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REVIEW OF STRATEGIES TO OVERCOME THE LACK OF DATA IN LANDMINE DETECTION

Abstract. This article reviews strategies to address the lack of data for training landmine recognition models. Since the outbreak of the war in Ukraine in 2014, the area of contaminated territories has gradually increased. However, after Russia's full-scale invasion on February 24, 2022, the problem of landmines in Ukraine has become much more severe, as the area of mined territories in the country has increased to 30%. It takes many years and efforts to clear such a large area. To overcome a problem of this scale, it is necessary to look for new methods of landmine detection that will allow demining to be conducted 24/7. Machine learning is one of the options for solving the problem of landmine detection. To train landmine recognition models, a large amount of data is required. However, the lack of diverse and large datasets creates significant obstacles to the development of effective detection systems. The safety concerns associated with conducting experiments with real landmines further exacerbate the problem. This article discusses three possible strategies to overcome the above problem: augmentation methods, the use of 3D printing technology, and crowdsourced data collection. Augmentation methods offer data generation to improve model performance. 3D printing allows for the creation of realistic replicas of landmines for safe experimentation. Crowdsourcing uses collective efforts to collect real-world data from conflict zones. Through the joint efforts of researchers, technology developers and humanitarian organizations, these approaches offer promising ways to improve landmine detection capabilities. The use of these approaches can address the data gap and ensure safe data collection.

Keywords: Landmine Detection, Data Augmentation, 3D Printing, Dataset Enhancement, Crowdsourcing.

Introduction

Landmines are a very large problem in the modern world, posing significant risks to civilians and hampering post-war reconstruction efforts. The detection and clearance of explosive ordnance is vital to ensure the safety of affected areas and to help restore normalcy in war-torn regions. However, the task of detecting landmines is fraught with challenges, ranging from a lack of reliable data to the dangers associated with conducting experiments in real-world environments.

Landmines continue to claim civilian lives and impede socio-economic development in conflict-affected regions around the world. The simplicity and reliability of landmine materials makes them a constant threat long after hostilities have ceased. The importance of effective landmine detection cannot be overemphasized, as it is crucial to enabling the safe return of displaced populations to their homes.

Despite the urgent need for reliable landmine detection systems, there are many obstacles that hinder progress. Manual mine detection by deminers is still the main type of demining. However, the speed of such demining is insufficient. For example, according to the latest data as of the beginning of 2024, it will take more than 700 years to demine the territories of Ukraine potentially contaminated with explosive devices [1]. This calculation is based on the current number of demining groups - 500, which is about 5,000 specialists. This number will allow demining 4,700 square kilometers in 20 years. Therefore, 174,000 potentially mined square kilometers can be demined in 740 years (Fig.1).

Considering these challenges, innovative approaches are needed to enhance landmine detection capabilities and overcome the limitations of existing methods. By addressing these obstacles, we can pave the way for more effective and efficient landmine detection systems, ultimately saving lives and helping to rebuild war-affected communities. A promising method of demining is the use of machine learning algorithms with the use of Unmanned Aerial Vehicles (UAV) [3,4,5]. However, the number of types and uses of landmines and shells is very large, so a huge amount of data is needed to develop effective machine learning algorithms. One of the main challenges of surveys listed above is the limited availability of complete datasets suitable for training and testing detection algorithms. In addition, handling real landmines poses a danger to data collection and experimentation. Augmentation methods [6,7,8] can significantly increase the amount of data for training. Paper [9] discusses ways to use augmentation for landmine detection.

