Iraqi Journal of Statistical Sciences

http://stats.uomosul.edu.iq

Using Deep learning and GIS applications to Extract Features from Remote Sensing Data

Faten Azeez Mustafa

Image Processing Dept., Remote Sensing Center, University of Mosul , Mosul ,Iraq

Article information

Article history:
Received: October 2, 2024
Revised:April 20,2025
Accepted: June 28, 2025
Available:December1,2025

Keywords:
Deep Learning,
Object Detection,
ArcGIS Pro,
Remote Sensing Data

Correspondence:
Faten Azeez Mustafa
faten.alani@uomosul.edu.iq

Abstract

In recent years, artificial intelligence (AI) has advanced quickly, equal or perhaps even outperforming human accuracy in tasks like picture recognition, reading comprehension, and text translation. Large-scale opportunities that were not previously available are now had been created by the confluence of AI and GIS with remote sensing data processing. The motivation of current study is to incorporate deep learning models that implemented through ArcGIS Pro tools particularly convolutional neural networks (CNNs), identifying complex patterns and features in high-resolution image. An automated Deep Learning model type Mask R-CNN had applied to extract model for training objects. The overall accuracy metric improved the performance of the current work accurately with less error when calculating RMSE criteria.

DOI: 10.33899/iqjoss.v22i2.54069, ©Authors, 2025, Image processing Department, Remote Sensing Center, and University of Mosul.

1. Introduction

In GIS, deep learning has become a crucial part of spatial analysis. Reprocessing techniques have been leveraged with these tools and methods to solve problems in three main areas: categorization, object identification, and feature extraction [4]. Due to the unavoidable impact of spatial resolution, spectral resolution, radiometric resolution, and other parameters in remote sensing image acquisition, the remote sensing approach has the complete potential to obtain rich information data from the surface. On top of that, satellite images are the most common approach to collecting information about geography [7], and there are numerous applications for satellite image analysis across an assortment of occupations, such as design, construction, urban planning, and object detection [9-12].

Recent research focused on analyzing remote sensing data using machine learning and deep learning models has distinguished between two classification approaches: supervised and unsupervised learning. Some recent studies have combined these two methods to obtain hybrid techniques that yield better results, deep learning models had employed to construct intelligent systems for the Internet of Things (IoT) and remote sensing data.

For civil engineering, a deep learning application with ArcGIS software tools that used to construct a 2D model for a city that implemented using stereo satellite images [16].

This work aims to show how to distinguish whole buildings as much as possible from satellite images that used as input data for processing and with high-resolution to improve the capacity of deep learning approaches for detecting and accurately segment the specified objects with rich visualization and high performance.

Consequently, in the next section, an automatic deep learning model has applied to detect building Objects from AOI training samples had implemented besides sequence steps, which clarified in Figure (1).

2. Literature Review

Deep neural networks (DNN) are increasingly being accelerated in various applications, particularly in data processing, data analysis, and predictive and knowledge portals. DNNs have achieved a significant role in numerous fields, especially in image processing and handling big data. Remote sensing data offers rich spatial and spectral information. Traditional GIS-based feature extraction relied on manual or semi-automated approaches, which are time-consuming and prone to human error. Deep learning, particularly Convolutional Neural Networks (CNNs), has emerged as a powerful tool to automate and enhance feature extraction. Various studies have extracted different objects land cover building and road.[2] that improve the performance of remote sensing big data analysis by advancement in information technology and machine learning algorithms using CNN (Convolutional Neural Network) to extract buildings and vehicles from high-resolution satellite image with improved accuracy. [5] Used a U-Net-based architecture for extracting buildings from large-scale remote sensing data, although initially designed for biomedical segmentation, U-Net has been widely adopted for building extraction due to its ability to perform pixel-level classification demonstrating superior performance compared to traditional methods. In the other hand [9] applied U-Net and deep learning model for building extraction from aerial imagery Incorporated attention mechanisms into the U-Net model to focus on relevant features, significantly improving building extraction accuracy.[14] developed multitask deep neural network for segmentation building objects from other land cover patterns with results of enhancing the models contextual understanding simultaneously. While in [15] authors discussed generalization issues, computational demands, and the need for explain ability in deep learning models for building extraction. Authors in [22] introduced a multi-scale CNN approach for building extraction, which improved the detection of buildings of various sizes significantly improving building extraction accuracy. However, the current study training deep learning model via ArcGIS Pro tools is challenging to extract building from high-resolution data to improve the efficiency of implemented model. This work aims to show how to distinguish whole buildings as much as possible from satellite images that used as input data for processing and with high-resolution to improve the capacity of deep learning approaches for detecting and accurately segment the specified objects with rich visualization and high performance

