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WILL MACHINES CHANGE MATHEMATICS?

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(Guest Editorial Committee)

Will artificial intelligence lead to a revolution in the way science, including pure mathematics, gathers and processes information? Will it change the way in which we do our research? These questions are both intriguing and disturbing. Opinions vary; some colleagues believe that widespread use of machine learning in our research is just around the corner, and others are more skeptical, pointing to the optimism of the 1960s and the subsequent "AI winter."

Nonetheless, the *possibility* of dramatic changes in the practice of mathematical research has become very real. We—the guest editorial panel—believe that *now* is the time for mathematicians—this means *you*—to begin thinking about the issues this raises; and it is with this in mind that we have prepared these two (solicited) special editions of the *Bulletin*. We are not aiming to offer answers but rather to raise questions and stimulate discussion amongst working research mathematicians.

The initial impetus for this volume was the Fields symposium "The Changing Face of Mathematical Research."[1] A central theme of the discussions was the growing role of machines in the verification and generation of mathematical proofs. What is feasible? What might become feasible? And how will this alter notions of the value and meaning of mathematics? Although the role of proof has been the cause of occasional debate in contemporary mathematical discourse (see [1–4]), such discussion has been rare.

On the other hand, analogous questions have been explored outside of mathematics departments, often from rather different points of view. Therefore, the Fields symposium included an intellectually diverse group of scholars from computer science (particularly machine learning), history, philosophy, and anthropology, as well as research mathematicians. We believe that much was gained by these perspectives, and so we have correspondingly solicited a broad range of articles for this issue.

The main topics discussed in the first theme issue (April 2024) are the following (though there are no strict boundaries).

- *AI and formalization as a tool for traditional mathematics*: An increasing number of traditional pure mathematicians are working with tools for formalizing proofs, and some have also used machine learning in a significant way in their research. The articles on formalization by Avigad, Buzzard, Commelin and Topaz, and Shulman; and on deep learning by Williamson, present various informed perspectives from research mathematicians.

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[1]This was the October 2022 Fields medal symposium in honour of Akshay Venkatesh's Fields medal, held at the Fields Institute in Toronto, Canada.

- *Can current AI do serious mathematics, itself*: The article by Davis examines the ability of current AI models to solve "simple" mathematical word problems. (This field is evolving extremely rapidly, and the article includes pointers to more recent literature.)
- *What do working mathematicians think about AI?*: The automation of mathematics raises a host of nontechnical issues, ranging from the social and philosophical, to very practical questions of employment. The articles by Cheng, Granville, Harris, and Venkatesh give perspectives from working mathematicians on these matters, whereas Ochigame gives the viewpoint of an anthropologist.

The main topics discussed in the second theme issue (July 2024) are the following.

- *Automation and philosophy*: Many of the issues raised by formalization are not new. As McLarty's article describes, Poincaré was discussing "reasoning machines" more than a century ago; Poincaré was already concerned with the relation between formalized proof and mathematical practice, a theme that is discussed further in de Toffolli's contribution.
- *Technology alters thought*: The article by DeDeo examines the potential impact of automated proof on the cognitive processes of mathematicians.
- *The interaction of deep learning and mathematics*: The article by Bengio and Malkin considers the specific challenges that doing mathematical research poses for machine learning, and, in the reverse direction, the article by Fraser and Poggio formulates questions related to the mathematical foundations of deep learning.

Pure mathematicians are used to enjoying a great degree of research autonomy and intellectual freedom, a fragile and precious heritage that might be swept aside by a mindless use of machines. On the other hand, a thoughtful and deliberate approach to the same technology may greatly enrich our subject. It is for *us* to determine how *our* subject should develop, and so we invite the mathematical community to think seriously about and discuss the questions raised in these two special issues, and to listen to colleagues in other fields who have deeply considered these same questions. Now is the time for mathematicians to learn about and then drive this debate, and to decide upon our subject's future direction.

References

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