Understanding Future AI-Green Technology Directions from Past Technological Trajectories

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Short Abstract

We combine scientometrics and generative AI (ChatGPT) to analyze the intersection of AI and green technologies. Leveraging technological trajectories built using the entire EPO data, the study identifies current common themes and projects future directions of twin (AI and green) technologies. Generative AI summarizes patent information, revealing technological paradigms and their expected future evolution. Initial findings highlight key areas like automation, environmental management, and IoT integration. In ongoing work we are expanding the analysis, enhancing replicability, and comparing results with other NLP methods for a more robust representation of past and future technological developments.

Extended abstract

The intersection of artificial intelligence (AI) and green technologies represents a crucial frontier in addressing the climate emergency. This paper studies the dynamic landscape of AI-related green innovations, aiming to map current trends and project future trajectories of technological development. Our methodology combines established scientometric analysis with the emerging capabilities of generative AI, leveraging a comprehensive database of technological trajectories constructed from the all inventions in the European Patent Office (EPO) data.

We focus on the convergence of AI and green technologies within our trajectory database that covers all inventions in the EPO. Technological trajectories, represented as chains of patents linked by citation relationships, offer valuable insights into the evolutionary pathways of these inventions. We employ generative AI, specifically ChatGPT, to synthesize information extracted from patent titles and abstracts, generating concise summaries for each technological trajectory.

This AI-driven summarization approach allows us to efficiently analyze a substantial number of trajectories. Our initial dataset comprises approximately 43,000 trajectories identified as relating to both green technologies (classified using Y02 and Y04S CPC codes) (Nomaler and Verspagen,

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2019) and digital technologies (as identified in our earlier work (Menendez De Medina et al, 2023; Prytkova et al 2024)). We then refined this set, focusing on 950 trajectories that explicitly mention "artificial intelligence" or "machine learning" within their titles or abstracts. From this refined set, a random sample of 32 non-overlapping trajectories was selected for in-depth analysis, ensuring that no single patent was represented in more than one trajectory.

For each trajectory within this sample, we provided a structured prompt to ChatGPT, requesting: (1) a descriptive summary of the trajectory's technological development, (2) a reasoned prediction of potential future directions for the technology, and (3) identification of closely related technologies that could contribute to these future advancements. We provided to ChatGPT a data record containing title, abstract, priority year, and the position in the trajectory. ChatGPT's responses were formatted to clearly distinguish between these three requested components.

Building upon these individual trajectory summaries, we further utilized ChatGPT to identify common technological "paradigms" emerging across the set of trajectories. These paradigms represent overarching themes or fundamental technological building blocks that characterize groups of related trajectories. We conducted separate analyses for past and future paradigms, providing ChatGPT with the descriptive summaries of the trajectories (1) for the former and the predicted future directions (2) for the latter. This process resulted in the identification of eight distinct past paradigms, including categories such as "Automation and Control Systems," "Environmental Management and Sustainability," and "Energy Productino and Management." For future paradigms, ChatGPT identified six key paradigms, such as "Integration with IoT and Smart Systems," "Enhanced AI and Machine Learning Integration," and "Sustainability and Energy Efficiency."

To visualize the relationships between these paradigms and the underlying trajectories, we constructed a tripartite network. In this network, the 32 trajectories serve as the connecting links between the past and future paradigms, as each paradigm is characterized by the set of trajectories it encompasses. We employed VOSviewer (Van Eck and Waltman, 2010) to map this tripartite network, providing a graphical representation of the patent landscape for green technology and AI derived from our ChatGPT-assisted analysis. The resulting network map revealed a central cluster of broadly applicable future paradigms, surrounded by more specialized clusters of trajectories and past paradigms. These specialized clusters corresponded to areas like mobility (with a focus on emission control), wind turbine technology, industrial automation, and environmental monitoring, offering a structured overview of the key areas of innovation within the AI-green technology domain.

This pilot study provides evidence for the potential of combining traditional scientometric methods with the capabilities of generative AI to gain insights into complex technological landscapes that may be diffocult to descrbe with standard labelling methods and topic modelling.

The current study is based on a relatively small sample of trajectories. Moreover, the reliance on ChatGPT introduces inherent challenges to replicability. We are currenlty addressing these limitations by scaling up the analysis to encompass a significantly larger number of trajectories, ultimately aiming to cover the entire dataset of 43,000 trajectories related to green and digital technologies. Furthermore, we are implementing this work using generative AI systems that can be replicable, such as Llama, offering greater control over parameters. Finally, we will compare and contrast our generative AI-driven findings with results obtained through more established

NLP techniques, such as sentence embeddings and semantic similarity analysis, to validate the insights generated by AI and ensure the reliability of our conclusions.

References

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