Consequently, in the next section, an automatic deep learning model has applied to detect building objects from selected study area samples had implemented besides sequence steps that clarified in Figure (1).

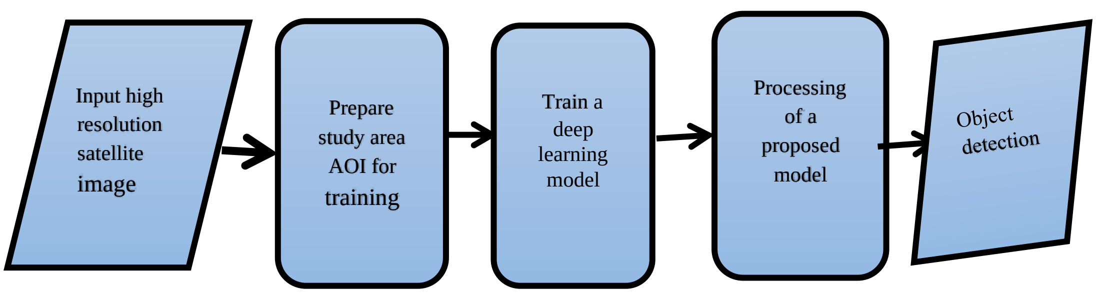

Figure (1) Workflow steps for deep learning model

Based on Figure (1), the following sections illustrated:

3. Materials and Methodology

This section includes the workflow of the deep learning method implemented in this study, as described in Figure.1, ArcGIS Pro version 2.8.1, utilized to illustrate the processing steps for this study. According to available methods for extracting different types of buildings, most of them use manual digitizing. Thus, this is a significant tension and time-consuming [12].

Consequently, artificial intelligence techniques are increasingly developed, integrated, and built Into the software to analyze big data for extraction, segmentation, and classification methods from Remote sensing data [9]. ArcGIS Pro software is a fully functional desktop GIS application from Esri for experts to create 2D maps and 3D sceneries, explore, visualize, and analyze data (Big data, remote sensing data) [11] The details about each section of workflow process were clarified as the following:

3.1. Data and Materials

According to the organization of process input data image with a high resolution near (15-25 cm), three bands (Red, Green, Blue) and 8-bit depth that taken from Esri web site [https://www.esri.com]. ArcGIS Pro software version 2.8.1 and Deep Learning tools that had implemented for this work.
As noted from the previous studies, the deep learning model needs time to match the training samples suggested with the training sets [15]; thus, from the input data, the AOI was captured as shown in Figure(2) to be ready for training this will consume the time for processing and get accurate outfit[20].

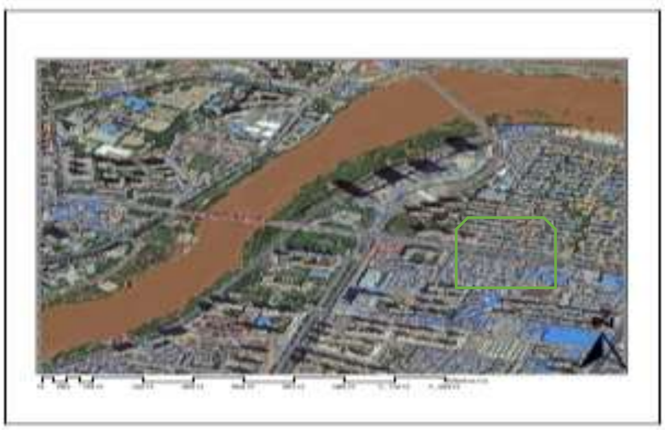

Figure (2) Study area section

Figure (2), illustrate the whole part for the current study location and from the suggested part (AOI) Area Of Interest for processing. Generating suggested study area (AOI) from satellite image data for training that is needed in this work is the first step to creating and preparing the study area, as shown in Figure(3), and choosing features by opening geoprocessing tools and implementing the Label Objects option for Deep Learning Tools to collect and generate objects from the data set.

