

This excerpt from

Adaptation in Natural and Artificial Systems.

John H. Holland.

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Preface

The first technical descriptions and definitions of adaptation come from biology. In that context adaptation designates any process whereby a structure is progressively modified to give better performance in its environment. The structures may range from a protein molecule to a horse's foot or a human brain or, even, to an interacting group of organisms such as the wildlife of the African veldt. Defined more generally, adaptive processes have a critical role in fields as diverse as psychology ("learning"), economics ("optimal planning"), control, artificial intelligence, computational mathematics and sampling ("statistical inference"). Basically, adaptive processes are optimization processes, but it is difficult to subject them to unified study because the structures being modified are complex and their performance is uncertain. Frequently nonadditive interaction (i.e., "epistasis" or "nonlinearity") makes it impossible to determine the performance of a structure from a study of its isolated parts. Moreover possibilities for improved performance must usually be exploited at the same time that the search for further improvements is pressed. While these difficulties pose a real problem for the analyst, we know that they are routinely handled by biological adaptive processes, *qua* processes. The approach of this book is to set up a mathematical framework which makes it possible to extract and generalize critical factors of the biological processes. Two of the most important generalizations are: (1) the concept of a *schema* as a generalization of an interacting, coadapted set of genes, and (2) the generalization of genetic operators such as crossing-over, inversion, and mutation. The schema concept makes it possible to dissect and analyze complex "nonlinear" or "epistatic" interactions, while the generalized genetic operators extend the analysis to studies of learning, optimal planning, etc. The possibility of "intrinsic parallelism"—the testing of many schemata by testing a single structure—is a direct offshoot of this approach. The book develops an extensive study of intrinsically parallel processes and illustrates their uses over the full range of adaptive processes, both as hypotheses and as algorithms.

The book is written on the assumption that the reader has a familiarity with

probability and combinatorics at the level of a first course in finite mathematical structures, plus enough familiarity with the concept of a system to make the notion of “state” a comfortable working tool. Readers so prepared should probably read the book in the given order, moving rapidly (on the first reading) over any example or proof offering more than minor difficulties. A good deal of meaning can still be extracted by those with less mathematics if they are willing to abide the notation, treating the symbols (with the help of the Glossary) as abbreviations for familiar intuitive concepts. For such a reading I would recommend chapter 1 (skipping over section 1.3), the first part of chapter 4 and the summary at the end, the discussions throughout chapter 6 (particularly section 6.6), section 7.5, and most of chapter 9, combined with use of the Index to locate familiar examples and topics. The reader whose first interest is the mathematical development (exclusive of applications) will find section 2.2, chapters 4 and 5, sections 6.2, 6.3, 6.4, 7.1, 7.2, 7.3, 7.5, and 9.1 the core of the book. By a judicious use of the Glossary and Index it should be possible for a well-trained system scientist to tackle this part of the book directly. (This is *not* a procedure I would recommend except as a way of getting a mathematical overview before further reading; in a book of this sort the examples have a particularly important role in establishing the *meaning* of the formalism.)

The pattern of this book, as the reader sees it now, only distantly resembles the one projected at its inception. The first serious writing began almost seven years ago at Pohoiki on the Big Island under the kamaaina hospitality of Carolyn and Gilbert Hay. No book could start in a finer setting. Since that time whole chapters, including chapters on hierarchies, the Kuhn-Tucker fixed point theorem, and cellular automata, have come and gone, a vital $\mu_c(f)$ emerged, blossomed and disappeared, 2-armed bandits arrived, and so on. At this remove it would be about as difficult to chronicle those changes as to acknowledge properly the people who have influenced the book along the way. Arthur Burks stands first among those who provided the research setting and encouragement which made the book feasible; Michael Arbib's comments on a near-final draft stand as the culmination of readings, written comments, commentaries, and remarks by more than a hundred students and colleagues; and Monna Whipp's perseverance through the typing of the final draft and revised revisions of changes brings to fruition the tedious work of her predecessors. For the rest, I cannot conceive that appearance in a long list of names is a suitable reward, but I also cannot conceive a good alternative (beyond personal expression), so they remain anonymous and bereft of formal gratitude beyond some appearances in the references. They deserve better.

JOHN H. HOLLAND

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