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ON THE COMPLEXITY OF ANALOGIES IN AI – COMMENTS ON PEDRO MONIZ LOPES[i]

SOBRE A COMPLEXIDADE DAS ANALOGIAS EM IA – COMENTÁRIOS SOBRE PEDRO MONIZ LOPES

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Abstract: In today's "algorithmic society," the proliferation of algorithmic and data-driven technologies offers significant benefits but also challenges traditional mechanisms of control. The dominance of a few Big Tech giants underscores the urgency for effective regulation, particularly in light of the platform economy and advancements in Artificial Intelligence. Initiatives like the European Union's Digital Markets Act aim to address antitrust concerns and promote fair competition. However, while efforts have begun to regulate the platform economy, AI remains a frontier requiring systematic legal responses, as highlighted by ongoing debates initiated by legal scholars such as Pedro Moniz Lopes. Achieving a delicate balance between fostering innovation and ensuring regulatory oversight is essential for navigating the complex landscape of emerging technologies in the digital age..

Keywords: Similarity, analogy, artificial intelligence, categories, perceptions

1. PI of the ERC STG HABITAT.

1. Introduction

Today we live in the "algorithmic society" (Balkin, 2018). On the one hand, algorithmic and data-driven technologies bring significant benefits (*e.g.*, reducing labor costs, improving security, faster trading, and more efficient communication platforms) and contribute to societal prosperity (EUROFUND, 2015; Huws, 2014). On the other hand, "[t]he speed, scope, and design-in opacity of the digitalization process has far outpaced and made obsolete ordinary social and legal process of control" (Postema, 2022: 263). These two interests must be balanced by governance models capable of managing the digital transformation accelerated by the pandemic and finding an optimal balance between innovation and fair competition.

Control over platforms and the digital economy is by and large concentrated in the hands of a few Big Tech giants operating in Silicon Valley – Meta, Alphabet, Amazon, Apple, Microsoft, and X – which, according to Postema, have become the "New Leviathans", i.e. the "centers of a new form of ruling power" (Postema 2022: 263). The rule of the New Leviathans lies in a system of autonomous, internal governance and "in their ability to influence the architecture of deliberation and decisions" of the individual (Postema 2022: 272).

The digital market, the platform economy, and, more recently, new developments in Artificial Intelligence (AI) pose major challenges for regulators. The recent EU regulatory framework introduced by the Digital Markets Act (DMA) is a good example of this phenomenon (Regulation (EU) 2022/1925). The DMA (applicable from the beginning of May 2023) is the EU"s latest antitrust regulation based on the ground-breaking "gatekeeper" system. The DMA introduces a set of objective criteria to qualify large platforms as "gatekeepers" and imposes strict antitrust obligations on them to strengthen competition. The inspiring principle is that with great power comes great responsibility. Conversely, smaller, or younger companies and start-ups – the outsiders of the digital market – are better protected. The purpose of the DMA is to promote a fair business environment for business users who depend on gatekeepers to offer their services in the Digital Single Market and to ensure competitiveness by removing barriers to entry for start-ups and smaller companies that are not subject to excessive and therefore unfair restrictions.

While both the EU and national governments have started to regulate the platform economy, AI still requires a systematic legal response. In April 2021, the European Commission proposed the first legal framework for AI (EUROPEAN PARLIAMENT, 2023), which includes various rules and obligations based on the level of risk posed by the new technology (unacceptable, high, and low). The AI law is also likely to include transparency requirements for generative AI (e.g., ChatGPT).

In recent years, legal philosophers such as Pedro Moniz Lopes have initiated a fruitful and most welcome debate on AI. In particular, the interesting and thought-provoking essay authored by Pedro Moniz Lopes proposes an analysis of analogical reasoning in AI that cannot be overlooked. Paragraph 2 of my contribution to this symposium offers a minimal definition of analogical reasoning in AI. Paragraph 3 argues that analogy in AI is best described as statistical reasoning about similarities that defy uniform treatment. This is the main point on which I disagree with Pedro Moniz Lopes. Finally, paragraph 4 offers a summary of the key arguments developed in my brief contribution.

2. Analogical Inferences and AI

Analogy is one of the most important cognitive processes for understanding, explaining, and – in a broader sense – thinking. Analogies are tools for knowledge transfer that serve to connect unknown objects (targets) with known objects (sources/prototypes) (Lamond, 2006). Thus, analogical thinking depends on the ability to generalize and categorize (Gick, Holyoak, 1980). Given a set of pairs of related objects S = {A1:B1,A2:B2, … ,An:Bn} – i.e. a sample containing pairs of related objects – analogy determines whether and how other pairs A:B fit into the set S.

