The Ethics of AI-Generated Maps: DALL · E 2 and AI's Implications for Cartography

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Abstract

The rapid advancement of artificial intelligence (AI) such as the emergence of large language models ChatGPT and DALL · E 2 has brought both opportunities for improving productivity and raised ethical concerns. This paper investigates the ethics of using artificial intelligence (AI) in cartography, with a particular focus on the generation of maps using DALL · E 2. To accomplish this, we first created an open-sourced dataset that includes synthetic (AI-generated) and real-world (human-designed) maps at multiple scales with a variety of settings. We subsequently examined four potential ethical concerns that may arise from the characteristics of DALL · E 2 generated maps, namely inaccuracies, misleading information, unanticipated features, and irreproducibility. We then developed a deep learning-based model to identify those AI-generated maps. Our research emphasizes the importance of ethical considerations in the development and use of AI techniques in cartography, contributing to the growing body of work on trustworthy maps. We aim to raise public awareness of the potential risks associated with AI-generated maps and support the development of ethical guidelines for their future use.

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Supplementary Material *Dataset*: https://github.com/GISense/DALL-E2-Cartography-Ethics archived at swh:1:dir:a9d23d429831d2625a02551e0b9b1bb7131a0431

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1 Introduction

Cartographers long have recognized the significance of developing ethical and trustworthy maps, i.e., maps that truthfully depict geographic information while minimizing the introduction of misinformation or bias [15, 6]. With the rapid advancements in Artificial Intelligence (AI), the use of AI in map-making has brought both opportunities and concerns [12, 9]. On the one hand, (Geo)AI techniques can facilitate map creation processes and even have

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demonstrated the potential to support human creativity in cartographic design. For instance, cartographers have employed (Geo)AI to support cartographic design decisions on the artistic aspects of maps such as map style transfer [10, 3], map generalization [4, 18], and map design critique [2]. On the other hand, despite its promise, cartographers have expressed ethical concerns about the uncertainty and opacity (i.e., machine learning and deep learning models often are considered as "black-boxes") of AI for generating maps [21, 9]. As [6] asks: "How much should we trust a machine-generated map?"

Recently, generative models such as ChatGPT and DALL · E 2 have attracted significant public attention [16, 19]. These generative language models have demonstrated impressive capabilities in tasks such as language generation and image synthesis. Yet, they have fueled debates surrounding the ethical concerns related to the development of generative AI [13, 22]. The advancement of these generative AI models also raises critical questions about the future of labor [20] and the consequences of unbridled technological development [19, 14]. Therefore, there is an urgent need for careful consideration and ethical evaluation of AI technologies in myriad domains to ensure their responsible and beneficial use.

As cartographers and geographers, we have a particular interest in investigating the ethical implications of maps created by these advanced generative models. The emergence of powerful tools such as DALL · E 2 has made it increasingly accessible to generate high-quality map images by providing specific prompts. However, this also has introduced new challenges related to the accuracy and trustworthiness of these synthetic maps generated by AI. While these maps may look realistic, they also may contain inaccuracies or be influenced by biases embedded in the AI models, resulting in the proliferation of potentially meaningless, and, at worse, harmful maps online [17]. To address these issues, it is necessary to build solutions for detecting and mitigating the risks associated with using such maps, as suggested by [21]. Hence, it is crucial to offer timely detection of "fake" maps to assess the trustworthiness of web maps and minimize the potential negative impacts associated with their use.

To this end, we aim to investigate the use of AI in generating maps and the associated ethical implications of AI-generated maps. We ask the following two fundamental questions: (1) What potential ethical concerns arise from the characteristics of maps generated by DALL · E 2? and (2) How can AI-generated maps be identified to ensure their trustworthiness on web maps? To accomplish this, we first created a dataset that contains synthetic maps generated by DALL · E 2 with diverse prompts at multiple spatial scales (hereafter referred to as *AI-generated maps*). We also collected real-world maps using search engines (hereafter referred to as *human-designed maps*). In addition, we trained a deep learning-based model capable of identifying AI-generated maps. In this paper, we hope to use this study to apply ChatGPT-like generative models (e.g., DALL · E 2) in cartography. Our research contributes to the growing body of work on trustworthy maps and the ethics of cartography by highlighting the importance of ethical concerns in the development and use of AI techniques with cartography for the public.

2 Data and Methodology

2.1 Construction of Dataset

We first created an AI-generated map dataset using the DALL · E 2 that relies on prompts to generate images. Specifically, we generated the maps using the following prompt format:

"*A {MapType} of {Region} on {Place} with {Description}*"

This format allows us to specify the type of map, the region of maps, the location where the map is put, and additional descriptive information for the AI model to generate a corresponding map.

