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Evripidis Bampis · Aris Pagourtzis (Eds.)

# Fundamentals of Computation Theory

23rd International Symposium, FCT 2021  
Athens, Greece, September 12–15, 2021  
Proceedings

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# Preface

The 23rd International Symposium on Fundamentals of Computation Theory (FCT 2021) was hosted virtually by the National Technical University of Athens due to the COVID-19 pandemic during September 12–15, 2021. The Symposium on Fundamentals of Computation Theory (FCT) was established in 1977 for researchers interested in all aspects of theoretical computer science and in particular algorithms, complexity, and formal and logical methods. FCT is a biennial conference. Previous symposia have been held in Poznan (Poland, 1977), Wendisch-Rietz (Germany, 1979), Szeged (Hungary, 1981), Borgholm (Sweden, 1983), Cottbus (Germany, 1985), Kazan (Russia, 1987), Szeged (Hungary, 1989), Gosen-Berlin (Germany, 1991), Szeged (Hungary, 1993), Dresden (Germany, 1995), Krakow (Poland, 1997), Iasi (Romania, 1999), Riga (Latvia, 2001), Malmö (Sweden, 2003), Lübeck (Germany, 2005), Budapest (Hungary, 2007), Wroclaw (Poland, 2009), Oslo (Norway, 2011), Liverpool (UK, 2013), Gdansk (Poland, 2015), Bordeaux (France, 2017), and Copenhagen (Denmark, 2019).

The Program Committee (PC) of FCT 2021 received 94 submissions. Each submission was reviewed by at least three PC members and some trusted external reviewers, and evaluated on its quality, originality, and relevance to the symposium. The PC selected 30 papers for presentation at the conference and inclusion in these proceedings.

Four invited talks were given at FCT 2021 by Constantinos Daskalakis (Massachusetts Institute of Technology, USA), Daniel Marx (Max Planck Institute for Informatics, Germany), Claire Mathieu (CNRS and University of Paris, France), and Nobuko Yoshida (Imperial College, UK). David Richerby (University of Essex, UK) offered an invited tutorial.

This volume contains, in addition to the 30 accepted regular papers, the papers of the invited talks of Claire Mathieu and Nobuko Yoshida, the abstracts of the invited talks of Constantinos Daskalakis and Daniel Marx, and the abstract of the invited tutorial of David Richerby.

The Program Committee selected one contribution for the best paper award and two contributions for the best student paper awards, all sponsored by Springer:

- The best paper award went to Marc Neveling, Jörg Rothe, and Robin Weishaupt for their paper “The Possible Winner Problem with Uncertain Weights Revisited.”
- Two papers shared the best student paper award: (a) “Faster FPT Algorithms for Deletion to Pairs of Graph Classes” by Ashwin Jacob, Diptapriyo Majumdar, and Venkatesh Raman, and (b) “On Finding Separators in Temporal Split and Permutation Graphs” by Nicolas Maack, Hendrik Molter, Rolf Niedermeier, and Malte Renken.

We thank the Steering Committee and its chair, Marek Karpinski, for giving us the opportunity to serve as the program chairs of FCT 2021, and for trusting us with the

responsibilities of selecting the Program Committee, the conference program, and publications.

We would like to thank all the authors who responded to the call for papers, the invited speakers, the members of the Program Committee, and the external reviewers for their diligent work in evaluating the submissions and for their contributions to the electronic discussions. We would also like to thank the members of the Organizing Committee and the members of the Local Arrangements team for the great job they have done; special thanks go to Dimitris Fotakis, Ioanna Protekdikou, and Antonis Antonopoulos.

We would like to thank Springer for publishing the proceedings of FCT 2021 in their ARCoSS/LNCS series and for their sponsoring of the best paper awards. We are thankful to the members of the Editorial Board of *Lecture Notes in Computer Science* and the editors at Springer for their help throughout the publication process. We also acknowledge support from the Institute of Communication and Computer Systems of the School of Electrical and Computer Engineering of the National Technical University of Athens, towards covering teleconference expenses and registration costs for a number of students. Sponsors that provided support after the preparation of these proceedings appear on the webpage of the conference: <https://www.corelab.ntua.gr/fct2021/>.

The EasyChair conference system was used to manage the electronic submissions, the review process, and the electronic Program Committee discussions. It made our task much easier.

This volume is dedicated to the fond memory of our friend and colleague Yannis Manoussakis, Professor at University of Paris-Saclay, France. Yannis, a specialist in graph theory, unexpectedly passed away earlier this year in his beloved hometown on Crete. We will always remember him for his open heart and his great passion for theoretical computer science.

July 2021

Evripidis Bampis  
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## **Plenary Talks**

# Min-Max Optimization: From von Neumann to Deep Learning Plenary Talks

Constantinos Daskalakis

Massachusetts Institute of Technology, Cambridge, MA, USA

**Abstract.** Deep Learning applications, such as Generative Adversarial Networks and other adversarial training frameworks, motivate min-maximization of nonconvex-nonconcave objectives. Unlike their convex-concave counterparts, however, for which a multitude of equilibrium computation methods are available, nonconvex-nonconcave objectives pose significant optimization challenges. Gradient-descent based methods commonly fail to identify equilibria, and even computing local approximate equilibria has remained daunting. We shed light on this challenge through a combination of complexity-theoretic, game-theoretic and topological techniques, presenting obstacles and opportunities for Deep Learning and Game Theory going forward.

(This talk is based on joint works with Noah Golowich, Stratis Skoulakis and Manolis Zampetakis)

# Tight Complexity Results for Algorithms Using Tree Decompositions

Dániel Marx

CISPA Helmholtz Center for Information Security, Saarbrücken, Germany

**Abstract.** It is well known that hard algorithmic problems on graphs are easier to solve if we are given a low-width tree composition of the input graph. For many problems, if a tree decomposition of width  $k$  is available, algorithms with running time of the form  $f(k) \cdot \text{poly}(n)$  are known; that is, the problem is fixed-parameter tractable (FPT) parameterized by the width of the given decomposition. But what is the best possible function  $f(k)$  in such an algorithm? In the past decade, a series of new upper and lower bounds gave us a tight understanding of this question for particular problems. The talk will give a survey of these results and some new developments.

# The Complexity of Counting Problems (Tutorial)

David Richerby

University of Essex, Colchester, UK

**Abstract.** Every computational decision problem (“Is there an X?”) has a natural counting variant (“How many X’s are there?”). More generally, computing weighted sums such as integrals, expectations and partition functions in statistical physics can also be seen as counting problems.

This tutorial will give an introduction to the complexity of solving counting problems, both exactly and approximately. I will focus on variants of constraint satisfaction problems. These are powerful enough to naturally express many important problems, but also being restricted enough to allow their computational complexity to be classified completely and elegantly. No prior knowledge of counting problems will be assumed.

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