Figure (3) Selected area of Interest (AOI)

2.2. Train DL Model

The building detection approach used in this paper is a model method of type Mask R-CNN. Thus, all buildings on satellite images are 2D structures that mostly made up of regions having borders being straight lines. The consecutive lines combine pixels in an image [8]. However, the input image were 2D (two dimension) with high resolution has implemented in the processing.

Consequently, building detection algorithms first extract the pixels that compose line segments using an edge detection process [20].

The efficiency of GIS applications combined with machine learning and deep learning approaches to detect buildings [17]. An automatic training model has implemented to extract structures using geoprocessing and environment tools [3], as shown in Figure (4). After adding the area of interest to Arc GIS Pro view to segment the exact objects, building features have distinct shapes that the zooming operator had done to detect most buildings exactly [18].

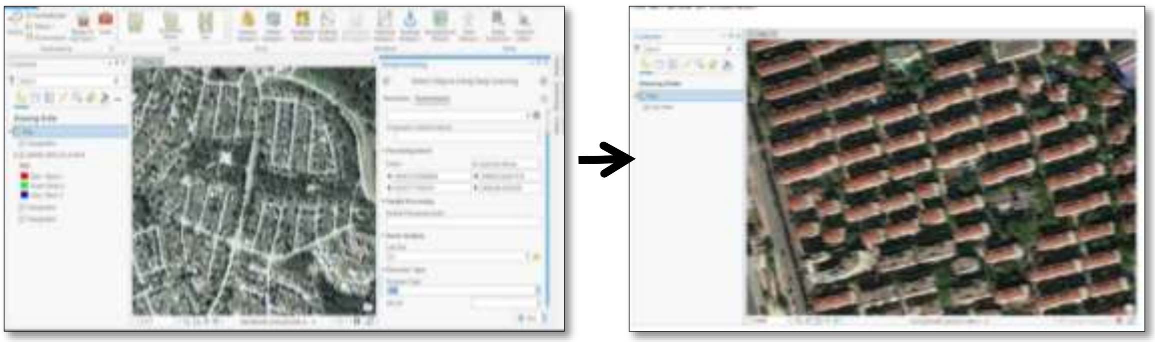

Figure (4) Detecting objects from (AOI)

According to processing for the proposed model sequential steps had implemented through ARC GIS Pro applications and geo processing tools window specifically to set the parameters for the input raster image and pertained model,

Furthermore, select the type of display, which includes the cell size of each segmented object that depends on the resolution of the raster image [11], according to the input image it's expected the cell size value be 0.2. In addition, defining the processor type to display the output layer after extracting the building is necessary, as mentioned in Figure(5), CPU processor was chosen for execution.

Figure (5) Extracted Building Objects

As illustrated from figure (5) regularization process needed to separate each selected object accurately and avoid overfitting this is so significant in machine learning methods. The goal of regularization is to encourage models to learn the broader patterns within the data rather than memorizing it [22].

AS described in this work, footprint building model the regularization process in Arc GIS Pro tools represented by digitizing operation applied during training to segment the boundary for each building not be sufficiently accurate , as displayed in Figure(6) .

Figure (6) Regularization Process

4. Performance Criteria

The examination for current work that related to extract and detect building objects focus on statistics calculations according to that accuracy assessment (AC) and mean square error (MSE) [15] approaches were included in testing efficiency of the current study.
The accuracy assessment approach is a significant process to test the efficiency of the executed algorithm for remote sensing data processed with all machine learning algorithms and techniques that still represent an active part of the applied work [19] [7]. Based on this, the performance described with a set of parameters in the confusion matrix, indicating the training model's activity in deep learning tools through ArcGIS Pro and identifying the parameters representing the case of implemented prediction. Thus, there were objects ideally detected that were determined by the value (TP) True positive, and the value (TN) True negative refers to the things not seen and correct (not building). In contrast, the value (FP) False Positive indicates the objects (building) predicted but not correctly, and the discount applied for assigned that there are no objects mentioned to facilities and not expected as objects identified with (FN) False Negative [21].
Consequently, table (1) illustrates the precision accuracy (Pre) of the model applied by calculating the ratio between values for predicted objects as mentioned in equation (1)[21], and the accuracy (Acc) performed as clarified in equation(2)[21].