The first two parameters for all prompts, *MapType* and *Region*, are required, while *Place* and *Description* are optional. For instance, to generate a United States choropleth map that is placed on the desk in warm colors, the prompt could be: "A choropleth map of United States with warm colors". Then, we randomly selected options and combines them to generate a diverse set of maps covering various regions and themes. We have made the dataset openly available on GitHub at: https://github.com/GISense/DALL-E2-Cartography-Ethics. As a comparison, we developed a Python web scrapper to collect maps from the Google search engine at the same levels and administrative regions. To do so, we entered a search query in the format "*{Region}* maps", such as "United States maps". We adopted such a strategy used in prior studies to construct map datasets for country and continent levels [5, 8]. Regarding images at the state level, we directly utilized the dataset released from [8].

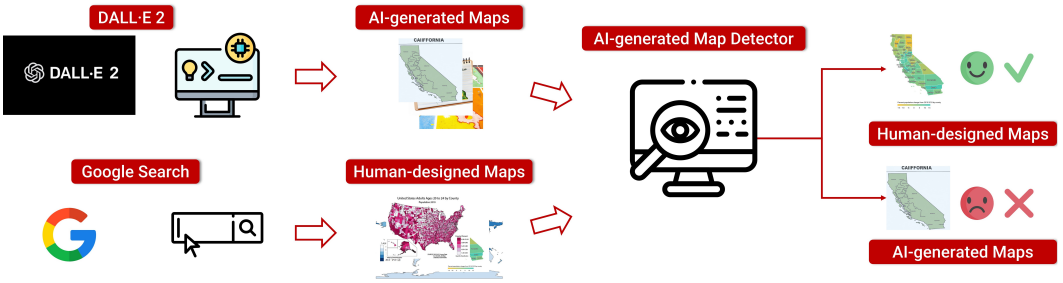

Figure 1 The computational framework of this study.

2.2 Development of AI-generated Map Detector

Based on the datasets, we developed an AI-generated map detector that can identify AI-generated maps which may offer potential solutions for creating trustworthy maps. Such a detector was developed based on a ResNet-18 model [7], a Deep Convolutional Neural Network (DCNN) that has been widely used in computer vision tasks due to its outstanding performance. Given its mature and high accuracy in image classification, we utilized the ResNet model in our study to classify maps as either generated by AI or created by humans. To train the model, we combine the two datasets, namely, AI-generated maps and human-designed maps, and input them into the ResNet-18 model.

3 Results

3.1 Ethical Issues of AI-generated maps

Based on our qualitative observations of AI-generated maps, we summarize four potential ethical concerns of such maps: inaccuracies, misleading information, unanticipated features, and the inability to reproduce results. We have included several examples of these map characteristics in figure 2, and we summarize our definitions of these characteristics below.

The inaccuracies observed in AI-generated maps are symbolized by unclear shapes of areas. Specifically, AI-generated maps may have unclear and distorted borderlines between different regions (e.g., states, and counties) or even unreasonable deformation of a certain

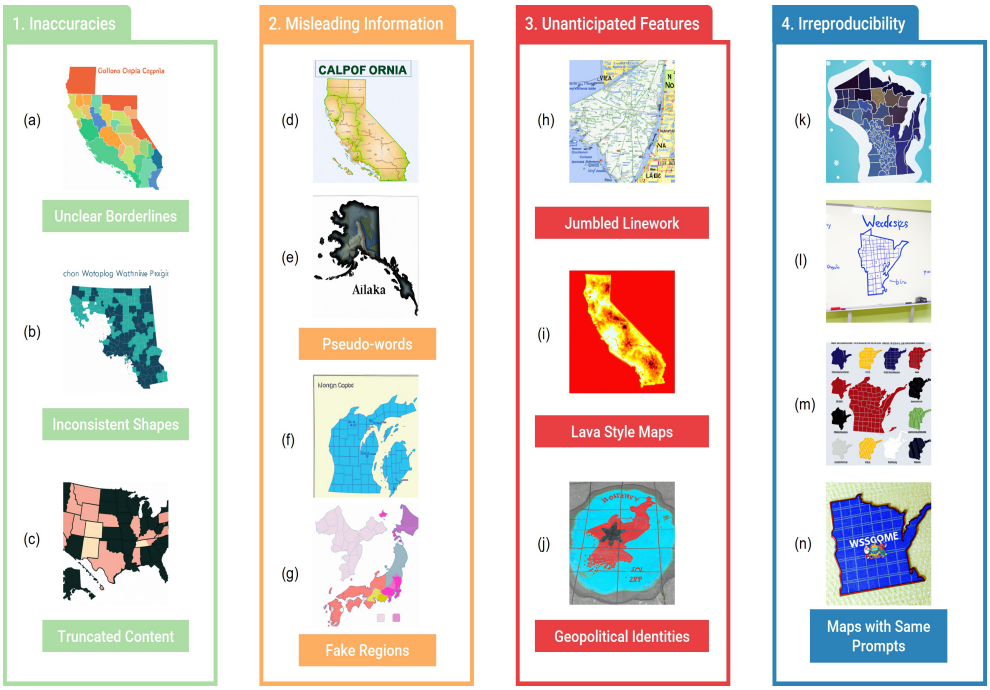

Figure 2 Example AI-generated maps: (1) inaccuracies, (2) misleading information, (3) unanticipated features, and (4) irreproducibility.

area. At the same time, AI-generated maps from Dall-E 2 are limited to square output shapes since users cannot set the scale of images and they typically only display certain content of a region.

