Earthquakes and AI: The Proposal of a New Research Model

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Abstract

Artificial Intelligences (AIs) have begun to emerge significantly about a decade ago, with rapid advancements in recent years. However, the roots of AI research trace back to the 1950s, with incremental developments along the way. The real explosion of interest and practical applications took hold with the advent of big data, increased computational power, and improvements in machine learning algorithms, especially since the early 2010s. In 2023, the Radio Emissions Project experimented with AIs to enhance the computing capability and data analysis of seismic data related to the research on seismic precursors. This study aims to understand whether AIs are capable of producing useful information for the comprehension of seismogenic mechanisms and interpreting data to perform short-term predictions on Italian seismic activity.

Keywords: AI, Seismic Precursors, Earthquake in Italy.

1 - Introduction

The evolution of Artificial Intelligence (AI) spans decades and is characterized by significant advances, challenges, and periods of stagnation known as "AI winters." This journey has led to revolutionary developments that have transformed the technological field and our way of interacting with machines.

The official history of AI begins in the 1950s when the concept of "intelligent machines" started to take shape through the work of pioneers like Alan Turing. The year 1956 is often cited as the birth year of AI, marked by the Dartmouth Summer Research Project, where the term "Artificial Intelligence" was coined, and researchers shared the vision that machine intelligence could be simulated through symbolic manipulation.

In the 1960s and '70s, AI experienced a period of optimism and progress with the development of expert systems and the promise to revolutionize various sectors. However, the complexity of mimicking human intelligence was underestimated, leading to the first "AI winters," periods during which funding and interest in AI drastically decreased due to unmet expectations.

Despite these obstacles, AI continued to evolve in the '80s and '90s, thanks to advances in machine learning, neural networks, and natural language processing (NLP). These years saw the development of systems capable of performing specific tasks with increasing precision, such as the IBM Deep Blue supercomputer defeating chess champion Garry Kasparov in 1997.

The arrival of the 21st century marked an era of data explosion and significant improvements in computing power, enabling notable advancements in deep learning. These developments led to the creation of AI systems capable of surpassing human performance in specific tasks, such as image recognition, automatic translation, and the game of Go.

The introduction of the Generative Pre-trained Transformer (GPT) by OpenAI in 2018 and the subsequent debut of ChatGPT were key milestones, demonstrating language generation capabilities and advanced conversational interaction. These developments have opened new frontiers for AI, showcasing its potential in enhancing efficiency and creating new modes of interaction between humans and machines.

AI continues to be a rapidly evolving field, with profound implications for the future of work, ethics, and society. Ongoing developments in machine learning, robotics, and brain-computer interfaces promise to take AI in new directions, continually challenging our expectations of what machines can do.

In 2022, the Radio Emissions Project began to consider the use of AI in a scientific context, leveraging the capabilities of Artificial Intelligence to gather seismic monitoring data and tackle new experimental projects that could aid researchers in understanding seismogenic phenomena.

The AIs made available to amateur research did not yet possess advanced functions capable of performing certain calculations or supporting researchers in a research context, but this problem was overcome in mid-2023 with the introduction of new functions made available to users worldwide.

Thus, in February 2024, following some successful seismic prediction trials, the Radio Emissions Project processed predictive data indicating that earthquakes were expected to occur in specific areas of Italy, based on monitoring data from the National Institute of Geophysics and Volcanology.

On February 4, 2024, AI was provided with monitoring data related to earthquakes that occurred in Italy in the last 7 days, from January 29, 2024, to February 4, 2024. During this time, AI was asked to retrieve data from the INGV archive and compile a list of earthquakes, sorting them by Italian province.

2 - Method and Data

For the creation of the map of the probabilistic imminence of earthquake occurrence in Italy, real-time accessible data on the INGV website (www.ingv.it) were utilized. Therefore, all earthquakes of magnitude M2+ that occurred on Italian territory were divided by each Italian region.

In this manner, AI created a ranking among the regions that experienced more earthquakes compared to those with fewer occurrences.