$$Pre = \frac{TP}{TP + FP} \quad (1)$$

$$Acc = \frac{TP + TN}{TP + FN + FP + TN} \quad (2)$$

To avoid the intersection between detected objects correctly, equation (3) clarified the ratio(R) between the things that predicted positively [22]. This can indicate the regularization approach [15].

$$R = \frac{TP}{TP + FN} \quad (3)$$

Furthermore, to increase the efficiency of the current work root mean squared error (RMSE) has applied to test the amount of error and evaluate the mean squared differences between observed and predicted values [15] as described in equation (4)

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{(Y\sim - Y)2}{N}} \quad (4)$$

Where: N is the digital number DN of dimension for raw input AOI
Y is the observed values from AOI
Y∼ is the predicted values from AOI

Table 1: Performance of the Model

Data	**Performance criteria**			
Observed Input AOI	Pre	Acc	R	RMSE
				0.67
Predicted values → Extracted	0.801	0.863	0.872	0.38
Regularization process	0.897	0.910	0.892	0.202

5. Results and Discussion

This paper outlines a model for extracting building footprints from satellite images using a deep learning approach integrated with GIS Pro tools. This method significantly enhances the efficiency and accuracy of results compared to traditional digitizing techniques, as demonstrated in Figures 4, 5, and 6. These figures illustrate the automatic training process of input data samples, which isolates building objects from others. Although the building boundaries in Figure 5 look good, there are still some unclear pixels between distinct objects, indicating that the deep learning model's training was not sufficient, complicating the processing flow.

In GIS applications, regularization techniques are used to accurately normalize object extraction and improve detection accuracy. Figure 6, along with equation (3) and the R value in Table 1, shows the precision and accuracy of detected objects. The Pre and Acc values demonstrate the model's effectiveness in isolating true, positive, and negative objects.

Manually digitizing building footprints is a labour- intensive and error-prone process. However, technological advancements, such as higher resolution imagery and faster computing speeds, have made object and pattern detection algorithms more convenient, faster, and highly accurate, providing rich information with high performance. Deep Learning (DL) algorithms, which use neural networks similar to the human brain, make decisions when faced with choices.

Combining deep learning methods with remote sensing can greatly improve accuracy and efficiency compared to traditional object detection and feature extraction techniques.

6. Conclusion

This study highlights the significant potential of a deep learning model for extracting building footprints from satellite images through an automatic training model. Integrating deep learning with GIS Pro application tools enhances the efficiency and accuracy of the results compared to traditional digitizing methods, as illustrated in Figures 4, 5, and 6. These figures demonstrate the flow process of how input data samples are automatically trained to isolate building objects. However, the output results reveal that while the building boundaries appear well detected.

The research introduces a particular approach to building footprint extraction by combining deep learning with GIS Pro tools, streamlining the process and improving accuracy. Furthermore, the applied method significantly improves the detection and boundary delineation of buildings, as evidenced by the results in Figures 4, 5, and 6.the more.

The automatic training model simplifies the workflow, reducing the need for manual intervention and accelerating the processing time. In The deep learning model effectively identified building boundaries, although some obscure pixels between objects indicated areas for further refinement.

Implementing a regularization process within GIS applications helped normalize object extraction, thereby increasing the accuracy of detected objects. This technique is included in the ARC PRO software library tools and proved effective in enhancing model performance.

The precision and accuracy metrics (Pre and Acc values) highlighted in Table 1 confirm the robustness of the proposed model in isolating true, positive, and negative objects, demonstrating its reliability for practical applications.

In summary, this research contributes a robust and automated solution for building footprint extraction, leveraging the strengths of deep learning and GIS technologies to achieve high performance and accuracy.

For the future work, This approach shows great potential for applications in urban planning, environmental monitoring, and disaster management, setting the stage for more advanced and efficient remote sensing methodologies.

