RESEARCH ON THE EFFECTIVENESS OF NEURAL NETWORK DETECTION OF PLOTS WITH THE DESTROYED BUILDINGS REMAINS

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In recent years, the proliferation of high-resolution satellite imagery and the increasing frequency of both natural disasters and armed conflicts have underscored the urgent need for automated methods capable of rapidly assessing structural damage in urban environments. Traditional manual interpretation of post-event imagery is labor-intensive, time-consuming, and subject to human error, which can lead to delayed response efforts and imprecise damage estimates. Within this context, the application of deep learning – particularly convolutional neural networks (CNNs) and their variants – offers a transformative approach to the detection and classification of scenes depicting the remains of destroyed buildings. By leveraging large-scale annotated datasets and end-to-end training paradigms, neural networks promise to deliver scalable, objective, and highly accurate assessments that can inform emergency relief, urban planning, and post-conflict reconstruction initiatives.

The relevance of research into the effectiveness of neural network-based detection in this domain is twofold. From a humanitarian perspective, rapid identification of heavily damaged areas can significantly improve the allocation of resources, guide search-and-rescue operations, and ultimately save lives [1]. The ability to distinguish between intact structures and rubble with minimal latency enables relief organizations to prioritize zones of greatest need and to coordinate logistics under time-critical conditions. Simultaneously, from a scientific viewpoint, the challenge of accurately detecting destroyed-building plots pushes the boundaries of computer vision research. Variability in lighting, occlusions by vegetation or clouds, and the diverse architectural styles encountered across different regions require models to generalize robustly under heterogeneous conditions. Investigating how architectural characteristics, spectral signatures, and spatial context influence detection performance contributes valuable insights into network design, data preprocessing, and domain adaptation techniques [2, 3].

Moreover, the preservation of cultural heritage sites devastated by natural or human-induced catastrophes demands precise mapping of structural remains. Neural network approaches that can identify and segment remnants of historically significant edifices support digital documentation and reconstruction efforts, providing archaeologists and conservationists with foundational data for virtual restoration. As climate change intensifies the frequency of extreme weather events and geopolitical tensions persist globally, the development of reliable, automated damage assessment tools emerges as a strategic priority [4]. Research on this topic not only addresses an immediate operational need but also advances the methodological toolkit of remote sensing and machine learning, laying the groundwork for next-generation monitoring systems capable of safeguarding both human communities and their built heritage.

Studies conducted by various researchers indicate that neural networks, particularly deep learning models [5, 6] and convolutional architectures [7], exhibit remarkable precision in image processing tasks, reliably detecting and categorizing structural elements such as concrete slabs, steel reinforcements, brick fragments, and timber remains within disaster-affected areas [8, 9, 10]. When applied to the analysis of plots containing the remains of destroyed buildings [11], these technologies enable automated extraction of key debris components, significantly reducing the reliance on manual interpretation of large image datasets [12, 13], a factor of critical importance in crisis scenarios where rapid situational awareness can save lives [14]. Moreover, the integration of neural network–based approaches not only accelerates data processing workflows [15] but also enhances detection accuracy [16, 17], thereby improving the efficiency of emergency response coordination, informing post-disaster recovery strategies, and facilitating the implementation of environmental remediation initiatives.

The purpose of the work is research on the effectiveness of neural network detection of plots with the destroyed buildings remains.

The approach to neural network detection of plots with the destroyed buildings remains is aimed at automating these processes. This approach involves the use of multi-class classification, where each photographic image with the remains of destroyed buildings is assigned several labels corresponding to different types of fragments of building materials.

The proposed approach to neural network detection of plots with the destroyed buildings remains in aerial imagery is built around a multi-stage pipeline that seamlessly integrates image preprocessing, object detection, and fine-grained classification. Initially, raw photographs are subjected to a series of preparatory transformations – such as pixel-value normalization, geometric scaling, and optional color-space adjustments – to homogenize input characteristics and mitigate variations in illumination or sensor noise, thereby laying a robust foundation for downstream analysis [18]. The scheme of the approach is shown in Figure 1.