Subsequently, AI was asked if it was possible to expect more earthquakes in particular regions compared to others, and the AI's response, after processing the Italian seismic data, confirmed that more earthquakes were expected in certain regions compared to others, based solely on seismic data.

After carrying out these procedures, AI was used to create a chart showing a ranking of regions most subject to future M2+ earthquakes in a short temporal context (a few days), starting from February 4, 2024 (Fig. 1).

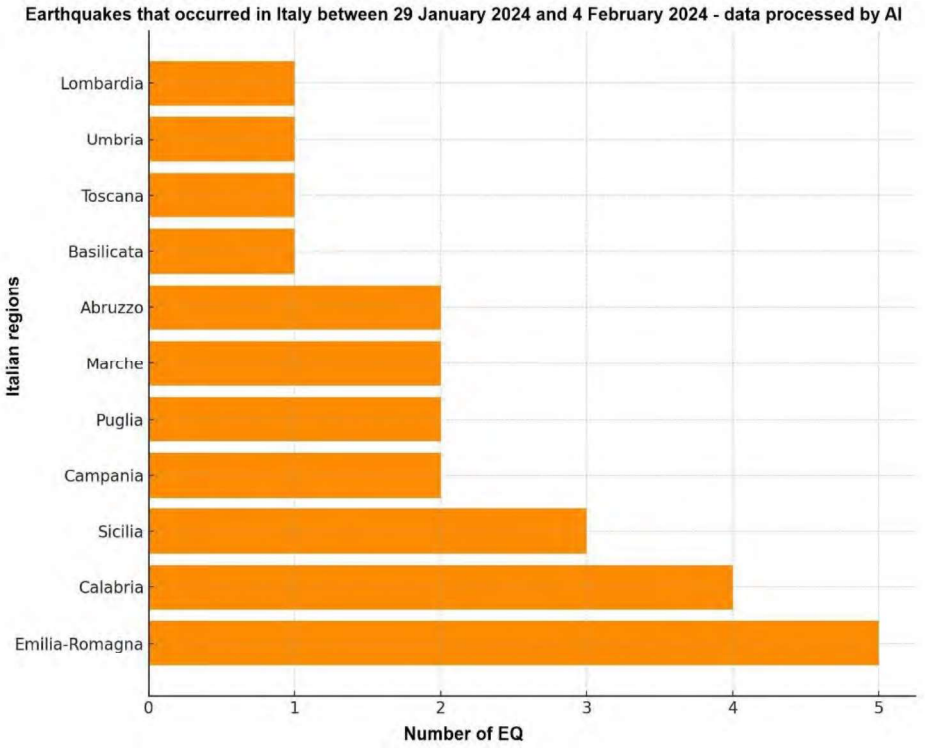

Fig. 1 *– Chart related to the number of earthquakes that occurred in Italy between January 29, 2024, and February 4, 2024. In this case, AI compiled a ranking of the regions with the most earthquakes. Credits: Daniele Cataldi.*

