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Anticipative Preduction And Automated Scientific Discovery

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1. Titolo del primo paragrafo (nel caso servisse, può andare su due righe)
2. Titolo del secondo paragrafo
3. Titolo del terzo paragrafo
4. Titolo del quarto paragrafo

ABSTRACT. My aim in this contribution is to introduce preduction as a deductive discovery practice in the methodology of theoretical physics. Preduction complements Charles Peirce's view that only via abduction are new ideas introduced into science. Moreover the automation of ampliative inferences in the field of Computational Discovery of Scientific Knowledge encourages the hypothesis of computational preduction.

1. Introduction

Throughout the twentieth century, philosophers of science have to a great extent neglected the issues relating to the context of scientific discovery. Popper's anathema towards the philosophical analysis of the ways in which new ideas enter science, as well as his negative solution to the logical and methodological problem of induction, may have contributed to an ignorance of the context of discovery in the methodology of science. Most philosophers have consequently ignored the creative role played in the observational natural sciences by ampliative inferences such as induction and abduction. Moreover the consolidation of the hypothetic-deductive method in the methodology of science in the twentieth century has ironically contributed to the neglect of the significance of deductive reasoning in the context of discovery. As Peter Medawar acknowledged in "Hypotheses and Imagination", his contribution to

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Schilpp's volume dedicated to Karl Popper, the "disclaiming any power to explain how hypotheses come into being" was a sign of the weakness of hypothetic-deductivism.

In this paper I will argue that deductive reasoning can be extended to the context of discovery of theoretical natural sciences such as mathematical physics. I use the term theoretical preduction to describe the method of reasoning which consists in the implementation of deductive reasoning in the context of scientific discovery. My aim will be to show the role that preduction plays in the methodology of physical sciences. I claim that preduction is a method of reasoning that, starting from the available theoretical background as a whole, allows for the anticipation of new results, provided that the combination and mathematical manipulation of the previously accepted results of different disciplines of theoretical physics –those which have been taken as premises of the preductive reasoning– are compatible with dimensional analysis. I affirm that this is the way in which many factual hypotheses, laws, and theoretical models are postulated in physics.

Preduction anticipates still-unknown ideas in physics via the combination of previously accepted results of different disciplines or theories of mathematical physics. Since these results, which are the premises of preductive reasoning, proceed from different theories, preduction represents transverse or intertheoretical deduction. This is what makes it possible to anticipate new ideas in physics.

In the final part of my paper I address the question of discovery from the point of view of machine discovery theory. Since the 1970s, despite the neglect of the scientific discovery by most academic philosophers of science, the field of computer-supported scientific discovery has attracted the attention of scientists working in the domain of artificial intelligence and knowledge acquisition, meaning that the field of computational discovery of scientific knowledge has become increasingly relevant and fruitful. Indeed, according to Shrager and Langley (1990:1): "Whereas early work in the philosophical tradition emphasized the evaluation of laws and theories (e.g., Popper 1965 [Conjectures and Refutations]), recent research in the paradigm of cognitive science has emphasized scientific discovery, including the activities of theory formation, law induction, and experimentation. Moreover, the early philosophical approaches focused on the structure of scientific knowledge, whereas recent work has focused on the process of scientific thought and on describing these activities in computational terms." Thus once ampliative inferences like induction and abduction have been implemented in the field of machine learning, the next step will encourage the computational hypothesis of theoretical preduction.

Computational preduction amounts to automating preduction mechanisms. This possibility complements any already existing computational methods for the automation of scientific discoveries. Automated preduction would facilitate the anticipation of new results in theoretical physics. The philosophy of science invites the discovery science to begin with the possibility of automated preductive discovery in theoretical sciences such as mathematical physics.

2. Theoretical Preduction

For the sake of the argument I turn to Charles Peirce (CP, 5.145): "Induction can never originate any idea whatever. No more can deduction". I disagree with him that "All the ideas of science come to it by the way of abduction." (CP, 5.145). Thus my main question is: can deductive reasoning be used in the context of scientific discovery? My answer will be: Yes, it can.

