# Applications of Mathematics in Models, Artificial Neural Networks and Arts

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Editors

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Mathematics and Society

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# Preface

The story of this book begins with the conference of 8–9 December 2007 entitled "Mathematics and Society" celebrating the 40 years of *Quality and Quantity, International Journal of Methodology* founded in 1967, under the auspices of Paul F. Lazarsfeld, by editor Vittorio Capecchi and co-editor Raymond Boudon. The journal at present is published by Springer Science & Business Media, Dordrecht. The editor is Vittorio Capecchi, the co-editors are Raymond Boudon and Massimo Buscema. It is a bimonthly publication and it is available online. In the first 10 years, *Quality and Quantity, International Journal of Methodology*published articles by authors writing from Europe and the United States, but in the last 10 years, a growing number of authors who present essays with mathematical models are living in Asia.

The conference of 8–9 December was promoted by the University of Bologna (at the conference, chancellor Pier Ugo Calzolari was present) and the AIS (Italian Association of Sociology) with Departments of Education, Mathematics and Natural and Physical Sciences and the Faculty of the Sciences of Education of the University of Bologna and with the Publishing House Springer (Myriam Poort was present). The success of the conference has produced the original project of this book edited by Vittorio Capecchi with Massimo Buscema, Pierluigi Contucci, Bruno d'Amore.

The book presents a historical introduction (by Vittorio Capecchi) followed by three parts. In the first part *Mathematics and Models* (coordinated by Pierluigi Contucci), mathematical models to study society elaborated in Department of Mathematics and Physics are compared to others that were elaborated in Department of Sociology and Economics. In the second part *Mathematics and Artificial Neural Networks* (coordinated by Massimo Buscema), the applications of ANNs to the social sciences are analysed in several directions and in the third part *Mathematics and Art* (coordinated by Bruno D'Amore), the essays explore the ways in which mathematics and arts relate each other.

In historical introduction, Capecchi analyses in what manner the relation between mathematics and sociology has changed. Three phases are presented: (1) Paul F. Lazarsfeld's choices concerning theory, methodology and mathematics as applied to sociological research; (2) the relations between mathematics and sociology from statistical methods to artificial society and social simulation models; (3) the new possibilities offered to sociology though by artificial neural networks. Then the

changes in the methodological problems linked to the relation between mathematics and sociology are analysed together with the changes in the most important paradigm utilized in sociological research, namely the paradigm of objectivity; the paradigm of action research/co-research and the paradigm of feminist methodology. At the end of the introduction, some new possible synergies are presented.

The first part of the book coordinated by Pierluigi Contucci deals with models coming from the community of mathematicians and physicists as well as from scholars in sociology, economy and cognitive psychology. The leading theme of the mathematical–physical approach concerns the identifications of those model features which are responsible for the collective behaviour as derived from individual contribution for large numbers of them. The paper by P. Contucci, I. Gallo and S. Ghirlanda studies the effect of the interaction between two cultures and the possible scenarios appearing including the phase transitions. The methods used are those coming from statistical mechanics. The paper by Bolina gives a transparent introduction to the statistical mechanics general methods for those readers who are not familiar with that discipline. The paper by F. Gallo et al. applies the method introduced in the previous papers to the study of the climate change and energy virtuous behaviour especially oriented to the recommendation to public policy makers. The paper by A. Borghi et al. explains the necessity of embodied models in cognitive psychology. The paper by Robert Smith (Social Structural Research, Inc., Cambridge, MA) presents the possibility to analyse with stronger mathematical models *The Academic Mind* by Paul F. Lazarsfeld; Simone Sarti and Marco Terraneo (University of Milano-Bicocca) apply a multilevel regression technique to validate a social stratification scale; Claudio Gallo (Crs4, Cagliari) discusses the mathematical models of financial markets.

The second part of the book, coordinated by Massimo Buscema, presents essays by the Semeion Group (Massimo Buscema, Giulia Massini, Guido Maurelli, Stefano Terzi) and by Enzo Grossi (Bracco SpA, Milano), Pierluigi Sacco (IUAV, University of Venezia), Sabina Tangaro (Istituto Nazionale Fisica Nucleare, Bari). Artificial adaptive systems (AASs) are a new area of the modern applied mathematics. The main goal of AAS is to generate models from data. So, AASs are systems able to make the different models explicit, hidden in the real world. To do that, AASs present a set of specific features:

1. AASs are completely data driven or more precisely, the less the free parameters they have to presume, the better.
2. AASs generate a specific model only during their active interaction with the data. So they are bottom-up systems and they produce a data model as an end point of an iterative and a feedback loop process. This means that the final model of the data emerges automatically during the process itself. Consequently, they are dynamic systems, where the time of their learning and/or evolutionary process is part of the final model.
3. During their learning and/or evolutionary process, they process all the variables of the data in parallel. So, at the end of this process, each variable has been

defined by its global interaction with all the others (many-to-many relationships); so, theoretically, every order of variable interaction should be coded.
4. AAS has to be able to code all the consistent non-linearity hidden in the data.
5. During the learning and/or the evolutionary process, both the variables and the records (points) of the data set work as agents. This means that they interact in active way among them and with the basic parameters of the AAS equations.
6. AAS, to be validated, has to follow specific validation protocol and procedures, very similar to the procedures used in experimental physics.

