of GeoAI for change detection and feature extraction using their high resolution (12cm) imagery with a particular focus on buildings.

The images below, for two different types of geography – one urban, one rural – illustrate the buildings (in red) identified with AI that were not in the master database. In the case of a cadastral use case where the aim is to identify buildings that are not registered (and therefore not taxed) the return on investment can be significant. Similarly, for updating topographic mapping, any time saved in manual intervention (i.e. looking for change) is helpful. For an NMCA in a developing country where the base mapping is either unavailable or significantly out of date, GeoAI offers the opportunity to create a "fit for purpose" base map that can gradually be improved over time. The conference presentation will expand on these case studies.




In conclusion, the results achieved have been encouraging and will only get better as more training data becomes available and training models are further refined for different geographies and use cases. Flexibility in product specifications will also be required if a fully automated flowline is to be deployed – a lesson learnt in automatic generalization.

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BIOGRAPHICAL NOTES

Nick is a senior manager at Esri with over 20 years' experience working in the fields of survey, mapping, cadastre, land registration, LIS/GIS and SDIs. He has extensive experience and knowledge of the industry having worked for Ordnance Survey, including in its international unit, and EuroGeographics – the European association of mapping and cadastral agencies.

Nick has a degree in Geography, is a professionally (RICS) qualified land surveyor, and has completed his doctorate in GIS/LIS.

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