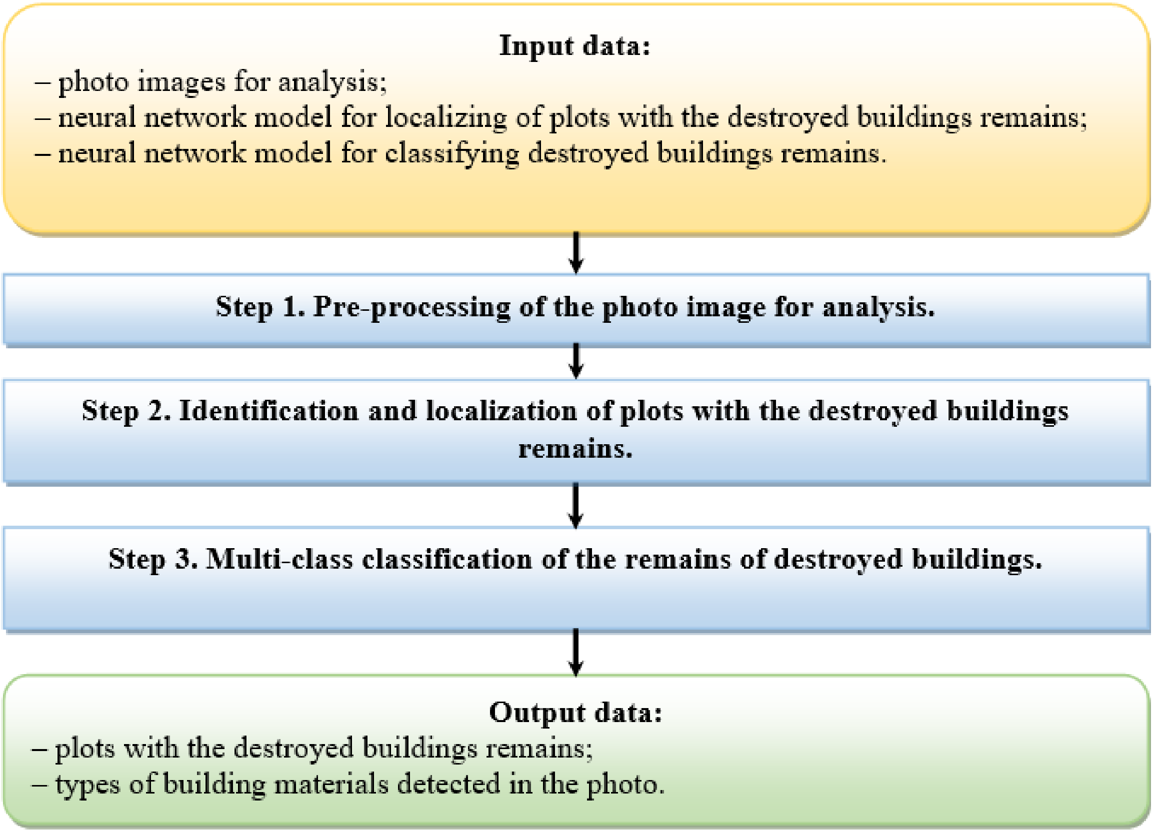

Figure 1. Scheme of approach to neural network detection of plots with the destroyed buildings remains.

Following this, the refined image data are processed by a YOLO-based detector, which swiftly scans each frame to propose bounding boxes around candidate regions likely to contain remnants of collapsed structures. YOLO's real-time inference capability and balanced architecture enable the rapid and accurate localization of debris, irrespective of cluttered backgrounds or the complex spatial arrangements of rubble fields.

Once localized, each candidate patch is forwarded to a Vision Transformer module for comprehensive multiclass categorization. Leveraging self-attention mechanisms, this transformer-based classifier evaluates the contextual relationships between pixels to distinguish among concrete slabs, steel girders, brick fragments, and timber elements. Training such an architecture necessitates diverse, high-quality ground-truth datasets.

