Annals of Mathematics and Artificial Intelligence (2024) 92:1–4
https://doi.org/10.1007/s10472-024-09922-0

ISAIM-2022: international symposium on artificial intelligence and mathematics

Dimitrios I. Diochnos[1] · Martin Charles Golumbic[2] · Frederick Hoffman[3]

Published online: 19 January 2024

Foreword

The series "International Symposium on Artificial Intelligence and Mathematics" has been held every two years in Fort Lauderdale since 1990. The general scope of the series is quite broad, fostering interactions between all aspects of AI, theoretical computer science, mathematics and their application. The series was founded by Martin Golumbic, Peter L. Hammer and Frederick Hoffman, with the editorial board of the *Annals of Mathematics and Artificial Intelligence* (AMAI) serving as the permanent Advisory Committee. Traditionally, the Symposium attracts participants from a variety of disciplines, thereby providing a unique forum for scientific exchange. The three-day symposium includes invited speakers, presentations of technical papers, and special topic sessions.

ISAIM-2022 was held online in hybrid mode due to the pandemic, allowing participation by researchers from across the globe. It was organized and sponsored by Florida Atlantic University, the University of Oklahoma, and the Caesarea Rothschild Institute at the University of Haifa. The full program can be found at the website: *https://isaim2022.cs.ou.edu/*

Keynote speakers: Four distinguished researchers presented invited lectures.

Noa Agmon (Bar-Ilan University), *Adversarial Robotics: from Teamwork to Swarms*. Developing robots for a wide range of goals requires addressing their ability to perform tasks as physical agents with specific characteristics, and the ways in which they act within and respond to their surroundings. As proximity to dangerous or hostile entities is among the foremost motives for using robots, it is therefore crucial to account for the presence of adversaries in robotic environments. The talk by Prof. Agmon described several key research threads examining the ability of robotic teams and swarms to (strategically) handle adversity, which strongly relies on the knowledge the robots have on the environment and the opponent, and the coordination scheme between the robots.

Cynthia Dwork (Harvard University), *Individual Probabilities: The Defining Problem of AI*. Prediction algorithms score individuals, or individual instances, assigning to each one a number in [0,1] that is often interpreted as a probability: What are the chances that this loan

✉ Martin Charles Golumbic
golumbic@gmail.com

1 University of Oklahoma, 660 Parrington Oval, 73019 Norman, OK, USA

2 University of Haifa, Haifa, Israel

3 Florida Atlantic University, Boca Raton, USA

will be repaid? How likely is the tumor to metastasize? What is the probability this person will commit a violent crime in the next two years? But what is the probability of a non-repeatable event? Without a satisfactory answer, we cannot even specify the goal of the ideal algorithm. In her talk, Prof. Dwork introduced the notion of *Outcome Indistinguishability*, a desideratum with roots in complexity theory, situating it within the decade-old investigation of the theory of algorithmic fairness.

Jérôme Lang (Université Paris-Dauphine), *From Portioning to Apportioning Under Ordinal Preferences*. When a public divisible resource (such as a monetary budget) is to be divided among alternatives (such as projects), a portioning rule decides on a distribution of the budget. Examples of such portioning problems are participatory budgeting, time shares, and parliament elections. In the latter case, an integral seat assignment must be found from the (real-valued) output of the portioning rule: this is the apportionment phase. In his lecture, Prof. Lang showed how both processes (portionment/apportionment) can be "plugged" into each other. The focus is on rules for which voters have ordinal preference rankings over alternatives.

Arun Ross (Michigan State University), *Modifying and Synthesizing Biometric Data*. Biometrics refers to the use of physical and behavioral traits such as fingerprints, face, iris, voice and gait to recognize an individual. The biometric data (e.g., a face image) acquired from an individual may be modified for several reasons. While some modifications are intended to improve the performance of a biometric system (e.g., image enhancement), others may be intentionally adversarial (e.g., spoofing or obfuscating an identity). Furthermore, the data may be subjected to a sequence of alterations resulting in a set of near-duplicate data (e.g., applying a sequence of image filters to an input face image). In this talk, Prof. Ross discussed methods for (a) detecting altered biometric data; (b) determining the relationship between near-duplicate biometric data and constructing a phylogeny tree denoting the sequence in which they were transformed; and (c) using altered biometric data to enhance privacy. The goal of the talk was to convey the dangers and, at the same time, the benefits of deliberately altered or synthesized biometric data.