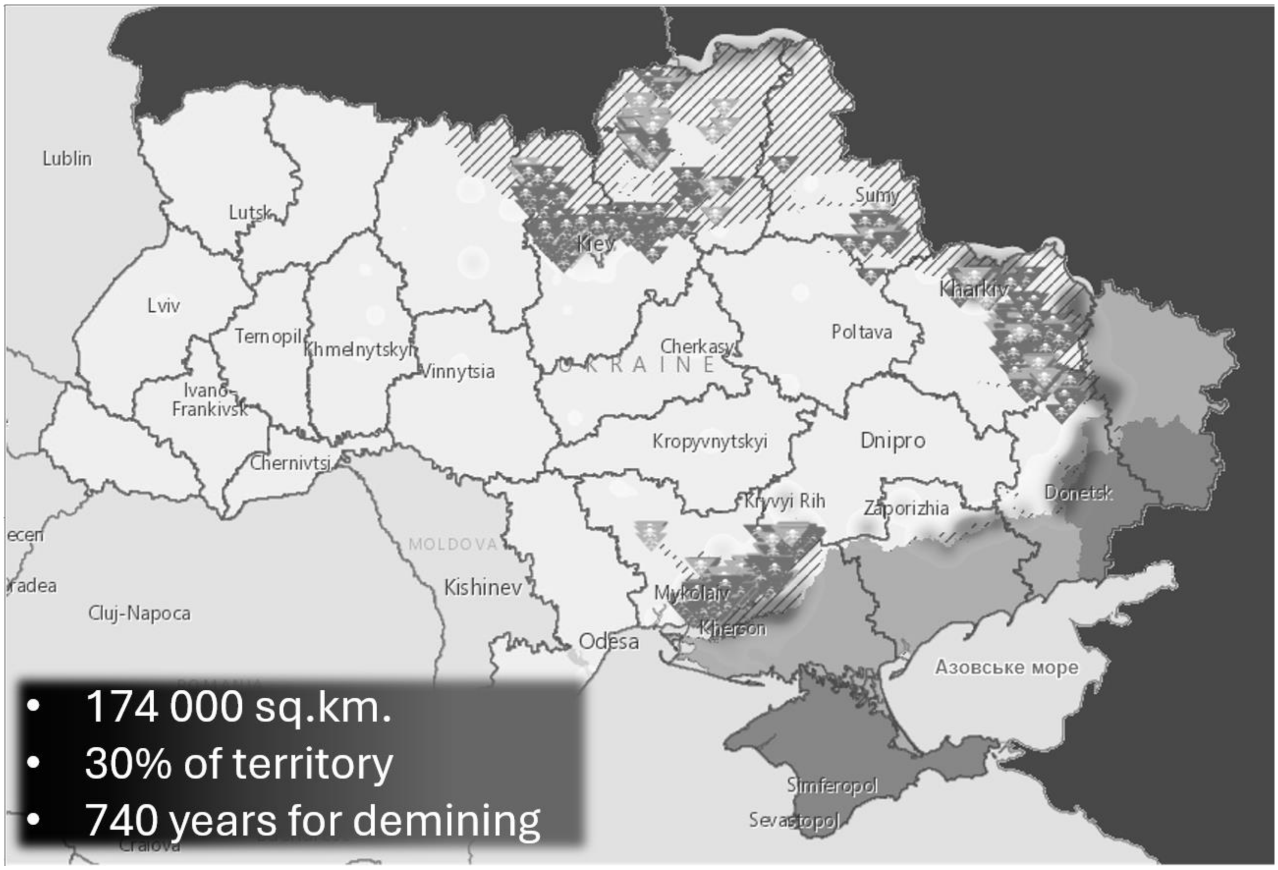

Fig. 1. The territory of Ukraine contaminated by landmines. Source https://ua.imsma.org [2]

1. Challenges in detecting landmines

1.1. Lack of data

The development of accurate and robust landmine detection algorithms is hampered by a severe lack of diverse and complete datasets. These datasets are necessary to train machine learning models to effectively recognize and classify landmines. However, obtaining such data is a huge challenge due to a variety of factors, including the lack of available imagery and the logistical difficulties of collecting data in conflict zones. The limited availability of data severely limits the ability of researchers to develop algorithms that can generalize across different terrains and types of landmines. Without access to a variety of data, algorithms may have difficulty accurately identifying landmines in real-world settings, resulting in reduced detection efficiency and increased risks to human safety.

1.2. Diversity of explosive hazards

The landscape of areas contaminated by explosive ordnance is characterized by an impressive diversity, and the same can be said for the number of types of landmines – from anti-personnel to anti-tank and improvised explosive devices (IEDs). Each type of landmine has unique characteristics, including variations in shape, size, and composition, which makes detection a complex and difficult task. Many mines have mostly plastic components, making them very invisible to metal detectors. The variability of landmines poses significant challenges for detection algorithms, as they must be able to accurately recognize and classify a wide range of explosive objects. Traditional detection methods, such as metal detectors, are often ineffective against non-metallic landmines, further complicating the detection process.

1.3. Safety concerns during experiments

Ethical and safety considerations pose enormous obstacles to conducting experiments with real landmines for data collection purposes. Handling real landmines poses a significant risk to human life and can have tragic consequences if mishandled. These safety concerns underscore the importance of finding alternative approaches to data collection that do not jeopardize human safety and environmental integrity.