The final output of the system comprises precise bounding-box coordinates for each detected region, annotated with the corresponding material label. By combining the strengths of a high-throughput object detector with the semantic depth of a transformer-based classifier, this approach achieves an effective synergy: it not only pinpoints the spatial extent of building remnants within large-scale imagery but also delivers detailed material classification that can support disaster response planning, structural assessments, and resource allocation in post-crisis scenarios.

The presented neural network pipeline for analyzing aerial photographs of collapsed structures operates through a series of well-defined stages driven by two pretrained models. Each input image first undergoes normalization, resizing, and other preparatory transformations to ensure stable performance of subsequent algorithms. Next, a YOLO-based detector identifies and frames regions containing structural debris, and these candidate patches are then forwarded to a Vision Transformer module that performs fine-grained multiclass classification of the rubble – distinguishing concrete, metal, brick, and wood fragments. This transformer is trained on specialized datasets encompassing diverse material types and presentation conditions. Finally, the system outputs precise bounding-box coordinates alongside the corresponding material category for each detected debris region, effectively combining object detection with deep semantic classification.

As part of the conducted experiment to evaluate the effectiveness of the model for multi-class classification of the remains of destroyed buildings, an error matrix was obtained (Figure 2) and micrometrics and macrometrics were calculated.

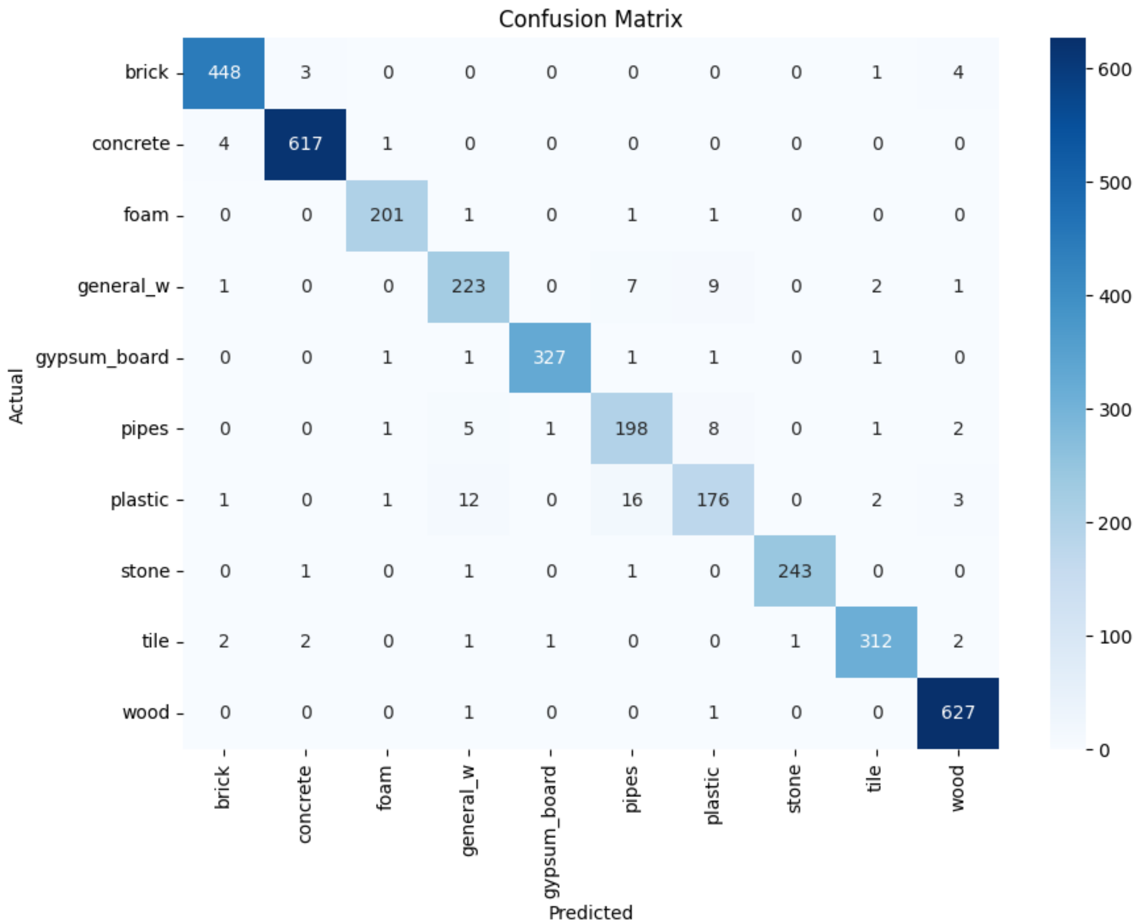

Figure 2. Confusion matrix for classification of remains of destroyed buildings.

The obtained results of multi-class classification demonstrate the following metrics: the Accuracy indicator is 0.97, the macro-average values of Precision, Recall and F1-measures are 0.96, the weighted average values of Precision, Recall and F1-score are 0.97.

The ongoing evolution of neural network methodologies for detecting plots containing the remains of destroyed buildings holds immense promise for transforming how emergency response teams, urban planners, and heritage conservationists approach post-disaster assessment and recovery. As convolutional and transformer-based architectures continue to mature, their capacity to process ever-larger volumes of satellite and aerial imagery in real time will facilitate near-instantaneous damage mapping across wide geographic areas. In the near future, this could enable disaster management agencies to deploy resources with unprecedented precision, directing heavy machinery, medical aid, and search-and-rescue teams to the most critically affected neighborhoods within minutes of a catastrophic event. Moreover, the integration of on-board inference capabilities into unmanned aerial vehicles (UAVs) promises to extend the reach of these neural systems into environments that are inaccessible or too hazardous for human operators, allowing for dynamic reconnaissance flights that continuously update damage assessments as conditions on the ground evolve.