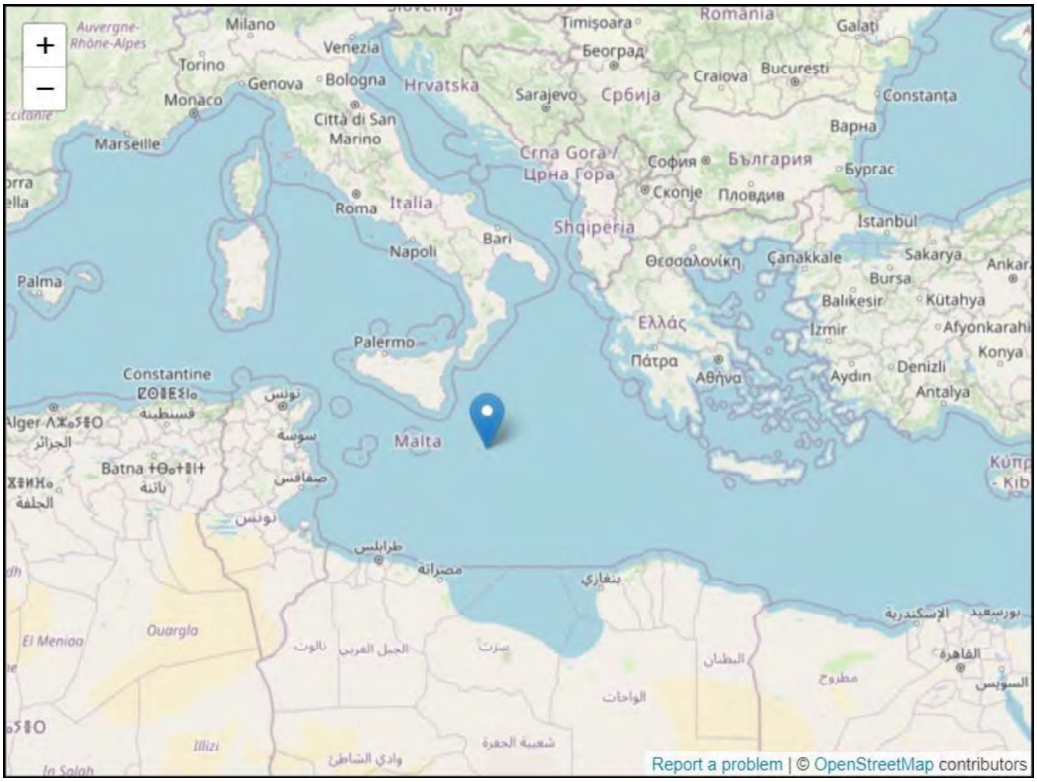

Fig. 2 - Earthquake of magnitude M4.2 on February 5, 2024. Credits: INGV.

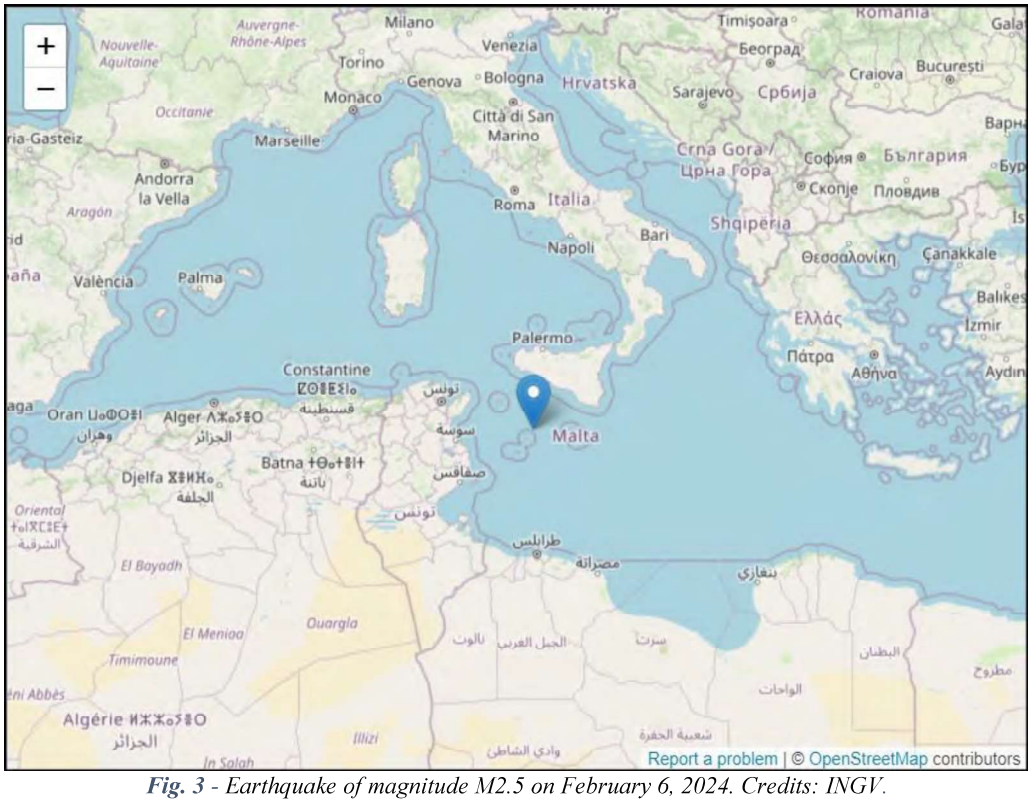

Fig. 3 - Earthquake of magnitude M2.5 on February 6, 2024. Credits: INGV.

