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Yoshitsugu Oono

The Nonlinear World

Conceptual Analysis and Phenomenology

 Springer

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ISSN 0172-7389
ISBN 978-4-431-54028-1 ISBN 978-4-431-54029-8 (eBook)
DOI 10.1007/978-4-431-54029-8
Springer Tokyo Heidelberg New York Dordrecht London

Library of Congress Control Number: 2012951556

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Typesetting: Camera-ready by author

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

This book explains a certain way of appreciating “the world filled with non-linearity.” Its core is conceptual analysis and phenomenology, which is backed up by renormalization philosophy. The main target of the book is young people who have just started to appreciate the world seriously. The author wishes the book to be helpful also for those who have been observing the world, but who wish to appreciate it afresh from a different angle.

The most important feature of the nonlinear world is that disparate space–time scales (e.g., macroscopic and microscopic scales) can interfere with each other. Consequently, events of the world directly observable on our own space–time scale are, generally speaking, not closed within themselves. That is, to understand a phenomenon occurring within our human space–time scale, we must often take into account the things happening at space–time scales disparate from ours. It is usually the case, however, that we cannot know what is actually going on at scales far from the ones we can directly observe. The so-called chaos clearly exhibits consequences of this intrusion of the unknowable (at small scales) into the world we experience directly. These intrusions of the unobservable into our directly observable world make the world we wish to comprehend not self-contained. Thus, nonlinearity generates various phenomena that are difficult for us to comprehend. We cannot know everything we need to in order to understand the world in terms of its fundamental laws (even if they exist).

If we wish to understand the world clearly, its description must be precise in terms of unambiguous words. Phenomena we have not understood clearly will demand novel concepts and terminologies to describe them. Trying to characterize the key concepts relevant to a not-yet-comprehended phenomenon may well be the better part of its study. Thus, ‘conceptual analysis,’ an attempt to make intuitively grasped concepts clear, is crucial. Needless to say, conceptual analysis is always important in any serious study. Therefore, this book begins its main body with the conceptual analysis, following an

introductory Chapter 1 that outlines the significance of ‘nonlinearity.’

If the unknowable of, e.g., the microscopic world, affects the world we directly experience, it is not always possible to understand what we observe solely in terms of the so-called fundamental principles. We are accustomed to trying to understand a phenomenon in terms of well-established microscopic fundamental laws, but this need not be a suitable strategy to understand a typically nonlinear phenomenon. That is why we need a method to rationalize what we observe without referring to ‘fundamental laws.’ This is ‘phenomenology.’ The understanding of the world we wish to attain must not only be clear, but also be general enough. In other words, we are not interested in understanding only a particular system, but wish to reach some level of universal understanding applicable to a class of phenomena. However, the reader will realize that not every phenomenon allows us to attain understanding with some universality; only the phenomenon whose ‘good phenomenology’ may be constructed allows that. Accordingly, in Chapter 3, after surveying general characteristics of phenomenology and its typical examples, ‘renormalization group philosophy’ is explained as a means to extract phenomenology, and in Chapter 4, modeling is explained as a means to express the accomplished phenomenological understanding.

Because very different space–time scales entangle and interfere with each other in the nonlinear world, not only chaos but also other well-known peculiar phenomena such as critical phenomena occur. This book only utilizes such phenomena for the sake of illustration and does not aim to explain them in detail. The chief purpose of the book is to advocate a particular stance to appreciate the world. Consequently, standard technical topics such as bifurcation theory will not be discussed in this book at all.

Nonlinearity is indispensable to create a complex system, so numerous books discussing nonlinearity also try to discuss ‘complex systems.’ Even the present book is no exception, since its last chapter is entitled “Toward Complexity.” However, the book is different from other such books in the respect that it clearly explains the distinction between the study of complexity and so-called complex systems studies. It will become clear to the reader that studying complex systems leads us to reflect critically upon the nature of so-called fundamental science. The ultimate goal of genuine complex systems studies must be, from the point of view of this book, to accomplish conceptual analysis of complexity and to construct a phenomenology of complex systems. The last chapter outlines preliminary efforts toward this goal.