In this part of the book we show new AAS algorithms, recently designed in AAS basic research, and their experimental application in real–world problems: bio-medicine and security.

These two applicative fields seem to be uncorrelated. Partially this is true. And so the application of the same algorithms to different areas is a good test to prove their capability to be really "data driven". From another point of view, bio-medicine and security are linked; both represent tough real problems, wherein the gold standard is very often grounded. Consequently, it is easy to analyse the performances of our AAS. Bio-medicine and security are also very sensitive "ethic" subjects; in the first, we try to defeat the disease, in the second one, we try to cope with violence and illegality, an impressive social disease.

The third part of the book, coordinated by Bruno d'Amore, presents essays on the relation between mathematics and art. Amongst the most widespread convictions, and not only in a low cultural profile perspective, there is the following: art (in all of its aspects, but here I will focus on figurative art) is the reign of freedom and fancy, whereas mathematics is that of formalism and rigour.

This approach refers to a position according to which we are dealing with two opposite worlds, with no cultural unity. Nevertheless the aforementioned four terms (freedom and fancy, formalism and rigour) do have common deep ties and are all produced by human beings, by their need to create and communicate.

Since the Renaissance there are examples of artists–mathematicians in which such terms are indissolubly bound, reinforcing each other; it is well known that Albrecht Dürer travelled in Italy to gain knowledge of the "scientific" art, widespread in the Peninsula and not yet in Bavaria, and to take courses as a geometry student at the *Alma Mater;* without rigorous knowledge, he said, art is an empty fancy and a blindly accepted practice.

Freedom and fancy must lay on a rigorous basis that gives them *sense*; otherwise it is *ignis fatuus*, uselessness, illogical. On the other hand, today it is well known that the first gift required by any high-level mathematician is fancy. Several mathematicians stated that a person quitted mathematics and became a poet (or a painter) because he or she was not fancy enough. Furthermore, when we say that a chess player plays with fancy, we do not mean he or she does not follow the rules of that game strictly but that he or she follows them conceiving unexpected and creative strategies.

We do not want to astonish the reader with these statements; in fact, we just want to convince the few that should still be so naive to believe these trivial dichotomies.

So if it is true, as it is, that many artists in centuries (more and more often at the present time) turned to mathematics as a source of inspiration or as an object of their pictorial practice, it is also true that many mathematicians (more and more often at the present time) did not despise to look at figurative art, with very different means, instruments and objectives, as an interesting and significant field of research and cultural speculation.

We tried to reproduce here the variety of these approaches. Bruno d'Amore (his essay is about mathematics and figurative art) has invited the following colleagues to discuss them from many points of view that are perfectly entangled, but each of them following specific and distinct lines, hoping to offer a significant variety of such interests: Igino Aschieri and Paola Vighi (University of Parma), From Art to Mathematics in the Paintings of Theo van Doesburg; Giorgio Bagni (University of Udine), Mathematics, Art, and Interpretation: A Hermeneutic Perspective; Giorgio Bolondi (University of Bologna), Points, Line and Surface. Following Enriques and Kandinsky; Michele Emmer (University of Roma I), Visibili armonie: The Idea of Space from "Flatland" to Artistic Avant-garde; Franco Eugeni and Ezio Sciarra (University of Teramo), Mathematical Structures and Sense of Beauty; Monica Idà (University of Bologna), Visual Impact and Mathematical Learning; Marco Pierini (University of Siena), Art by Numbers. Mel Bochner, Roman Opalka and other Filaritmici; Aldo Spizzichino (CNR of Bologna), My Way of Playing with the Computer; Gian Marco Todesco (Digital Video SpA), Four-Dimensional Ideas.

The essays presented in these three parts are interesting not only for their contribution to mathematical methodology and to the methodology of social research but also for other two important directions of action research: (1)technological innovations regarding the quality of life (climate changes through efficient energy, mathematical models against criminality, mathematical models for medicine and so on) and (2) technological innovations for creativity (the papers of the section *Mathematics and Art* are in the direction of projects as the *Creative Cities Network* of UNESCO).

Finally this book is useful not only for those who make use of mathematics in the social sciences but also for those who are engaged in the diffusion of technological innovation to improve life quality and to spread creativity in all directions of the arts.

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