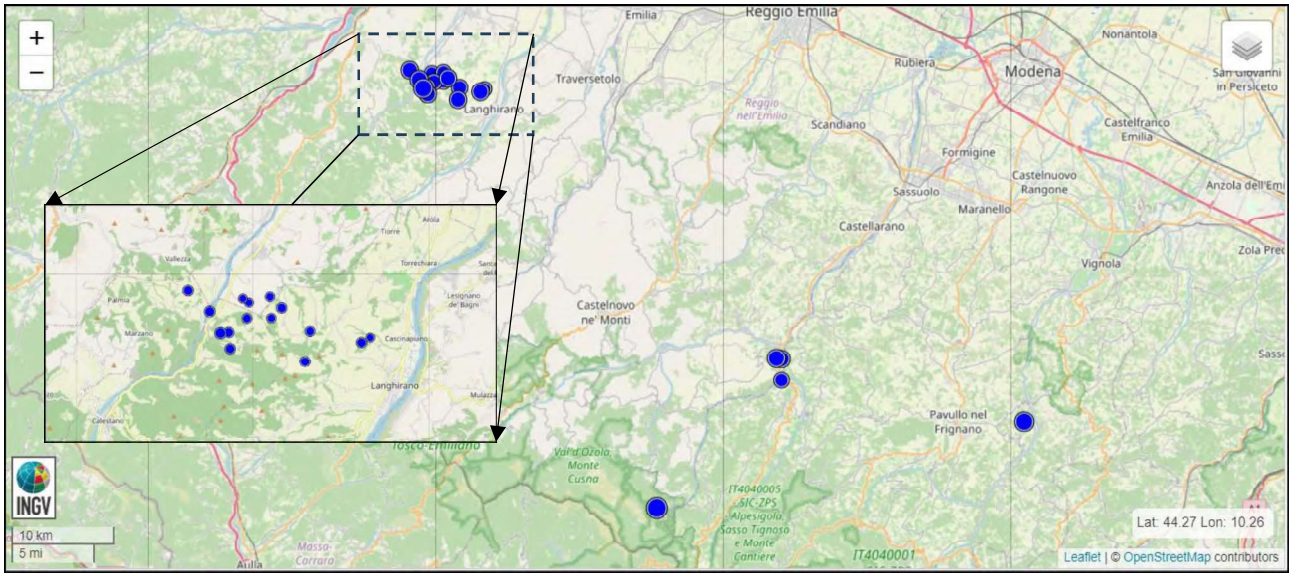

Fig. 4 - Local seismic swarm in Emilia Romagna, Italy, occurred between February 6 and February 7, 2024. Credits: INGV.

The subsequent question posed to the AI concerned the higher likelihood of earthquake occurrences in areas where seismic events had already taken place. The AI's response was positive despite the complexity of the phenomena, where it is not possible to derive certain data from statistical data alone.

The earthquakes considered in this study, referring to the seismic sequence in Emilia, are the following:

- 2024-02-06 22:49:22 ML 2.2 - 2 km NW Montefiorino (MO)
- 2024-02-06 23:37:36 ML 2.5 - 6 km E Calestano (PR)
- 2024-02-07 05:02:02 ML 3.2 - 9 km W Frassinoro (MO)
- 2024-02-07 05:31:42 ML 2.3 - 6 km NW Langhirano (PR)
- 2024-02-07 05:32:00 ML 2.6 - 4 km W Langhirano (PR)
- 2024-02-07 05:41:59 ML 2.8 - 6 km NE Calestano (PR)
- 2024-02-07 05:46:33 ML 2.0 - 7 km W Langhirano (PR)
- 2024-02-07 06:24:29 ML 2.5 - 6 km NE Calestano (PR)
- 2024-02-07 06:26:38 ML 2.1 - 2 km NW Langhirano (PR)
- 2024-02-07 06:33:10 ML 2.2 - 6 km W Langhirano (PR)
- 2024-02-07 07:25:32 ML 2.4 - 6 km W Langhirano (PR)
- 2024-02-07 08:15:18 ML 2.4 - 4 km W Langhirano (PR)
- 2024-02-07 08:20:32 ML 2.1 - 7 km W Langhirano (PR)
- 2024-02-07 08:29:55 ML 2.7 - 6 km NE Calestano (PR)
- 2024-02-07 09:01:13 ML 2.6 - 5 km NW Langhirano (PR)
- 2024-02-07 09:14:58 ML 2.5 - 6 km NE Calestano (PR)
- 2024-02-07 09:27:59 ML 2.6 - 2 km NW Langhirano (PR)