Today, AI relies heavily on analogy-based reasoning to perform creativity and problem-solving tasks. AI models use analogies, for example, to establish new relationships between words or to project the relevant properties of previous knowledge onto new problems. NLP models generate new analogies based on training data. Of course, AI also produces "bad" results, but the accuracy of analogies generated by AI is increasing as this technology is rapidly evolving.

Pedro Moniz Lopes, in his excellent paper, focuses mainly on two categories of analogy models in AI: Case-Based Reasoning (CBR), which exploits retrieval processes, and Symbolic Models (SMT) – which are both rule-based and alignment-based (Gentner, Markman, 1997; Gentner et al., 2001). This distinction is certainly useful, but it would be more accurate to further unpack the AI models for the analogy in both CS and cognitive sciences.

There are other models that, to my knowledge, play an important role today: Conceptual Blending, based on cognitive linguistics (see e.g., Turney, Littman, 2005); Latent Semantic Analysis (see e.g., Evangelopoulos, 2013), Bayesian models, and neural networks, to name a few. Bayesian models and neural networks (namely, computational models inspired by the structure and functioning of biological neural networks) seem to be particularly promising: the former, based on probabilistic reasoning, are especially helpful in coping with uncertainty, belief revision, and context-dependent phenomena; the latter are highly effective in pattern recognition.

Certainly, these models are neither exhaustive nor mutually exclusive: one of the best ways to deal with analogies in AI is – and this should be emphasized – to combine multiple methods and develop new, more accurate models. This element may have been overshadowed by Pedro Moniz Lopes.

3. Analogy, Similarity, and Identity

At the beginning of his contribution, Pedro Moniz Lopes proposes a useful distinction between analogy, similarity, and identity; as he notes, analogy presupposes that there is no identity between two objects A and B. Both similarity and analogy map a set of shared properties between separate objects in order to draw conclusions and ultimately find correspondences.

However, analogies are more specific because they are used to transfer knowledge from one domain (the source) to another (the target). I believe that this is the most important feature of analogy, rather than its connection to a specific purpose, as Pedro Moniz Lopes suggests. In my view, the conceptual connection between analogy and purposive reasoning assumes too much. One can draw analogies indiscriminately without any purpose. Certainly, analogy presupposes similarity: to say that A is analogous to B, one must assume that A is like B or that A resembles B. The transfer of knowledge is justified by the fact that the target and source are considered similar in terms of properties, form, features, structure, function, behavior, color, pattern, etc..

There is an extensive literature on analogy and similarity in psychology and the cognitive sciences (see e.g., Goldstone, Kersten, 2003; Holoyak, Thagard, 1995; Medin, Schaffer, 1978; Palmeri, 1997; Smith, Medin, 1981; Tversky, 1977), which Pedro Moniz Lopes partially considers in his work; perhaps he pays less attention to the equally extensive literature that has emerged in CS, which is quite surprising, given the paper's focus on AI and metaphors (see e.g., Falkenhainer, Forbus, Gentner, 1989; Gentner, Markman, 1997; Hofstadter, Mitchell, 1995; Gentner, Holyoak, Kokinov, 2001; Veale, 2012). Also overlooked is the current discussion of analogy in NLP: and note that NLP models are generally considered more effective than classical CBR and SMT models in generating sound analogical relationships.

An important consideration might emerge from a comparison of the two literatures: while humans draw analogies based on intuitions, AI systems rely on statistical reasoning, suggesting a reduction of AI-based analogy to "statistical" similarities. This reasoning is anything but trivial.

In his paper, Pedro Moniz Lopes draws extensively on the inferential models of analogy developed within the theory of legal interpretation by Canale & Tuzet (2017) and a number of other authors. However, looking at the extensive literature in the field of AI, it is difficult to see how computer models and algorithms used by AI can be explained, translated, or reduced to the common philosophical concepts of abduction, induction, and the theories developed by philosophers of law, which seem insufficient to explain how analogy works in AI.

For example, the Bayesian framework for inferring analogies – which generates similarities and analogies based on estimating the probability of shared properties based on past priors, clustering, and complex probability functions – hardly translates into the simple language of a traditional abduction/induction model.

Bayesian probabilities and propensity scoring functions quantify the strength of analogical relationships, something that eludes the treatment of traditional abduction models. Similar considerations apply to the so-called "dense vectors" used to draw analogies and similarities in NLP.