The author belongs to a physics department and has always wished to be a student of fundamental physics. A fundamental physicist is a person who pursues ‘good ways’ to understand an object under study, whatever it may be. Here, ‘good ways’ imply the ‘right frameworks’ (‘right coordinate systems,’ metaphorically) that allow us to understand the object simply and clearly. A fundamental physicist is the kind of person who thinks she is stupid

if she cannot find ‘good ways.’ Biology is so called because it studies biological systems, and chemistry is so called because it studies chemical substances and reactions. Physics is also regarded as a discipline to study the so-called physical world. However, this view is oblivious of the original meaning of *Physica*, which is the study of nature in general. Physics should not restrict its research topics; everything in nature is fair game.

There must be readers who claim that the basic framework explained in the book cannot be general enough for unbiased appreciation of the world; it is only enough for the fundamental physicists’ way of appreciating the world. It is the author’s firm belief, however, that the way of appreciating the world acquired through fundamental physics is sufficiently universal and is an important part of human culture.

“The way of appreciating things” would be, if perfected, mathematical for objects and phenomena that permit clear description in words. However, being mathematical need not mean being technical. In contrast to the ordinary books devoted to nonlinear science, in this book technical topics will be kept to a minimum. We can appreciate music without much understanding of musical grammar. Without listeners with good taste, no sophisticated musical culture would be sustained, but these listeners need not be familiar with musical grammar. Mathematical and science culture would be similar. Therefore, the book does not emphasize tools and techniques.¹ Some parts may be, however, mathematically rather heavy, but in such cases there are suggestions on how to skip or browse through complicated passages.

The aim of this book is to present a certain “way to think,” so inevitably many topics and subjects outside physics must be discussed. The author firmly believes that there should not be the so-called two cultures.² Therefore, this book has comments, remarks and footnotes that may urge natural scientists to pay some attention to topics of the humanities.³ The author wishes to count the people on the humanities side among the readers, but

¹ Some of the more detailed explanations of tools and techniques as well as actual examples will be given in the supporting website as noted below.

² **«The two cultures»** “A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is about the scientific equivalent of: *Have you read a work of Shakespeare’s?*” (C. P. Snow, *The Two Cultures and the Scientific Revolution*, The Rede Lecture 1959 (Cambridge University Press, 1961) pp15-16). (However, the reader must be critical about whether Snow’s understanding of thermodynamics is sound enough.)

³ This is an example of such footnotes. This book has many long footnotes. The reader may only browse through such footnotes, regarding them as “boxed notes.”

«On scientists, Ortega said» “That is to say, modern science, the root and symbol of our actual civilization, finds a place for the intellectually commonplace man and allows him to work therein with success. The reason of this lies in what is at the

free use of elementary mathematics in this book probably requires the writing of another book more suitable for a wider audience. However, even if no single formula in this book is comprehended, still a considerable portion of the discourse should be understandable; the reader could browse through only provocative footnotes.

Is this a kind book for students learning natural sciences? The book is for those who wish to reconsider very basic topics. Consequently, it demands some discipline and patience on the readers' side. However, even if early chapters are not understood well, still the remaining parts should make considerable sense. The main ideas of the chapters are related, but can be read almost independently. Chapter 2 is, however, more mathematical than the other chapters, so reading it lightly and going to subsequent chapters might be a wise first reading. Needless to say, Chapter 2 cannot be totally irrelevant to the subsequent chapters. Technical terms and concepts explained in Chapter 2 appear in the subsequent chapters. This chapter also prepares the reader to look at the so-called complex systems studies critically. Reviewing certain parts of Chapter 2 later when needed may be practical.

This book is based on the lecture notes for a special course the author gave at Keio University (Yokohama, Japan) in the summer of 1996 as Toshiba Chair Professor. The course was sponsored by the Toshiba Corporation. The zeroth version was prepared (in English and in Japanese simultaneously) toward the end of the last century, taking into account comments from Shin-ichi Sasa, Ken Sekimoto, Yoichiro Takahashi, Hal Tasaki, and Ichiro Tsuda. Then, a set of lecture notes in English was prepared for a University of Illinois at Urbana-Champaign (UIUC) special physics course. Based on it, a book in Japanese was constructed with the last chapter added, which is based on the commentary portion of the lecture notes called *Integrative Natural History*

