The Current Limits of AI in Replacing Human Mathematicians

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Nowadays, many people are familiar with AI in their daily lives—increasing numbers of college students use ChatGPT for studies, while office workers use Copilot to lighten workloads. This integration has sparked debates on AI's potential in specialized fields like mathematics, since AI has shown its potential in other professional fields such as predicting the behavior of protein folding. While AI excels in structured tasks and data processing (Ha & Schmidhuber, 2018), its capability to replace human mathematicians remains limited. True mathematical innovation often requires the creation of new theories and concepts, areas where human creativity and abstract thought still surpass AI. This essay will explore AI's current capabilities in mathematics, arguing that it remains an invaluable tool rather than a replacement for human mathematicians.

One of the primary arguments against the capability of current AI systems to replace human mathematicians lies in their inability to generate new mathematical concepts. Human often involves creation when forming mathematical reasonings. One example is the Galois's proof of "trisection of an arbitrary angle cannot be achieved through ruler and compass construction" in the 19th century, where he ingeniously transformed the geometric question into an algebra question (the geometric problem had remained open in the past two thousand years). This innovative movement allowed him to process the problem within the framework of equations and algebra, extracting the mathematical logic hidden in the geometric problem, which was the breach point of his work. The creation of novel methods and theories is a task that human mathematicians navigate with creativity and abstract understanding. AI of current type, on the other hand, predominately based on neural networks, excel in pattern recognition and simulating human languages. (Li et al., 2024) However, they fall short in pioneering original concepts, which are crucial to mathematical process. Their proficiency in data handling and language imitation does not equate to the innovative capacity required to tackle entirely new mathematical challenges. The later, however, often involves connecting several disjoint concepts that seems irrelevant, creating new concepts to tackle a problem.

Another significant hurdle for AI in mathematics is the comprehension of complex, open mathematical problems. These problems typically require an extensive understanding of numerous theories and the interrelations between them, acquired through the study of vast amounts of academic literature. We, as human, understand knowledge in tree or net structures (A Human in the Loop: AI won't Surpass Human Intelligence Anytime Soon, n.d.)—we see inner connection and dependence of them. While AI can process natural language effectively, it lacks the ability to grasp and organize complex mathematical proofs and definitions in a way that is comparable to human understanding. In contrast, even the most advanced common AI systems such as GPT-4o or Claude 3 can be confused by errors in undergraduate course level math proofs. Admittedly, there are specialized AI that can form rigorous proof in specific questions such as geometry (Trinh et al., 2024), there is no evidence that AI has the ability to understand the mathematical logic underneath the generated answer. The existing AI technologies can manage straightforward tasks and have shown competence in understanding formal proof processes, but they still do not possess the deep conceptual grasp necessary for tackling higher-level mathematical inquiries that require an extensive synthesis of multiple advanced concepts.

A common critic argues that future AI systems might overcome current limitations such as using specialized algorithm architecture. However, this perspective overlooks the fundamental nature of algorithms that drives AI's recognition—neuron network. Though there are numerous variations of neuron network, the algorithms were all designed to fit and predict discrete data. While neuron network lies firm foundations for AI exceling in pattern recognition and natural language processing, true mathematical innovation involves more than just applying known methods to new problems. It requires the ability to conceive entirely new frameworks and theories, as evidenced by historical breakthroughs like Gödel's incompleteness theorems or the development of calculus by Newton and Leibniz. These breakthroughs were not merely the result of analyzing existing pattern but arose from profound conceptual insights and imaginative leaps that current AI lacks. Therefore, despite the potential for AI to assist in mathematical research, its role remains complementary rather than substitutive, (Chapinal-Heras & Díaz-Sánchez, 2023) as it cannot replicate the deep, intuitive, and creative processes that are the hallmark of human mathematicians.

In conclusion, while AI continues to revolutionize various fields and enhance productivity in daily tasks, its role in the realm of mathematics remains supportive rather than replacement-level. The limitations of current AI systems lie in its fundamental architecture, particularly in innovating new mathematical concepts and comprehending complex open problems. Human ingenuity, characterized by creativity and abstract thought, is essential for pioneering innovative mathematical theories and frameworks. Although AI excels in data handling, pattern recognition, and language processing, it lacks the profound insights and creativity that define true mathematical breakthroughs. Thus, AI should be viewed as a powerful tool that aids human mathematicians, complementing their efforts rather than a replacement. The future of mathematics will likely involve a partnership between AI and human minds, using the strengths of both to achieve greater advancements.

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