Acknowledgment

The authors are very grateful to the University of Mosul, and Remote sensing Center , which helped improve this work's quality.

Conflict of interest

The author has no conflict of interest.

References

1. Ball, J.E., Anderson, D.T., and Chan, C.S. (2017). “A comprehensive survey of deep learning in remote sensing: Theories, tools, and challenges for the community.” Journal of Applied Remote Sensing, 11. https://doi.org/10.1117/1.JRS.11.042609.
2. Chen, L., Papandreou, G., Kokkinos, I., et al. (2018). “DeepLab: Semantic image segmentation with deep convolutional nets, atrous convolution, and fully connected CRFs.” IEEE Transactions on Pattern Analysis and Machine Intelligence, 40, 834-848. DOI: 10.1109/TPAMI.2017.2699184
3. Croce, V., Caroti, G., De Luca, L., Jacquot, K., Piemonte, A., Véron, P. (2021). “From the semantic point cloud to heritage-building information modeling: A semiautomatic approach exploiting machine learning.” Remote Sens., 13, 461. ; https://doi.org/10.3390/rs13030461.
4. Ding, D., Zhang, M., Pan, X., Wu, D., and Pu, P. (2018). “Geographical feature extraction for entities in location-based social networks,” in Proceedings of the 2018 World Wide Web Conference, 833–842. ISBN:978-1-4503-5639-8.
5. Hatamizadeh, A., Sengupta, D., and Terzopoulos, D. (2020). “End-to-end trainable deep active contour models for automated image segmentation: delineating buildings in aerial imagery,” in Proceedings of the European Conference on Computer Vision, 730–746, Glasgow, https://doi.org/10.48550/arXiv.2007.11691.
6. Helber, P., Bischke, B., Dengel, A., and Borth, D. (2018). “Introducing Eurosat: A novel dataset and deep learning benchmark for land use and land cover classification.” In Proceedings of the IGARSS 2018—2018 IEEE International Geoscience and Remote Sensing Symposium, Valencia, Spain, 22–27 July. DOI: 10.1109/IGARSS.2018.8519248.