same time the great advantage and the gravest peril of the new science, and of the civilization directed and represented by it, namely, mechanisation. A fair amount of the things that have to be done in physics or in biology is mechanical work of the mind which can be done by anyone, or almost anyone. For the purpose of innumerable investigations it is possible to divide science into small sections, to enclose oneself in one of these, and to leave out of consideration all the rest. The solidity and exactitude of the methods allow of this temporary but quite real disarticulation of knowledge. The work is done under one of these methods as with a machine, and in order to obtain quite abundant results it is not even necessary to have rigorous notions of their meaning and foundations. In this way the majority of scientists help the general advance of science while shut up in the narrow cell of their laboratory, like the bee in the cell of its hive, or the turnspit in its wheel." [José Ortega y Gasset, *The Revolt of the Masses* (Norton & Co., New York 1932) p110-111]. "The most immediate result of their *unbalanced* specialisation has been that today, when there are more 'scientists' than ever, there are much less 'cultured' men than, for example, about 1750." (p113) "The majority of men of science have given themselves to it through fear of facing life. They are not clear heads; hence their notorious ineptitude in the presence of any concrete situation." (p157)

(for the courses given at UIUC, Keio, and Waseda).⁴ On this occasion detailed criticisms/corrections supplied by Hal Tasaki, Hayato Chiba, Masahiko Todoroki, Tohru Tsujishita, and Seiichiro Honjo (in chronological order) and further comments of Hisao Hayakawa, Kuni Kaneko, Yoichiro Takahashi, and Akira Shimizu were incorporated. This present volume is also based on the same source as the Japanese book, but several comments by the editor of the Japanese book, Junsei Kishi, were utilized. The explanation of the proto-normalization group approach was composed with the help of Yasuhiro Shiwa. Encouraging philosophical discussions with Piet Hut and useful comments of Phil Baldwin are gratefully acknowledged.

At the end of the Foreword to *Homo Ludens*⁵ Huizinga wrote in June 1938, “In treating of the general problems of culture one is constantly obliged to undertake predatory incursions into provinces not sufficiently explored by the raider himself. To fill in all the gaps in my knowledge beforehand was out of the question for me. I had to write now, or not at all. And I wanted to write.”

So did the author.

Urbana, Illinois, USA, September, 2011

Yoshitsugu Oono

⁴ A short version of the commentary portion is published in *Physics of Self-Organization Systems* (S. Ishiwata and Y. Matsunaga, editors, World Scientific, 2008).

⁵ J. Huizinga, *Homo Ludens, a study of the play-element in culture* (Beacon Press, 1950; based on the German original and the author’s translation).

How to Read This Book

The book intertwines general discussions, more technical discussions with formulas, and rather technical explanations. Although some technical topics are relegated to appendices to sections and chapters and fine-lettered notes, still many heavy parts remain in the main text, which the readers seeking an overview may wish to skip. Therefore, ‘jumping guidance and instructions’ are explicitly written at various strategic positions to facilitate easy browsing. These instructions are in italic in the text.

The reader will realize that most pages have footnotes and some of them are long, even with titles surrounded by $\langle\langle \rangle\rangle$. As stated earlier many of the footnotes especially with titles may be read as ‘boxed’ articles without referring to the main text. Thus, skimming only footnotes may be one way to read this book.

The book has an accompanying support webpage as stated below, where errata as well as additional and augmenting material and updating information may be found. Long materials such as a detailed introductory ε -expansion calculation are posted there. Also useful comments from the readers will be gratefully posted with explicit acknowledgment of the contributors.

The following explanations repeat the key points.

Footnotes

As already noted this book has numerous footnotes, some of which are quite long. Some readers may find them bothersome, but long footnotes, especially with titles, may be read almost independently of the text. Therefore, such footnotes may be regarded as boxed short articles. Some readers may read only these footnotes, since they may be more radical or provocative. This is one way to read this book. The author reads many notes and comments while reading books and is irritated if he has to look for them at the end of chapters and books. This is why remarks and notes are placed as closely as possible to their relevant locations.

Discussions

We will occasionally pose problems and questions as Discussions. Some of them are mere exercises, but some are intended to supply the seeds of discussion. Accordingly, Discussions may have more than one solutions or may have none. The author wishes the reader to pause occasionally to reflect on ‘deeper questions.’

Support Pages

A lot of material has been relegated to the Support Pages for this book: http://www.yoono.org/NonlinearWorldSpringer/Nonlinear_World_Supplements.html. Additional information, some technical details and updates will be found there. Ideally, the book itself is a *growth kernel of a collection posted here of long and short lecture notes and memos* relevant to any topic discussed in this book.

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