Beyond immediate crisis response, the application of these detection networks is poised to influence long-term urban resilience strategies. By systematically cataloguing structural damage over successive disaster events, municipalities can build predictive models of vulnerability that account for building age, construction materials, and local environmental stressors. Coupled with geographic information system (GIS) layers and historical urban data, neural network outputs could inform zoning regulations, retrot-fitting priorities, and targeted reinforcement projects designed to mitigate the impact of future earthquakes, storms, or armed conflicts. This shift toward data-driven infrastructure planning has the potential to reduce economic losses and save lives by proactively identifying the weakest links in the urban fabric before disaster strikes again.

In the cultural heritage domain, neural detection of debris fields will serve as a critical enabler of digital preservation and archaeological investigation. High-fidelity segmentation of collapsed structures can feed into photogrammetric reconstruction pipelines, generating accurate three-dimensional models of historical edifices from scattered rubble. Such virtual reconstructions not only support scholarly research but also allow displaced communities to reclaim a visual memory of their landmarks, fostering a sense of continuity and identity in the aftermath of destruction. As these techniques converge with advancements in multi-spectral and hyperspectral imaging, they may even uncover hidden architectural features beneath layers of dust and overgrowth, revealing previously unknown aspects of culturally significant sites.

Technological convergence will further amplify the impact of neural network-based detection systems. Edge computing hardware optimized for deep learning inference, when deployed in conjunction with cloud-native analytics platforms, will create a seamless pipeline from image capture to actionable insights. Advances in model compression and quantization will ensure that high-accuracy detection algorithms can run on low-power devices carried by first responders, maintaining performance even in bandwidth-constrained or offline scenarios. Simultaneously, research into explainable AI will demystify the decision-making processes of these networks, providing transparency into why certain debris regions are flagged and bolstering trust among users. In sum, the horizon for neural network detection of destroyed-building plots is exceptionally broad, encompassing rapid emergency relief, strategic urban fortification, heritage recovery, and the development of robust, interpretable AI systems that collectively enhance our resilience to both natural and human-mediated catastrophes.

Thus, an approach to neural network detection and localization on photographic images of areas with the remains of destroyed buildings was developed and investigated, which is integrated into an intelligent information system with a database that provides effective storage, processing and further use of data, and therefore increases the productivity and accuracy of the system in real conditions.

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