Special sessions:

A special session was held in memory of Naftali Tishby, professor of computer science and computational neuroscience at the Hebrew University of Jerusalem, who passed away on August 9, 2021 at the age of 68. He was an invited plenary speaker at ISAIM-2008 lecturing on *Extracting Relevant Information from Samples*. Three of his coauthors and former students gave invited lectures on their current research in his memory.

Ohad Shamir (Weizmann Institute of Science), *Elephant in the Room: Non-Smooth Non-Convex Optimization*. It is well-known that finding global minima of non-convex optimization problems is computationally hard in general. However, the problem of finding local minima-like points (at least in terms of gradient and Hessian properties) is tractable, and received much attention in the machine learning community in recent years. The resulting literature has been largely motivated by the rising importance of non-convex optimization problems such as deep learning, but in fact, does not quite address them. Nearly all computationally efficient guarantees in this area require the objective function to be smooth, which is seldom satisfied in deep learning problems. This highlights the importance of understanding what we can do efficiently on such non-convex, non-smooth optimization problems. In this talk, Prof. Shamir described some results, challenges, and possible approaches to tackle this fundamental question.

Noam Slonim (IBM Research), *Project Debater - An Autonomous Debating System*. Project Debater is the first AI system that can meaningfully debate a human opponent. The system, an IBM Grand Challenge, is designed to build coherent, convincing speeches on its

own, as well as provide rebuttals to the opponent's main arguments. In 2019, Project Debater competed against Harish Natarajan, who holds the world record for most debate victories, in an event held in San Francisco that was broadcasted live world-wide. In this talk, Dr. Slonim told the story of Project Debater, from conception to a climactic final event, describe its underlying technology and its value to business use cases, and present the results of recent systematic evaluation of the system performance.

Noga Zaslavsky (MIT), *The Information Geometry of Human Pragmatic Reasoning*. A key aspect of language is the ability to pragmatically reason about each other's intentions and beliefs in order to understand meaning in context. A prominent approach to pragmatics is the Rational Speech Act (RSA) framework, which formulates pragmatic reasoning as Bayesian speakers and listeners recursively reasoning about each other. While RSA enjoys broad empirical support, its predictions have been explored mainly numerically rather than analytically, and on that basis it has been conjectured that the RSA recursion locally increases communicative utility. In this talk, Prof. Zaslavsky presented an information-geometric analysis of the RSA framework that sheds new light on the principles that may govern pragmatic reasoning. First, she showed that RSA's recursive reasoning implements an alternating minimization algorithm. Rather than optimizing utility, however, it optimizes a tradeoff between utility and communicative effort. Second, that RSA can be grounded in Rate-Distortion theory, yielding RD-RSA: a principled model of pragmatic reasoning that has similar predictive power for human behavior as RSA while avoiding a provable bias of RSA toward random utterance production. These results suggest that pressure for efficient compression may give rise to pragmatic reasoning, leading to a new approach for endowing artificial agents with human-like pragmatic skills without direct human supervision.

An invited special track, *Boolean and Pseudo-Boolean Functions*, was organized by Endre Boros and Yves Crama, dedicated to the memory of Peter L. Hammer, one of the great leaders in the area. Boolean and pseudo-Boolean functions are pervasive today in all areas of mathematics, computer science, operations research, various sciences and engineering. An ever increasing number and areas of applications demand new results from both structural and algorithmic points of views. The special session brought together researchers from all walks of science to discuss the latest results and the most important open problems. Three extended papers from this track appear in this issue of AMAI:

On those Boolean functions that are coset leaders of first order Reed-Muller codes, by Claude Carlet and Serge Feukoua, studies the class of those Boolean functions that are coset leaders of first order Reed-Muller codes. They study their properties to better understand their complex structure. They characterize those coset leaders that belong to the well known classes of direct sums of monomial Boolean functions and Maiorana-McFarland functions.