I maintain that in the methodology of theoretical physics, we can extend deductive reasoning into the context of discovery, beyond its ordinary uses in the context of hypotheses testing. This is possible because theoretical physics uses mathematics as an indispensable tool. Theoretical physicists apply at will Leibniz's principle of substitutio salva veritate: dimensional analysis guarantees substitutio salva legalitate, i. e. the legitimacy of the undertaken substitutions. Thus a new form of reasoning in scientific methodology becomes recognizable. I call it theoretical preduction or simply preduction.

Preduction is a method of reasoning that begins with previously accepted results of the available theoretical background. It consists in resorting to the available results of theoretical physics as a whole, in order to anticipate new ideas by mathematical combination and manipulation, compatible with dimensional analysis, of the available results, although not every combination need be heuristically fruitful. The results postulated methodologically as premises of an inferential procedure proceed from different theories, and any accepted result can serve as a premise –on the understanding that accepted does not imply accepted as true. This suggests the notion of a hypothetic-deductive method. Indeed, preduction is an implementation of the deductive way of reasoning. The specificity of preduction is that it is an extension of deductive reasoning to the context of scientific discovery.

In a natural way physicists apply preductive reasoning in order to anticipate as yet unavailable ideas. Stellar astrophysics can be considered paradigmatic for the application of preductive reasoning. The British physicist Arthur S. Eddington (1926:1. My italics, A. R.) affirms, for instance, that although "At first sight it would seem that deep interior of the sun and stars is less accessible to scientific investigation than any other region of the universe…, the interior of a star is not wholly off from such communication. A gravitational field emanates from it …; further, radiant energy from the hot interior after many deflections and transformations manages to struggle to the surface and begin its journey across space. From these two clues alone a chain of deduction can start, which is perhaps the more trustworthy because it is only possible to employ in it the most universal rules of nature –the conservation of energy and momentum, the laws of chance and averages, the second law of thermodynamics, the fundamental properties of the atom, and so on. There is no more essential uncertainty in the knowledge so reached than there is in most scientific inferences." And Dale A. Ostlie & Bradley W. Carroll (1996: 590.My italics, A. R.) claim, with regard to the Chandrasekhar limit formula for the mass of white dwarfs: "This formula is truly remarkable. It contains three fundamental constants – , c, and G– representing the combined effects of quantum mechanics, relativity, and Newtonian gravitation on the structure of a white dwarf." These quotations confirm that, if we wish to postulate theoretical models in stellar astrophysics, we have to combine available relevant results from different disciplines of theoretical physics, so as to derive an equation, or a set of coupled equations, relating to the phenomenon under investigation.

As a matter of fact the discovery of the interior structure of main sequence stars amounts to preducing a theoretical model of the stellar interiors. This model consists of five basic differential equations: pressure, mass, luminosity and temperature (twofold) gradients (Cfr. Ostlie & Carroll 1996: Chapter 10). From a methodological viewpoint the most interesting equations of this theoretical model are the equations of hydrostatic equilibrium and of temperature gradient.

The idealisations needed for hydrostatic equilibrium are that of a spherically symmetric and static star. The corresponding preductive procedure consists in the combination of three theories: Newtonian mechanics (second and third laws, and the universal gravitation law), classical statistics mechanics (the Maxwell-Boltzmann distribution of the ideal gas pressure), and quantum physics (Planck's radiation law of the radiative pressure of a black body).

The idealisations, assumed for the obtaining of the temperature gradient, are also that of a static sphere with black body conditions plus the conditions of adiabatic expansion. The corresponding preductive procedure consists in the combination of three disciplines: classical physics for the temperature gradient of radiative transfer (combination of the equation of radiative transfer with the equation of the black body radiation pressure), and classical statistical mechanics and thermodynamics of adiabatic processes (for the obtaining of the temperature gradient of a gas expanding adiabatically).

