

Asteroseismology AI-Driven Seismic Event Detection for Extra-Terrestrial Missions

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Abstract—Planetary seismology faces significant challenges in transmitting continuous seismic data due to bandwidth and power constraints. Traditional event detection methods generate numerous false positives, leading to inefficient data transmission. This paper presents Asteroseismology, an AI-enhanced seismic event detection framework that integrates classical phase-picking algorithms with machine learning to optimize seismic data processing for space missions. The workflow begins with automatic bandpass filtering, outlier removal, and normalization to enhance signal clarity. A Short-Term Average to Long-Term Average (STA/LTA) analysis is then applied to detect candidate events, followed by a filtering mechanism that refines initial picks based on characteristic function slopes. The final step employs a Convolutional Neural Network (CNN), trained on seismic data from the Apollo Lunar Surface Experiments Package (ALSEP) and NASA’s Mars InSight mission, to distinguish true seismic events from noise, ensuring high precision while minimizing false detections. Designed for computational efficiency, the system processes a month’s worth of seismic data in under 60 seconds on an average processor. It also features six tunable parameters, allowing adaptation to different planetary environments and mission constraints. Initial results demonstrate that the CNN, despite limited training, achieves over 80 percent event detection accuracy with a false positive rate of approximately 5 percent. Future enhancements include refining the CNN within an Auxiliary Classifier Conditional GAN (AC-GAN) framework to further improve detection reliability. This AI-driven approach enables autonomous seismic data analysis onboard spacecraft, significantly reducing the need for raw data transmission and paving the way for more efficient planetary and lunar seismology missions.

Index Terms—Seismic Event Detection, Planetary Seismology, Machine Learning, CNN, STA/LTA, AI in Space Exploration.

I. INTRODUCTION

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$$a + b = \gamma \quad (1)$$

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- The subscript for the permeability of vacuum μ_0 , and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
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TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
	Table column subhead	Subhead	Subhead
copy	More table copy ^a		

^aSample of a Table footnote.

Fig. 1. Example of a figure caption.

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ACKNOWLEDGMENT

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REFERENCES

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REFERENCES

- [1] G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529–551, April 1955.
- [2] J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
- [3] I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in *Magnetism*, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
- [4] K. Elissa, “Title of paper if known,” unpublished.
- [5] R. Nicole, “Title of paper with only first word capitalized,” *J. Name Stand. Abbrev.*, in press.
- [6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetism Japan, p. 301, 1982].
- [7] M. Young, *The Technical Writer’s Handbook*. Mill Valley, CA: University Science, 1989.

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