Proceedings of the Conference on

SYNERGETICS, ORDER AND CHAOS

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World Scientific
Singapore • New Jersey • London • Hong Kong

Published by

World Scientific Publishing Co. Pte. Ltd.
P O Box 128, Farrer Road, Singapore 9128

USA office: World Scientific Publishing Co., Inc.
687 Hartwell Street, Teaneck, NJ 07666, USA

UK office: World Scientific Publishing Co. Pte. Ltd.
73 Lynton Mead, Totteridge, London N20 8DH, England

Library of Congress Cataloging-in-Publication Data

Synergetics, order, and chaos/editor, Manuel G. Velarde.
p. cm.
Papers from an international symposium organized by Fundación Ramón Areces and U.N.E.D. in Madrid, Oct. 1987.
Includes index.
ISBN 997150717X
1. System theory—Congresses. 2. Physics—Congresses. 3. Mathematics—Congresses. 4. Chaotic behavior in systems—Congresses. 5. Haken, H. I. Velarde, Manuel G. (Manuel Garcia) II. Fundación Ramón Areces. III. Universidad Nacional de Educación a Distancia.
Q295.S955 1988
003 -- dc 19 88-27582

Printed in Singapore by General Printing Services Pte. Ltd.

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BIENHECHORES Y FAVORECIDOS

Parece que los bienhechores quieren más a aquellos a quienes han favorecido, que éstos a aquéllos, y este hecho se discute como contrario a la razón. La mayoría es de la opinión de que unos deben y a otros se les debe...

Al mismo tiempo, el resultado de la acción es hermoso para el bienhechor, de modo que se complace en la persona en que se da, mientras que el servicio del bienhechor no es hermoso para la persona que lo recibe, sino, en todo caso, útil, y esto es menos grato y amable.

WHY ARE BENEFACTORS MORE LOVING THAN BENEFICIARIES?

Benefactors are thought to love those whom they have benefited more than the beneficiaries love their benefactors, and the apparent paradox calls for explanation. Most people conclude that it is because the latter owe and the former are owed a debt...

There is also the point that for the benefactor there is something fine in the performance of his action, so that he takes pleasure in the person upon whom it is performed; but to the beneficiary there is nothing fine in (his relation to) the agent, but at most some advantage, and this is a weaker ground for pleasure and affection.

ARISTOTELES
Etica Nicomaquea / The Nicomachaus Ethics

PRESENTATION AND ACKNOWLEDGMENTS

The present volume contains contributions written to commemorate the Honorary Doctorate offered by U.N.E.D., the Spanish Open University, to Professor Doctor Hermann HAKEN. Most of these contributions were delivered at the JORNADAS INTERNACIONALES/INTERNATIONAL SYMPOSIUM organized by the Fundación RAMON ARECES and U.N.E.D. in Madrid, October 1987.

As Professor Haken's *padrino* in the ceremony that took place on Tuesday, October 13th at U.N.E.D. it is with great pleasure that I acknowledge his acceptance of our Honorary Doctorate. Professor Haken helped U.N.E.D. to a rather outstanding level by offering advice, support and encouragement to me as a scientific leader of a group of Ph.D. students. With the economic support of the Stiftung Volkswagenwerk (thanks to the kindness of Dr. H. Plate) and later on of the CAICYT (Spain) I have done my best with, however, the limitations of doing science in a country with little scientific tradition and not much solidarity, i.e., generally unsynergetic.

Rodrigo's and Schubert's music played by the Orquesta de Cámara Española (Victor Martin, Concertmaster) gave us great pleasure and brought reminiscences of time when Science was not really a profession but a gentleman's job.

The JORNADAS and this BOOK have been possible thanks to the economic support of Fundación Ramón Areces, Stiftung Volkswagenwerk, Ministerio de Educación y Ciencia (Dirección General de Política Científica), Phywe Espanã S.A., A.P.D.-Ordenadores, Alava Ingenieros, U.N.E.D.-Centro Asociado de Valdepeñas, Consejo Regulador de la Denominación de Origen-Valdepeñas, D. Fernando Galatas, D. Jorge Núñez (Consejero-Delegado de Torras Hostench S.A.) and D. Manuel Rollán (Compolaser).

Instrumental to the development of JORNADAS and the processing of the book have also been my dear colleagues and friends Begoña Bermejo, Javier Bermejo, Jorge Castaño, Baltasar Fernández, Rafael Guzmán, Francisco Gódinez, Angel Rodriguez, Julio Moro, José M. Rey, Ezequiel del Rio, Pergentino Arias, Rodolfo Cuerno, Juan L. Valero, Luis Conde, Xiao-Lin Chu, Ricardo Fernández and Victor Fairén.

To all these Individuals and Institutions I express my gratitude.

Manuel G. Velarde
Professor of Physics, U.N.E.D.

FOREWORD

Our Universidad Nacional de Educación a Distancia, U.N.E.D., is a young institution with, however, over one hundred thousand students and more than sixty branches (*Centros Asociados*) scattered across the country. Surely, we lack the tradition of other universities where decades or centuries of good science and respectable and, on occasion, outstanding professors have set the standard. I see, however, the extraordinary dedication and effort of many and, particularly, of a few really brilliant personalities who are placing our U.N.E.D. at a high international level. Several colleagues from other universities in Spain and abroad indeed helped in this endeavor.

The Honorary Doctorate was a token of gratitude to Professor Dr. Hermann Haken for what he has done to U.N.E.D. It also shows the respect that U.N.E.D. professors and its Rector have for his outstanding achievements in Science. On the other hand, by accepting our Honorary Doctorate, Professor Haken conferred a high honor to our young university.

