Spin glasses in physics, mathematics, and biology

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Heidelberg Colloquium on Glassy Dynamics. Eds. J. L. Van Hemmen and I. Morgenstern. Springer-Verlag, Berlin; Heidelberg; New York; Tokyo (1987) pp. 576, (Lecture Notes in Physics, V. 275).

The collection of papers under review is based on the materials of the Heidelberg Colloquium on the dynamics of glasses which is, in a sense, a continuation of the Heidelberg Colloquium on Spin Glases (cf.: Lecture Notes in Physics, 1983, V. 192), and is devoted to three topics: experimental and theoretical study of spin glasses, application of the theory of spin glasses and its methodology to problems of optimization, and the so-called spin model of memory.

The collection of articles begins with the paper by D. Sherrrington, a leading specialist in the theory of spin glasses, "Disorder, frustration and metastability: The development of a new era." It is a good review of the present day status of the theory of spin glases in the general sense—as systems combining disorder and sign alternation of the interaction.

The first part of the book—"spin glasses"—consists of two sections: experiment and theory. The first section contains a general review by J. A. Mydosh, a review by S. Hunklinger of low-temperature experiments, and also a review presented by the Swedish group and devoted to relaxation experiments in spin glasses. Into this section, as well as into other sections, several original papers have been included on the investigation of spin glasses (mostly of Eu-Sr-S glasses). The second section consists of nine articles of a partially review nature devoted to individual problems of the theory of spin glasses, such as scale transformation (A. J. Bray and M. A. Moore), numerical modeling of spin glasses (R. N. Bhatt and A. F. Young), relaxation (R. G. Palmer), utrametricity (C. De Dominicis and M. Schreckenberg), and also a review presented by the group from L'Ecole Normale Supérieure, an article by H. Horner and others.

A tribute to the time are the second and third parts of the collection. The second part under the common title "Optimization" refers to the direction which in fact was opened up only in 1983 starting with the publication in "Science" of the article by S. Kirkpatrick *et al.*, "Optimization by Simulated Annealing." This "daughter" branching off from the theory of spin glasses consists in the application of ideas and methods developed in numerical and analytic investigations of spin glasses to so-called NP-complete problems of the theory of optimization (among them are, for example, the well-known problem of the traveling salesman and numerous problems of placing elements of printed circuits).

The first article "A pedestrian review of the theory and application of the simulated annealing algorithm" by E. H. L. Aarts and P. J. M. van Laarhoven does not correspond to its title. In fact this review is written not for "pedestrians" but for mathematicians (and this is quite important, since the optimization problems, being in their formulation mathematical ones, are solved in this case by physicists and by physical methods). Considerable attention in this review is also paid to purely practical aspects. The extensive bibliography is also noteworthy: 59 titles for the period 1983–1986.

In contrast, the review by M. Mezard is devoted to the study of optimization problems from the point of view of physics. In particular, Mezard uses the replica approach popular in the theory of spin glasses. Finally, the two last articles in this part are devoted both to optimization and to networks with associative memory—the topic of the following part of the book. In the review presented by the Paris group the principal attention is devoted to engineering and applications, mostly to design of printed circuits and image recognition. Finally, the article by I. Morgenstern is primarily directed towards the elucidation of the interconnection of the theory of phase transitions in spin glasses with the simulated annealing algorithm, and also to the use of the latter in associative memory systems.

The last portion of the book is entitled "Neuron networks" and deals with the analogy actively discussed in recent years between spin glasses and certain models of the brain. The property of associative memory discovered in systems of the type of spin glasses not only associated the latter with neuron networks, but also proposes numerous practical applications. Two detailed reviews are presented by the Jerusalem group—an introductory one is by D. J. Amit, and a more complicated one by H. Sompolinsky. Individual aspects of the problem are discussed in the original articles by W. Kinzel, J. A. Hertz *et al.*, J. L. Van Hemmen, and G. Toulouse.

Finally one must not fail to note the artistic taste of the editors of the book J. L. Van Hemmen and I. Morgenstern who illustrated the book with the famous paradoxical drawings to M. C. Escher.

On the whole one can say that the book under review is of great interest not only for specialists in the field of spin glasses, and even not only for physicists, but also for mathematicians, and for biologists and for "computer scientists" in the broadest sense of this term. Unfortunately, so far in our country the representatives of the above specialties still have not "caught sight of" the new direction which appeared three years ago coming from physics, while their western colleagues have already shown practical interest in it.

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