2. Proposed strategies

2.1. Augmentation techniques

Data augmentation techniques offer a promising solution to the problem of limited datasets for landmine detection. By artificially expanding the dataset using techniques such as rotation, scaling, blending, mosaic, augmentation increases the diversity of the available data. Fig. 2 shows an example of mosaic augmentation, when an image for model training is composed of several images.

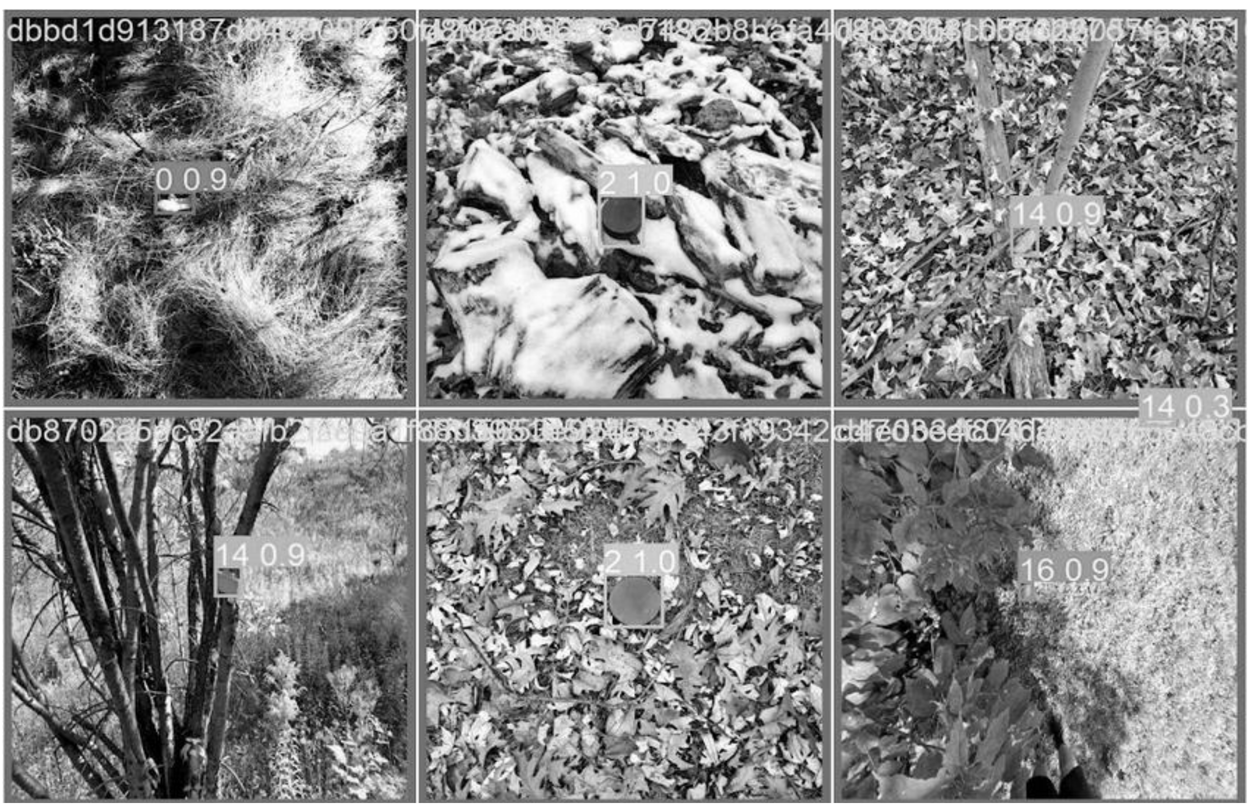

Figure 2. Images that are combines into one in an augmented image (mosaic augmentation)

This synthetic data generation allows algorithms to learn from a wider range of scenarios, increasing their reliability and ability to generalize across different environments and types of landmines. The effectiveness of augmentation in improving the performance of algorithms has been demonstrated in various machine learning applications [6,7,8], including image classification and object detection. By introducing variability into the training data, augmentation helps algorithms adapt to real-world complexities, ultimately leading to more accurate and reliable landmine detection systems [9].