A complete account of the theoretical model of stellar interiors should be completed with the mass conservation equation and the equation of the luminosity gradient, with the latter depending on the energy generated both by nuclear and gravitational processes.

Preductive reasoning differs from abduction, and from any ampliative inference, in that the preduced results do not proceed from empirical data, but rather follow from deductive reasoning starting from the available accepted theoretical background taken as a whole. As the premises of preductive inferences are accepted results of different theories, or even different disciplines of theoretical physics, preduction is transverse or inter-theoretical deduction. This makes it possible to introduce deductively new ideas into physics. (Cfr. Rivadulla 2010).

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3. Computational Preduction

The computational study of science brings into evidence the lack of imagination of many academic philosophers of science, including both the propositivist Hans Reichenbach and the anti-positivist Karl Popper, who neglected the importance of the context of scientific discovery in favour of the context of justification. The ignoring of scientific discovery left the field open for researchers into cognitive science and artificial intelligence for the development of the computational study of science. Indeed, Shrager and Langley (1990: 20) acknowledge: “This chapter has attempted to define a new field of study –the computational modeling of scientific behavior. Despite its relatively recent development, this research area has already made significant progress on issues that philosophers of science have traditionally ignored. In particular, the field has emphasized the nature of discovery rather than evaluation, and it has dealt with the processes that underlie science as well as the representation of knowledge. The result has been a rapidly growing set of computational models that deal with many facets of the scientific enterprise.”

Computational science is a branch of cognitive science and of artificial intelligence that aims at constructing science by computational means.

This defines the field of computational research on scientific discovery, which means "research on computational models of scientific discovery", i.e. the construction of "detailed computational models of the acquisition of knowledge in scientific domains." (Shrager & Langley 1990: 1-2)

Indeed, the implementation of AI methods for the discovery of scientific knowledge permits the automation of inductive and abductive inferences. In the past thirty years, machine learning scientists have provided us with computational systems that implement the rediscovery of many empirical laws of chemistry and physics, the automated discovery of equations in data bases, etc. Systems such as Bacon, PI, Dendral, Echo, IDS, Lagramge, Fahrenheit, etc. have been designed and applied for empirical discoveries. The philosophers Herbert Simon and Paul Thagard and the computational scientists Pat Langley, Jeff Shrager, Bernd Hordhausen, Brian Falkenhainer, Raúl Valdés and Jan Zytkow, among others, have contributed to a general optimism about the possibility of automated inductive and abductive scientific discovery. The computational hypothesis of theoretical preduction is tantamount to assuming the possibility of automating preduction mechanisms. The achievement of computational preduction is a task that must be carried out by computational scientists. The role of the philosopher of science now is to point to an as yet unexplored possibility, namely that the research on computational models or systems of scientific discovery must be extended beyond ampliative inferences such as induction and abduction, and into the realm of anticipative inferences like theoretical preduction. This is the content of the computational hypothesis of theoretical preduction. If this hypothesis is worthy of consideration, then it is down to computational scientists whether or not they develop the powerful deductive reasoners which are capable of putting it into practice.

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REFERENCES

EDDINGTON A. (1926), The internal constitution of stars, Cambridge: University Press.

OSTLIE D. A. & CARROLL B. W. (1996), An Introduction to Modern Stellar Astrophysics, Reading, MA: Addison-Wesley.

PEIRCE C. S. (1965), Collected Papers. Cambridge, MA.: Harvard Univ. Press.

RIVADULLA A. (2010), "Complementary Strategies in Scientific Discovery: Abduction and Preduction". In Bergman, M., Paavola, S., Pietarinnen, A., & Rydenfelt, H. (eds.), Ideas in Action: Proceedings of the Applying Peirce Conference. Nordic Studies in Pragmatism 1. Helsinki: Nordic Pragmatism Network, pp. 264-276.

SHRAGER J. and LANGLEY P. (1990): "Computational Approaches to Scientific Discovery". In Jeff Shrager & Pat Langley, Computational Models of Scientific Discovery and Theory Decision, San Mateo, California: Morgan Kaufmann Publishers.