Even a bird's eye view of the CS literature clearly shows the lack of a unified term for analogical inference. Bayesian models, for example, seem to reduce analogy to a complex inferential framework for deriving and measuring similarity relations and associations based on set values and Gaussian priors. In this model, analogical reasoning maps "latent functions" to the intersection $A \times B \rightarrow \{0, 1\}$. The similarity is a function of observing the priority distribution over the two functions f (A,B) and g (A,B). The first function f (A,B) quantifies the similarity of pairs linked by the second function g (A,B), which in turn classifies all pairs (Ai, Bi) ∈ S. In particular, the correspondence is given by a latent parameter vector and predicted by structural logistic regression algorithms. The complexity of this models clearly goes far beyond the schemes used by legal philosophers to map analogies in legal reasoning.

Finally, it appears that AI models also treat semantic similarities/analogies and shape similarities/analogies differently. Complex 3D objects are captured by vectors that extract and evaluate salient geometric and topographic features. Advanced methods of shape analysis, geographic information systems (GIS) and computer-aided design (CAD) are typically used for 3D shape matching (Vasic et al. 2022). As far as I know, 3D CAD and similar technologies do not use text-based AI or other tools for extracting dimensional features (vectors).

4. Tacking Stock

In CS, analogies are based on inferential patterns that radically differ from the ones used in legal reasoning. The complexity of the diverse statistical and predictive methods used by AI is extremely high and requires a different set of conceptual tools. This is further evidence in favor of the claims that: *first*, analogies escape unitary treatment; *second*, analogy in CS is not so different from similarity.

References

Balkin J. Free Speech in the Algorithmic Society: Big Data, Private Governance, and New School Speech Regulation. UC Davis Law Review. 51(3) 1149; 2018
Canale D., Tuzet, G. Analogical Reasoning and Extensive Interpretation. ARSP. 103(1) 117; 2017

EUROFUND. New Forms of Employment. Luxembourg: Publications Office of the European Union; 2015

EUROPEAN PARLIAMENT. EU AI Act: First Regulation on Artificial Intelligence. (08/06/2023). https://www.europarl.europa.eu/topics/en/article/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence; 2023

Evangelopoulos NE. Latent semantic analysis. Wires-Cogn Sci. 4(6) 683; 2013

Falkenhainer B, Forbus KD, Gentner D. The Structure-mapping Engine: Algorithm and Examples. Artificial Intelligence. 41(1) 1; 1989

Gentner D, Markman AB. Structure Mapping in Analogy and Similarity. American Psychologist. 52(1) 45. 1997

Gentner D et al.. Metaphor is Like Analogy. In: Gentner D, Holoyoak KJ, Kokinov BN, editors. The Analogical Mind: Perspectives from Cognitive Science. Cambridge (MA): MIT Press; 2001. pp 199-253.

Gick ML, Holyoak KJ. Analogical Problem Solving. Cognitive Psychology. 12(3) 306; 1980

Goldstone RL, Kersten A. Concepts and Categorization. Boston (MA): MIT Press; 2003

Hofstadter DR, Mitchell M. The Copycat Project: A model of Mental Fluidity and Analogy-Making. AAAI Technical Report. WS-95-01; 1995

Holyoak KJ, Thagard P. Mental Leaps: Analogy in Creative Thought. Boston (MA): MIT Press; 1995

Huws U. Labor in the Global Digital Economy: The Cyebertariat Comes of Age. New York: Monthly Review Press; 2014

Lamond G. Precedent and Analogy in Legal Reasoning."Stanford Encyclopedia of Philosophy ; 2006 http://plato.stanford.edu/entries/legalreas-prec/

Medin DL, Schaffer MM. Context Theory of Classification Learning. Psychological Review. 85(3) 207; 1978

Palmeri TJ. Exemplar Similarity and the Development of Automaticity. J Exp Psychol Learn Mem Cogn. 23(2) 324; 1997

Postema G. Laws Rule. The Nature, Value, and Viability of the Rule of Law. Oxford: Oxford University Press; 2022

Smith EE, Medin DL. Categories and Concepts. Boston (MA): Harvard University Press; 1981

Turney P, Littman M. Corpus-based Learning of Analogies and Semantic Relations. Machine Learning Journal. 60 251; 2005

Tversky A. Features of Similarity. Psychological Review. 84(4) 327; 1977

Vasic I et al.. A Method for Determining the Shape Similarity of Complex Three-Dimensional Structures to Aid Decay Restoration and Digitization Error Correction. Information, 13(3) 145; 2022

Veale T. Exploding the Creativity Myth: The Computational Foundations of Linguistic Humor. London: Bloomsbury Publishing; 2012

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