These are the earthquakes that occurred between February 6, 2024, at 22:49 UTC, and February 7, 2024, at 09:27 UTC. (Source: INGV).

3 - Discussion

The pursuit of earthquake prediction research represents a context of significant development, particularly when considering new instruments and technologies capable of supplying a more extensive and diverse array of data. This diversification, when combined with other data within a multidisciplinary framework, may yield more accurate insights into crustal diagnostics and phenomena preceding earthquakes.

The initial seismic event documented was an earthquake of magnitude ML 4.2 on February 5, 2024, at 08:14:56 (UTC) in Italy (offshore), as depicted in Figure 2. Despite occurring at sea, this earthquake is part of the Sicilian region, ranked third by AI as an area prone to seismic activity.

The second seismic event documented was an earthquake of magnitude ML 2.5 on February 6, 2024, at 23:37:10 (UTC) in the southern Sicilian Channel (sea). Though not occurring on land, this event also took place within Italian territory, specifically referring to the Sicilian area (as shown in Figure 3).

The most significant event, from an AI predictive perspective, occurred between the end of February 6, 2024, and February 7, 2024, when a local seismic swarm began in Emilia Romagna (as shown in Figure 4). Given this latest event (swarm), occurring precisely in the area AI had identified as the most likely Italian geographical zone to experience earthquakes with magnitudes over M2, it is evident that data from the INGV archives can have predictive value if interpreted in a certain manner.

The processed data are of a simple type, based on the temporal localization of earthquakes, their number, their magnitude, and their distribution relative to a specific geographical area, in this case, Italy.

Hence, this result takes into account actual seismic data from which predictive information provided by AI could be derived, within a very short temporal context and given the low heterogeneity of the data, it was not possible to provide more precise spatial and temporal indications.

Existing studies are contemplating the use of AI within a seismic research context [10] [11] [12] [13] [14]. These studies represent merely the initial phase of research that, in the coming years, will deliver significant advancements across all fronts of technology and research.

4 - Conclusion

The pursuit of earthquake forecasting represents a highly developed field, particularly when considering new tools and technologies capable of providing a larger and more diversified array of data. Such diversification, when combined with other data already in possession of researchers, can undoubtedly offer more precise indications that may aid in understanding parts of the seismogenic phenomena preceding earthquakes.

In this instance, although the study was based on a limited set of data, it highlighted how AI was capable of retrieving and corroborating data, providing predictive insights that proved to be accurate. It is no coincidence that the seismic swarm, which occurred in Emilia Romagna, Italy, happened precisely in the location the AI had identified as the first Italian region where there would be a higher probability of expecting earthquakes with a magnitude of M2+ (as shown in Fig. 1).

This demonstrates the importance of utilizing increasingly up-to-date tools, of employing multiple data sources, which can then be processed by AI. In this case, this small study was conducted solely with seismic data from INGV, but it is hopeful that in the not-too-distant future it will be possible to provide AI with more types of data, so that it can offer more accurate seismic forecasting indications.

There are already studies in this area that contemplate the use of AI within a seismic research context [10] [11] [12] [13] [14]; these studies are merely the initial phase of research that in the coming years will provide significant developments on all fronts of technology and research. In this scenario, researchers must employ such knowledge and tools to overcome, as soon as possible, the challenges that still exist today in earthquake forecasting research.

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