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Machines, Computations, and Universality

9th International Conference, MCU 2022
Debrecen, Hungary, August 31 – September 2, 2022
Proceedings

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Preface

This volume contains the papers presented at MCU 2022, the 9th Conference on Machines, Computations and Universality, held during August 31 – September 2, 2022, at the Faculty of Informatics of the University of Debrecen, Hungary. This edition was co-located with the 24th International Conference on Descriptional Complexity of Formal systems (DCFS 2022) and the 12th International Workshop on Non-Classical Models of Automata and Applications (NCMA 2022).

The MCU series of international conferences traces its roots back to the mid-1990s, and has since been concerned with gaining a deeper understanding of computation through the study of models of general purpose computation. MCU explores computation in the setting of various discrete models (Turing machines, register machines, cellular automata, tile assembly systems, rewriting systems, molecular computing models, neural models, concurrent systems, etc.) and analog and hybrid models (BSS machines, infinite time cellular automata, real machines, quantum computing, etc.). There is a particular (but not exclusive) emphasis given to the following:

– The search for frontiers between decidability and undecidability in the various models. (For example, what is the smallest number of pairs of words for which the Post correspondence problem is undecidable, or what is the largest state-symbol product for which the halting problem is decidable for Turing machines?)
– The search for the simplest universal models (such as small universal Turing machines, universal rewriting systems with few rules, universal cellular automata with small neighborhoods and a small number of states, etc.).
– The computational complexity of predicting the evolution of computations in the various models. (For example, is it possible to predict an arbitrary number of time steps for a model more efficiently than explicit step by step simulation of the model?)
– Universality and undecidability in continuous models of computation.

Previous MCU conferences took place in Fontainebleau, France (2018), Famagusta, North Cyprus (2015), Zürich, Switzerland (2013), Orléans, France (2007), Saint Petersburg, Russia (2004), Chisinău, Moldova (2001), Metz, France (1998), and Paris, France (1995).

There were 18 papers submitted to this edition of MCU, all in the scope of the conference, and each submission was reviewed by three Program Committee members. The committee decided to accept 10 papers for presentation and publication in these proceedings.

The program included four invited talks.

– **Enrico Formenti** from the University of Côte d'Azur, France, presented in "Complexity of local, global and universality properties in finite dynamical systems" some complexity bounds for the case when such systems are presented as their evolution graph. Some results of universality for simulation on some classes were provided.

– **Mika Hirvensalo** from the University of Turku, Finland, presented how quantum computation can be improved by taking advantage of wave-particle dualism in "Using Interference to Boost Computing".
– **Hava T. Siegelmann** from the University of Massachusetts at Amherst, USA, explained how to handle and benefit from ever learning AI in "Super Turing Computing Enables Lifelong Learning AI".
– **Bianca Truthe** from the University of Gießen, Germany, provided "A Survey on Computationally Complete Accepting and Generating Networks of Evolutionary Processors". In this model, each processor is assigned the fixed task to add, remove, or change a single symbol on strings which move from one processor to another according to filters.

The conference was held in hybrid mode with the possibility of in-person and online presentation. More information on MCU 2022 can be found at https://konferencia.unideb.hu/en/mcu-2022.

We would like to thank everybody in the organizing committee who worked hard to make this edition successful.

Partial financial support for the conference was provided by the Department of Computer Science and by the Faculty of Informatics of the University of Debrecen.

The editors warmly thank the Program Committee, the organizers, the invited speakers, the authors of the papers, the external reviewers, and all the participants for their contribution to the success of the conference.

June 2022

Jérôme Durand-Lose
György Vaszil

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Invited Abstracts

Using Interference to Boost Computing

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Abstract. In the nature, interference [4] occurs almost everywhere in the presence of undulating motion. Water waves, sonic waves, as well as electromagnetic waves may interfere, meaning that sometimes the wave crests amplify each other, but sometimes the wave crest and trough annul each other. This mechanism may create patterns which a single wave propagation can never form [3].

In the smallest level, the physical world is depicted by using quantum mechanics, which involves so-called *wave-particle dualism* [1]. This principle signifies that the physical objects can be described as particles, but as waves, as well. It is possible, not only in principle, but also in practice, to regard physical systems carrying information as quantum waves and design algorithms that utilize interference as a computational resource [2]. This is actually rather generally regarded as the source of the efficiency of quantum computing [3].

We will underline some notable interference patterns used to implement famous quantum algorithms, but also to point out that interference-like effect has been used to design computational procedures already long before quantum computing [5, 6].

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Super Turing Computing Enables Lifelong Learning AI

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Abstract. State of the art AI systems demonstrate great capabilities in playing computer games and classifying images, as long as these operate on a computer screen. But once AI systems are embedded in autonomous technology and require to classify on the go and act efficiently and safely in the real world, they show a significant reduction in capabilities. This difference may be explained by the way state of the art AI is prepared, being trained in advance, typically on large datasets (and great amount of energy waste). Once fielded, the AI is frozen: It is unable to use its real-world experience to improve expertise, neither to note that situations move away from what it was originally trained on; and worse, since datasets cannot cover all possible real-world situations, systems with such frozen intelligent control are likely to fail.

A main reason that the field has developed an AI which is frozen once it is fielded, is that it was designed on the Turing machine foundations, where a fixed program is loaded to the universal machine which then follows the program's instructions. But—another theory of computation—the Super Turing computation enables more advanced type AI, one that can lifelong learn from its environment and experience, is not dependent solely on its training set, and interleave computing and learning to increase expertise.

Lifelong Learning is the cutting edge of artificial intelligence - encompassing computational methods that allow systems to learn in runtime and incorporate learning for application in new, unanticipated situations. Our presentation will introduce Super-Turing Computation from the point of view of AI, and follow with a number of state-of-the-art approaches that achieve lifelong learning intelligent systems.

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