Galois theory for analogical classifiers, by Miguel Couceiro and Erkko Lehtonen, explores the relation between formal models of analogy and the corresponding classes of analogy preserving functions. They establish a Galois theory of analogical classifiers, and illustrate the usefulness of this Galois framework over Boolean domains,. Further, they explicitly determine the closed sets of analogical classifiers, i.e., classifiers that are compatible with the analogical inference, for each pair of Boolean analogies.

Lexicographically maximal edges of dual hypergraphs and Nash-solvability of tight game forms, by Vladimir Gurvich and Mariya Naumova, prove a new property of dual hypergraphs and derive from it Nash-solvability of the corresponding (tight) game forms. This result is known since 1975, but its new proof is much simpler.

A special track on *Coalition Formation Games* was organized by Judy Goldsmith and Jörg Rothe. Many AI applications concern settings in which individual agents choose to act as a group, or coalition. Such scenarios can be modeled as cooperative games, including hedonic

games, coalition formation games, weighted voting games, and many more. The aim of this special session was to bring together different communities working in cooperative games from various perspectives in computer science and economics and to bridge and bundle their research activities. Selected expanded papers from these sessions will appear in an issue of AMAI later this year.

Sessions on *Combinatorial and Geometric Problems in Imaging Sciences* were organized by Valentin Brimkov. A separate Preface to the accepted journal versions of these contributions follow this Foreword, and appear in this AMAI issue.

Three other tracks consisted primarily of oral presentations.

The sessions on *Sequencing, Sequential Decision Making and Scheduling*, organized by Lisa Hellerstein and Thomas Lidbetter, dealt with problems important in many areas of artificial intelligence and operations research. Examples are how to optimally schedule a set of jobs or tests, or how to optimally search for a hidden target.

The special track on *Uncertain Reasoning*, organized by Alessandro Antonucci, Salem Benferhat, and Kamal Premaratne, raised the issue that many applications are increasingly being challenged with how to deal with imperfect data of various kinds, managing and reasoning about uncertainty. This question is vital in almost all data-driven applications. Different models of uncertainty have been proposed ranging from classical Bayesian probability theory to more general models such as those based, among others, on belief functions and possibility measures. The goal of this special session was to discuss recent methodologies for managing, reasoning, and decision-making under uncertainty from these different perspectives.

Formalization in Mathematics organized by Gonzalo A. Aranda-Corral and Francisco Jesús Martin Mateos, emphasized that nowadays many processes are developed by autonomous systems that are designed to follow algorithms with a mathematical basis. The key to ensure the correctness of these processes is the formalization of underlying mathematical theory. Therefore, Formalization of mathematics can play a very important role in many areas, from the statement of simple theories to the verification of correctness for properties in complex algorithms and systems. Formalization of mathematics can be the main tool used to increase our confidence in the results. One extended paper from the session appears in this AMAI issue:

Cost-aware sequential diagnostics, by Bernhard Ganter, studies a simple search problem in which a binary n-tuple is to be found in a list, by sequential bit comparisons with cost. The problem can be solved (for small n) using dynamic programming. Ganter shows how the *bottom up* part of the algorithm can be better organized by means of formal concept analysis.

Special event: *Judea Pearl 85th Birthday Celebration*

A most interesting interview of Judea Pearl by Stephen Wolfram was held as a concluding event of ISAIM. Wolfram and Pearl's intellectual explorations and conversation will fascinate all who watch the 3-hour video, available at *https://www.youtube.com/watch?v=230PsGBxkCo*

Acknowledgements We would like to thank the ISAIM 2022 session organizers who put together the excellent program of lectures, and the speakers who met the challenges of online lecturing. We are happy to acknowledge the hard work by all authors who submitted papers to this AMAI issue, and our appreciation to the referees for their evaluations and recommendations that improved the selection to be enjoyed by readers. Finally, a huge round of applause goes to Dr. Maria Provost from Florida Atlantic University and to the computing team of the University of Oklahoma for much of the technical support needed to organize the symposium.