May Professor Haken's life last for quite long for the benefit of all of us.

Mariano Artés
Professor of Mechanics and
Rector, U.N.E.D.

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SYNERGETICS: FROM PATTERN FORMATION TO PATTERN RECOGNITION

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ABSTRACT

So far, synergetics has primarily dealt with the selforganized formation of spatial and/or temporal structures in physics, chemistry, biology and other fields. In this contribution I show how its basic concepts on nonequilibrium phase transitions allow us to devise an algorithm for pattern recognition by machines which has been implemented on a serial computer, but which can also be realized by a parallel network.

1. PATTERN FORMATION

The interdisciplinary field of synergetics studies systems which are composed of many subsystems and which may produce spatial, temporal or spatio-temporal structures [1],[2]. In other words, synergetics has been concerned with the spontaneous formation of patterns. In this contribution I wish to show how pattern recognition can be considered as a process dual to pattern formation. To this end I first remind the reader of some basic concepts of synergetics and of some of its typical examples. The spontaneous formation of structures or patterns can be observed in many disciplines. In physics I mention only a few examples, namely spatial or spatio-temporal patterns in fluids and plasmas or the coherent light of lasers. In chemistry we observe chemical oscillations as well as the formation of spirals or concentric rings in specific chemical reactions. Biology provides us with a variety of examples which include morphogenesis, theories of evolution, behavioral patterns or population dynamics. There are many other examples and other fields but we shall not dwell on these details here. Rather we pick up a specific physical example, namely the convection instability [3]. When a fluid layer is heated from below, beyond a critical temperature difference it may spontaneously form a pattern in form of rolls (Fig. 1). As a detailed analysis reveals, the following happens close to the instability point (see for instance [1] where many further references are given). Due to fluctuations the fluid may test various mode configurations which may either increase or decay (Fig. 2). The amplitudes of mode configurations which tend to increase will act as order parameters. According to the slaving

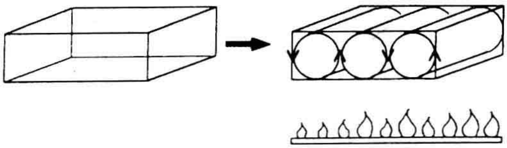

Fig. 1: When a fluid layer is heated from below it may spontaneously form a roll pattern.

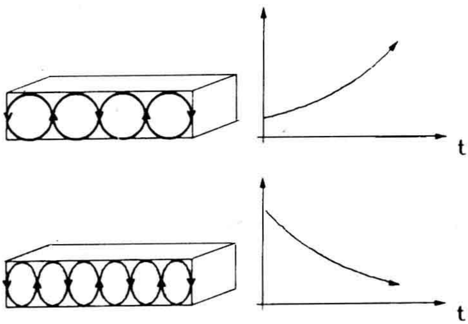

Fig. 2: Different configurations of collective motions can grow (upper part) or decay (lower part) after they have been generated by a spontaneous fluctuation.

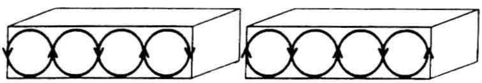

FIG. 3: Symmetry breaking with respect to the rotation direction of rolls.

principle of synergetics [1], [2], these slowly varying amplitudes enslave the subsystems or elements of the systems so that order is impressed on the system. In other words the patterns formed are determined by the order parameters. By means of the slaving principle a great reduction of degrees of freedoms may be reached, e.g. the 10^{22} degrees of freedom of a fluid may be reduced to the single degree of freedom of the mode amplitude of the order parameter. We observe the phenomenon of symmetry breaking, namely the rolls may move in one direction or in the opposite (Fig. 3). In the case of the formation of rolls in a fluid the dynamics of the order parameter can be simply visualized by means of a potential function [1], [3]. Namely when we identify the amplitude of the order parameter with the coordinate of a particle, the order parameter behaves as if the particle moves in a potential under overdamped motion. The potential is depicted for two cases, namely below the instability point (dashed curve) and above the instability point (solid curve) (Fig. 4). Evidently above the instability point there are two equal minima, i.e. there are two possible realizations of a macroscopic state of the liquid (corresponding to broken symmetry, cf. Fig. 3). In the parlance of dynamic systems theory there is one fixed point in the case below the instability point (Fig. 5a). Beyond the instability point a bifurcation occurs and two new stable fixed points are established (Fig. 5b). In the case of a large aspect ratio the roll system in a circular vessel can be oriented in different directions so that in this case there is a continuous symmetry which can be broken (Fig. 6). Because of the action of the order parameter the system will be pulled into one of its stable states (fixed points) even if it is initially not in that state but close to it; i.e. in other words the system may complete an originally incomplete pattern.

2. PATTERN RECOGNITION

To get a grip at pattern recognition in living beings as well as in machines it is useful to introduce the concept of associative memory. A simple example for such a device is provided by the telephone dictionary. In it names, such as Rolf Mueller, are associated with their telephone numbers, such as 60 35 42. When we now prescribe the name Rolf Mueller, the telephone dictionary supplements it by the number which can then be read off. Another example is provided by faces to which we attach names (Fig. 7). When a face is offered to a human being or to the machine, he or it will supplement it by the name which can be read off and in this way the face has been recognized. There are various ways how to realize an associative memory. In 1961 Karl Steinbuch introduced the concept of the Lernmatrix [4]. This concept has been carried further by Kohonen [5], Palm [6] and others by their work on associative memory. A further approach is suggested by the study of the behavior of neurons. A typical neuron receives messages from other neurons by means of dendrites (Fig. 8). On the other hand it