AI-Enhanced Seismic Imaging for Detecting Subsurface Archaeological Sites

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Abstract. The study explores advanced **non-invasive seismic imaging** methods, for archaeological findings supported by AI-driven interpretation, to improve site mapping. Current techniques face **limitations** in resolving **fine details**. Ethical considerations, including data **accessibility** and heritage **protection**, are also addressed to ensure responsible application.

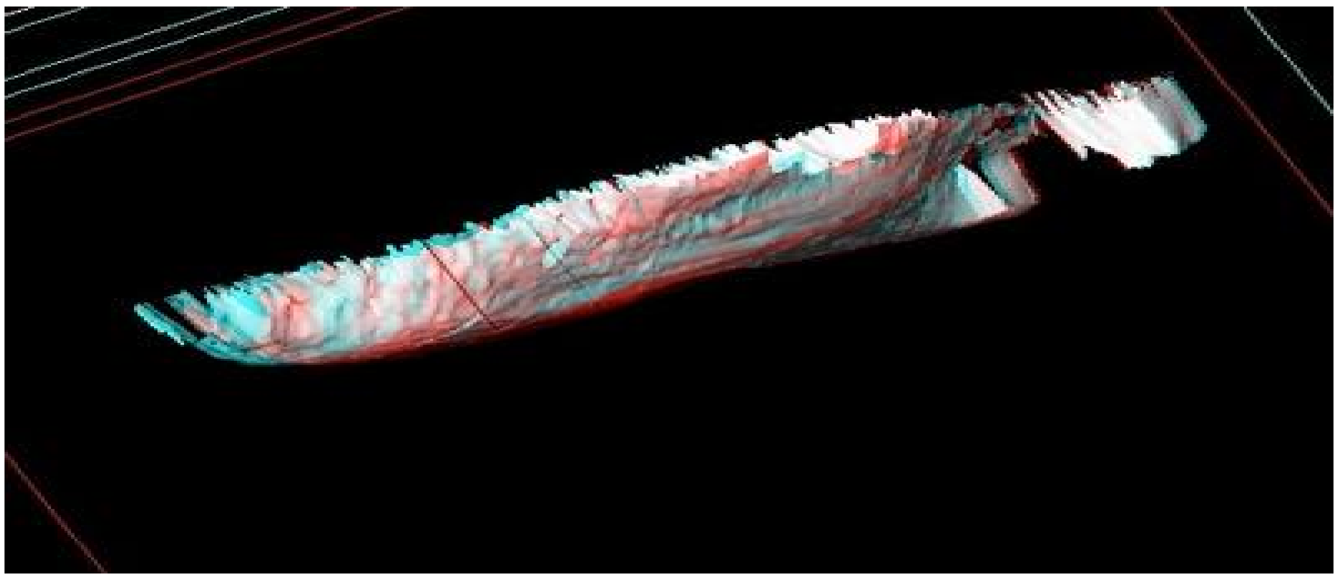

Fig. 1. Buried shipwreck visualised by seismic imaging

INTRODUCTION

Non-destructive imaging are powerful tools for archaeological exploration, enabling the detection of buried structures **minimizing excavation efforts**. However, manual interpretation of seismic data, which is scattered and reflected acoustic waves, is complex and error-prone, requiring automation for greater accuracy. Deep learning, particularly **Convolutional Neural Networks** (CNNs) like **ResNet** and **Unet** offer a promising solution, enhancing the resolution of seismic data, yet its application in archaeology raises concerns about data **privacy**, model **explainability**, and site protection. By integrating technology and ethics, this study aims to advance non-intrusive archaeological methods while safeguarding cultural heritage.

Related works

Ma, Han and Feng demonstrated the potential of CNNs in enhancing the resolution of seismic images in intermediate frequency ranges [1]. Zhang et al. suggest that machine learning has **great potential** in enhancing the efficacy of subsurface anomaly detection. [2] Albeit both exclusively in the context of geological structures. In an archaeological setting Magnetometry is the primer tool of non-invasing surveys due to **low resolution**.

Currently there is **minuscule** to none research about the **human aspects** of AI-enhanced archaeological site surveys.

Seismic refraction techniques are most effective in the presence of sub-horizontal stratification, characterised by an increase in seismic velocity with depth. [2] However, the use of near-surface imagery for archaeological purposes is not feasible without enhancing resolution. [3]

RESEARCH METHODOLOGY

The technical aspect of the topic under consideration is a general signal processing problem in the context of acoustic waves. The **preprocessing**, **feature extraction** and **classification** stages are conducted in accordance with the conventional steps of semi-supervised learning techniques, such as CNN-enhanced image processing. One property of those systems is their blackbox nature. **Explainable AI** (xAI) could be implemented with the help of visualization tools like **Grad-Cam**. The tool uses gradients that flow into the final convolutional layer to create a localisation map that highlights important regions in the image for predicting the concept. [5] The above example image could be supported with a **Large Language Model** (LLM) to give context to the produced **heatmap** and for the user to monitor the output of the tool.

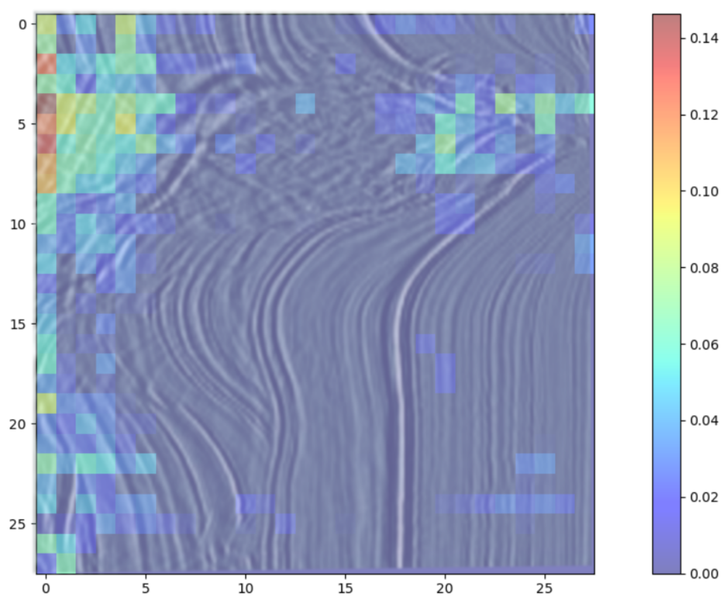

Fig. 2. Potential heatmap output for visualization

CONSIDERATIONS ABOUT RISKS

Although the issue poses a **limited risk** to human health and privacy, the neglect of history could lead to increasing **inequalities** and the **deterioration** of human rights. In addition, the inappropriate application of the tool has the potential to result in the **pillaging** of heritage sites. The data will be distributed **exclusively** to professionals via closed-source software and datasets. This approach is being adopted in order to address the **paucity of training materia**l available, with the use of **synthetic datasets** being employed to enhance the model.

CONCLUSIONS

This research aims to develop an AI-driven non-destructive seismic imagery system to enhance the detection of archaeological structures while ensuring ethical use. By leveraging CNNs like ResNet, and implementing xAI with the help of Grad-Cam to ensure that stakeholders are involved and provide professionals the reasoning of the tool. The integration of an ethical framework will address concerns related to data privacy and heritage site protection, which most current literature omits. The approach will hopefully contribute to archaeological exploration and **heritage preservation.**

References.

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