2.2. Use of 3D printing

3D printing technology offers a unique opportunity to create realistic replicas of landmines for experimentation and data collection (Fig.2). 3D printed models copy the physical characteristics of real landmines, providing researchers with a safe and controlled environment to conduct experiments without risking human life or harming the environment. The use of 3D printed models is safe. These replicas can be easily customized and scaled to simulate different types of landmines, allowing researchers to study a wide range of scenarios and environmental conditions. Additionally, 3D printing enables rapid prototyping and iteration, making it easier to develop more advanced detection algorithms. The application of 3D printing will be covered by the author of the article in a separate publication.

2.3. Collecting data through crowdsourcing

Crowdsourcing is a new approach to collecting data from conflict zones that utilizes the collective efforts of professionals to provide information on landmines. Mobile applications equipped with crowdsourcing features allow deminers to take pictures and provide relevant information about landmines they encounter in their daily activities. Through crowdsourcing, researchers can access a large amount of real-world data from a variety of sources, increasing the quality and diversity of available datasets. In addition, crowdsourcing involves experts in the data collection process, creating a database that can be used in a variety of applications, from training to detection from drones.

The use of the crowdsourcing approach will be covered in a separate article by the author of this work.

Fig. 3. Different types of landmines annotated in the crowdsourcing program. Photos by Forester, D. Kapusta.

4. Conclusion

In summary, landmine detection remains a critical challenge with far-reaching implications for global security and humanitarian efforts. The lack of diverse and large datasets, combined with the complexity of detecting different types of landmines, poses significant obstacles to the development of effective detection systems. Moreover, the ethical and safety concerns associated with conducting experiments with real landmines emphasize the need for innovative and alternative approaches to data collection. However, augmentation techniques offer a promising way to address the data gap by creating synthetic data that increases the reliability and generalizability of algorithms. Similarly, the use of 3D printing technology allows researchers to create realistic replicas of landmines for safe experimentation and data collection. In addition, crowdsourcing makes it possible to collect real-world data from conflict zones using the collective efforts of professionals. In light of these advances, it is crucial for researchers, technology developers and humanitarian organizations to collaborate and innovate in the field of landmine detection. By pooling resources and expertise, we can overcome the challenges posed by landmines and pave the way for a safer and more secure environment in conflict-affected areas.

References

1. Iuliia Osmolovska. (2023). Walking on Fire: Demining in Ukraine. GLOBSEC. https://www.globsec.org/sites/default/files/2023-04/Demining%20in%20Ukraine%20report%20ver5%20web.pdf
2. Interactive map "Informing about the dangers of IEDs and risk prevention education. https://ua.imsma.org/portal/apps/webappviewer/index.html?id=814d2770d197474d8ad7e8014c0a275e&locale=uk
3. Baur, J.; Steinberg, G.; Nikulin, A.; Chiu, K.; de Smet, T.S. (2020). Applying Deep Learning to Automate UAV-Based Detection of Scatterable Landmines. *Remote Sens*. 12, 859. https://doi.org/10.3390/rs12050859.
4. Kovács, Zoltán & Ember, István. (2022). *Landmine Detection with Drones. Land Forces Academy Review.* 27. 84-92. https://doi.org/10.2478/raft-2022-0012.
5. Cherednychenko, O. & Palamarchuk, N. & Shemendiuk, O & Martynyuk, V. (2023). Synthesis of the system for detection of explosive objects on the base of an unmanned aerial vehicle. *Communication, informatization and cybersecurity systems and technologies.* https://doi.org/10.58254/viti.3.2023.18.163.
6. Shorten, C., Khoshgoftaar, T.M. A survey on Image Data Augmentation for Deep Learning. *J Big Data* 6, 60 (2019). https://doi.org/10.1186/s40537-019-0197-0
7. Mingle Xu, Sook Yoon, Alvaro Fuentes, Dong Sun Park. A Comprehensive Survey of Image Augmentation Techniques for Deep Learning. *Pattern Recognition, Volume 137*, (2023) https://doi.org/10.1016/j.patcog.2023.109347.
8. P. Kaur, B. S. Khehra and E. B. S. Mavi, "Data Augmentation for Object Detection: A Review," *2021 IEEE International Midwest Symposium on Circuits and Systems (MWSCAS)*, Lansing, MI, USA, 2021, pp. 537-543. https://doi.org/10.1109/MWSCAS47672.2021.9531849
9. Kunichik O., Tereshchnko V. (2023). Improving the accuracy of landmine detection using data augmentation: a comprehensive study. *Artificial Intelligence and Intelligent Systems.* https://doi.org/10.15407/jai2023.02.042.

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