Moreover, AI-generated maps also can produce misleading information. AI-generated maps also can contain pseudo-words, non-existent provinces, or symbols, which create a false impression of the current map with a given input prompt. These features potentially can lead to the spread of misinformation or the distortion of popular notions of reality and have unintended geopolitical consequences and raise significant ethical concerns.

In addition to the inaccuracies and misleading information, AI-generated maps may create unexpected or unanticipated features. For instance, AI-generated maps are unaware of the underlying geographic processes that lead to repeated patterns in the landscape, particularly for the build environment in our study, resulting in distorted polygons or depicting a heat map as lava. The presence of polygons or lava suggests that the model may have misunderstood the meaning of the prompt. In addition, AI models may generate specific themes of maps that reflect certain geopolitical identities, even if not input in keyword prompts. Further work is needed to evaluate the degree to which AI-generated maps may stoke nationalism and thus reinforce xenophobic or otherwise biased geopolitical discourse.

Finally, AI-generated maps cannot be reproduced even with the same prompt. Due to the randomness inherent in the generation process of DALL · E 2, it is impossible to generate two maps that have the exact same map content, map shapes, map styles, or overall layouts. Without greater reproducibility, cartographic research on GeoAI cannot be validated or replicated, and therefore poise ethical questions about the effectiveness of a conventional, science-based peer-review system, and what "counts" as knowledge and scholarship more broadly. From a technical perspective, the model may reproduce the same outputs if we have the same hyperparameters (e.g., random seed, steps, prompts, weights). However, DALL · E 2 is not currently open-sourced and therefore is not reproducible at this time.

3.2 System Results of our AI-generated Map Detector

We evaluated the performance of our deep learning-based AI-generated map detection model on the test set. Based on the results, we computed four commonly used metrics in machine learning, namely, accuracy, precision, recall, and F1 score, to measure the performance. The system achieved an accuracy of 0.908, precision of 0.87, recall of 0.878, as well as an F1 score of 0.874 on the testing dataset. These metrics suggest the system is robust and effective in distinguishing between human-generated and AI-designed maps.

4 Discussions and Conclusions

While generative AI such as DALL · E 2 and ChatGPT have the potential to assist the cartographic design process, they also raise significant ethical concerns. In this paper, we present an AI-generated map dataset using DALL · E 2 and investigate the potential ethical issues associated with AI-generated maps based on their characteristics. The findings reveal that despite their promises, such AI-generated maps may deliver inaccurate and misleading information, contain unanticipated features, and lack reproducibility. In addition, we develop an AI-generated map detector with deep learning that can identify whether a map is generated by humans or by AI. This map detector is intended to be used in various applications, such as identifying potential cases of AI-generated maps being used to spread misinformation on online social media platforms. Inaccurate or misleading maps, whether intentionally or unintentionally created, may cause significant negative impacts, particularly in sensitive political or cultural contexts. It is possible for this map detector to help prevent the spread of misinformation and reduce the potential harm caused by AI-generated maps.

We acknowledge several limitations that are worth examining in the future. First, the dataset we collected in this paper was limited in geographic coverage and diversity since more diverse characteristics are required for the generalizability of our findings. Second, this paper has only investigated the maps generated by DALL · E 2 while numerous other models have been available that can produce maps. In this early stage of the application of AI technology, it is also important to explore more options in prompts and other parameters. More settings and models allow for a wide range of cartographic applications in generative AI that can be incorporated into future studies.

The future of AI in cartography involves generating more accurate and visually appealing maps through the rapid evolution of (Geo)AI technology, an emerging field known as "GeoAI for cartography", "CartoAI", or "MapAI". It's critical for cartographers to collaborate with AI developers to ensure cartographer-in-the-loop developments by addressing the limitations and minimizing potential ethical concerns. Also, AI could be used to facilitate collaborative mapping efforts [1]. By integrating multiple data sources, AI may make maps more accessible. However, the potential ethical issues (e.g., bias, trustworthiness) should be monitored or reduced. Participatory mapping, incorporating local knowledge, could improve map accuracy, promote community engagement, and foster collaboration, while addressing ethical concerns.

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