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Preface to the special issue on Analogies: from Mathematical Foundations to Applications and Interactions with ML and AI

Miguel Couceiro^{1,2*}, Esteban Marquer¹, Pierre Monnin³,
Pierre-Alexandre Murena⁴

¹*Université de Lorraine, CNRS, LORIA, Nancy, France.

²INESC-ID, Instituto Superior Técnico, Universidade de Lisboa, Lisboa,
Portugal.

³Université Côte d’Azur, Inria, CNRS, I3S, Sophia-Antipolis, France.

⁴Hamburg University of Technology, Hamburg, Germany.

*Corresponding author(s). E-mail(s): miguel.couceiro@loria.fr;
Contributing authors: esteban.marquer@loria.fr; pierre.monnin@inria.fr;
pierre-alexandre.murena@tuhh.de;

1 Motivation

Analogical reasoning is a remarkable capability of human reasoning, used to solve hard reasoning tasks. It consists in transferring knowledge from a source domain to a different, but somewhat similar, target domain by relying simultaneously on similarities and dissimilarities. Analogical reasoning is often rooted on analogical proportions, *i.e.*, statements of the form “A is to B as C is to D”, that are the basis of analogical inference. The latter are tightly related to case-based reasoning and to multiple machine learning tasks such as classification and decision making with applications in NLP, preference learning, logics, knowledge discovery and engineering. Also, they support a variety of downstream tasks, for instance, dataset augmentation, visual question answering, and other AI-related tasks.

This special issue follows the two workshops IARML¹ co-located with IJCAI-ECAI 2022 and ATA² co-located with ICCBR 2022, that targeted foundational and application aspects of analogical reasoning by bringing together AI researchers of various above mentioned fields as well as industrial practitioners with real-world applications.

2 Contributions

This special issue comprises five contributions that cover computational theories of analogical reasoning with applications in NLP and logic.

The first, *Learning from Masked Analogies between Sentences at Multiple Levels of Formality* is by Liyan Wang and Yves Lepage, and proposes the MaskPrompt method to infer sentence analogies by fine-tuning a pre-trained language model with different masking strategies: arbitrary, one-term, or target-oriented. This proposal outperforms a basic fine-tuning method. The paper also investigates the impact of various levels of formality for sentence analogies, that are defined using three formal criteria, namely Sentence Length Constraint, Word Distribution Postulate, and Edit Distance System of Equalities. Results highlight that analogies with relaxed formality capture implicit analogical regularities since their consideration in training leads to improved results on strict analogies.

The second, *Solving morphological analogies: from retrieval to generation* is by Esteban Marquer and Miguel Couceiro, and describes a deep learning framework to tackle solving analogical equations. The approach is applied to word morphology in more than 16 languages from the Sigalogies dataset, and outperforms the previous state of the art. The paper summarizes and completes a series of works on detecting and solving analogies with light weight neural network models, and doing so provides a comprehensive description of the framework: several embedding models, models to solve and detect analogies, and training criteria are compared, and a data augmentation procedure based on the axiomatic approach to analogical proportions is presented.

The third, *A study of universal morphological analysis using morpheme-based, holistic, and neural approaches under various data size conditions* is by Rashel Fam and Yves Lepage, where the authors present a new analogy-based method to address the morphological analysis task on the SIGMORPHON data set. They perform an experimental comparison of case-based and neural approaches, which shows that while state-of-the-art transformer-based neural approach outperforms case-based approaches on medium and large data sets, the latter outperform the former on small data sets.

The fourth, *Analogical proportions in monounary algebras* is by Christian Antić, and extends preliminary works of the author on an algebraic analysis of analogies. The previously introduced framework differs from existing mathematical formalizations of analogy by the fact that it does not rely on an axiomatic nor generative definition. This

¹<https://iarml2022-ijcai-ecai.loria.fr/>

²<https://icabr-ata2022.loria.fr/>

paper explores a specific domain for analogies, namely monounary algebras containing one single unary function.

The fifth, *Logic program proportions* is by Christian Antić, and describes how analogies can be used to generate logical programs. The paper is articulated around the idea that it should be possible to generate new programs by analogical mapping of a source domain (e.g. integers and addition of integers) to a partially known target domain (e.g. lists and concatenation of lists). The paper builds upon an algebraic formalization of analogies and is an alternative to existing techniques such as Inductive Logic Programming, which requires specifications for the form of the expected programs.

The editors would like to express their sincere thanks to the authors and reviewers of this volume. We are also indebted to the editor in-chief Professor Martin Golumbic and the whole editorial team of the *Annals of Mathematics and Artificial Intelligence* journal³ for their continuous help and support.

Lisbon, Portugal
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Miguel Couceiro
Esteban Marquer
Pierre Monnin
Pierre-Alexandre Murena

³<https://link.springer.com/journal/10472>