7. Iglovikov, V., Mushinskiy, S., and Osin, V. (2017). “Satellite imagery feature detection using deep convolutional neural network: A Kaggle competition,” arXiv preprint arXiv:1706.06169. https://doi.org/10.48550/arXiv.1706.06169.
7. Kumar, M., and Bhardwaj, A. (2020). “Building extraction from very high resolution stereo satellite images using OBIA and topographic information.” Environ. Sci. Proc., 5, 1. https://doi.org/10.3390/IECG2020-08908.
8. Alex Lamb. (2021). “A Brief Introduction to Generative Models “DOI: 10.48550/arXiv.2103.00265.
9. Misra, P., Avtar, R., and Takeuchi, W. (2018). “Comparison of digital building height models extracted from AW3D, TanDEM-X, ASTER, and SRTM digital surface models over Yangon City.” https://doi.org/10.3390/rs10122008.
10. Raj, V., and Kalyani, S. “Design of communication systems using deep learning: a variational inference perspective,” IEEE Transactions on Cognitive Communications and Networking. DOI: 10.48550/arXiv.1904.08559.
11. Tan, M., Pang, R., and Le, Q.V. (2020). “EfficientDet: Scalable and efficient object detection.” In Proceedings of the 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), Seattle, WA, USA, 14–19 June. DOI: 10.1109/CVPR42600.2020.01079
12. Ali Sabah Husain., and Mustafa Faten Azeez (2020). “Evaluation of The Population Distribution Using GIS Based Geostatistical Analysis in Mosul City, Korean Journal of Remote Sensing , Vol 35, issue 1, 83-92 pp. https://doi.org/10.7780/kjrs.2020.36.1.7.
13. Varatharasan, V., Shin, H. S., Tsourdos, A., and Colosimo, N. (2019). “Improving learning effectiveness for object detection and classification in cluttered backgrounds,” in Proceedings of the e2019 Workshop On Research, Education And Development Of Unmanned Aerial Systems (RED UAS), pp. 78–85, IEEE, Cranfield, UK, November. https://doi.org/10.1109/REDUAS47371.2019.8999695.
14. Venugopal, N. (2020). “Automatic semantic segmentation with DeepLab dilated learning network for change detection in remote sensing images,” Neural Processing Letters, 51(3), 2355–2377. https://doi.org/10.1007/s11063-019-10174.
15. Dilshad Altalabani and Fevsi Erdogan, (2024). “Classification of Diabetes Data Set from Iraq via Different Machine Learning Techniques.Iraqi Journal Of Statistical Sciences 21(1):170-189 .DOI: 10.33899/iqjoss.2024.183258.
16. Wang, S., Cao, J., and Yu, P. (2020). “Deep learning for spatio-temporal data mining: A survey.” IEEE Transactions on Knowledge and Data Engineering, https://doi.org/10.48550/arXiv.1906.04928.
18. .Xu, Y., Wu, L., Xie, Z., and Chen, Z. (2018). “Building extraction in high-resolution remote sensing imagery using deep learning and guided filters.” Remote Sens., 10, 144. https://doi.org/10.3390/rs10010144.
19. .Dilshad Altalabani and Fevsi Erdogan, (2024). “Classification of Diabetes Data Set from Iraq via Different Machine Learning Techniques.Iraqi Journal Of Statistical Sciences 21(1):170-189, DOI: 10.33899/iqjoss.2024.183258.
20. Charif, Aicha Salah, (2024).“Artificial Intelligence Algorithms and their Role in Assessing the Financial Health of Municipalities in Algeria based on the Logistic Regression Model” Iraqi Journal of Statistical Science , Vol 21, No 2, pp(112-124) , DOI: 10.33899/iqjoss.2024.185245
21. Osamah Basheer Shukur, Omar Akram Malaa, “Comparison of Logistic regression, Convolution Neural Network, and Kernel Approaches for Classifying the Caenorhabditis Elegans Motion”. Iraqi Journal Of Statistical Science . pp.175-187, DOI: 10.33899/iqjoss.2023.181225.
22. Bakhshan Ahmed Hamad, (2025).” A Comparative Study of K-means Clustering Algorithms Using Euclidean and Manhattan Distance for Climate Data”. Iraqi Journal of Statistical Science, vol 22, NO.1, pp 47-58. DOI 10.33899/iqjoss.2025.187754 .

استخدام التعلم العميق ونظم المعلومات الجغرافية في تمييز الانماط من بيانات التحسس النائي

فاتن عزيز مصطفى

قسم المعالجة الرقمية ، مركز التحسس النائي ، جامعة الموصل ، الموصل ، العراق

الخلاصة: زادت كفاءة تقنيات الذكاء الصناعي في السنوات الاخيرة الى الحد الذي تطابقت به مع دقة البشر في معظم المجالات مثل ترجمة النصوص وفهم القراءة والتعرف على الصور معالجتها ومن ثم تحليلها، حيث ان لهذه التقنيات دور كبير في معالجة بيانات الاستشعار عن بعد في مختلف الدراسات التي تتعلق بمعالجة الصور الفضائية، وتطبيقات برامجيات نظم المعلومات الجغرافية (GIS) . حيث تهدف هذه الدراسة الى تسليط الضوء بابراز امكانيات وكفاءة تقنيات الذكاء الصناعي والتعلم العميق في استخراج وتمييز الانماط المختلفة من بيانات الاستشعار عن بعد بالاستفادة من التطبيقات والوسائل التي يمتلكها برنامج ArcGIS Pro. بالإضافة الى ذلك فان هذه الدراسة استخلصت في مضمونها قدرة وقابلية تقنيات التعلم العميق في كيفية استخراج مختلف البنايات من بيانات الاستشعار عن بعد من خلال تطبيق نموذج التعلم الالي العميق باستخدام وسائل التعلم العميق المتوفرة في برنامج ArcGIS Pro وانشاء موديل او نموذج الذي تم تطبيقه بتدريب عينات مختلفة من الصورة الفضائية وتمييز المباني في النتيجة بدقة عالية وتحسين في الاداء .

الكلمات المفتاحية: التعليم العميق، تمييز الانماط , برنامج الارك جي اي اس برو، بيانات الاستشعار عن بعد.