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Book review

Fuzzy Networks for Complex Systems: A Modular Rule Based Approach, Alexander Gegov, Springer-Verlag, Berlin, Heidelberg, 2010

In many practical situations, we encounter complex systems, i.e., systems consisting of many inter-related subsystems and components. Often, we do not know the exact relation between different components, we only have expert knowledge about these relations, knowledge formulated in terms of imprecise ("fuzzy") words from natural language like "weak", "small", "large".

The traditional system theory approach to describing such systems is based on a seemingly natural idea: since we do not have too much information about the actual dependence, let us use the simplest possible functions that are consistent with the expert's informal description. As a result, usually, linear functions are used to describe these dependencies. The problem with this approach is that compositions of linear functions are also linear functions. Thus, by combining linearly interacting elements, we get linear models for complex systems – while the actual behavior of real-life complex systems is usually strongly non-linear.

An alternative idea, promoted by the book's author, is to translate the expert knowledge into precise computer-understandable form by using *fuzzy logic* – techniques specifically designed for processing such natural language expressions. It is well known – from the experience of fuzzy control and fuzzy modeling – that even simple fuzzy rules lead to non-linear dependencies. As a result, when we use this idea, we get the desired highly non-linear description of the complex system.

An additional advantage of using fuzzy techniques is that, in contrast to the traditional system theory approach, these techniques automatically take into account the expert's uncertainty – because uncertainty is the basis of fuzzy techniques.

The idea of using fuzzy techniques to describe complex systems seems natural, but surprisingly, this field is still at its infancy, and the author of the book is the main research pioneer in this direction. Traditionally, fuzzy logic techniques have been used in fuzzy modeling and fuzzy control, when fuzzy rules directly describe the relation between the input and the output values. Fuzzy networks are a natural generalization of this simple case, when fuzzy rules describe relations between neighboring nodes, and the resulting input-output relation has to be composed from these node-to-node relations. Chapters 1–3 of the book contain the main motivations for using fuzzy techniques and fuzzy networks, and a formal description of the corresponding fuzzy networks.

The transition from traditional fuzzy modeling to fuzzy networks leads to new operations which make sense in the context of a complex system. For example, if the original description of a system is too complicated, it makes sense to simplify this description by making the description less detailed – i.e., by combining several nodes (corresponding to individual component of a subsystem) into a single node corresponding to the subsystem as a whole. Vice versa, if the current model of a complex system is oversimplified, we may want to make it more accurate by making it more detailed – i.e., by splitting a current node corresponding to a subsystem into several nodes corresponding to several components of this subsystem.

We can perform similar operation on nodes describing different stages of the processes within the complex system: when a description is too complicated, we can combine several small steps into a single complex step; and when a description is too crude, we can subdivide the large-scale step into its distinct sub-steps. In Chapters 4–6, the author describes the corresponding operations in precise terms, and describes when important properties like associativity are satisfied.

Chapters 7 and 8 deal with two important cases of fuzzy networks: when the influence mainly goes from the input to the output (via intermediate steps), and when the influence mainly goes from the output to the input.

Finally, Chapter 9 describes applications of the fuzzy network techniques – and issues related to these applications. Fuzzy networks are an exciting new idea. At present, there are only a few available practical applications of fuzzy networks – to price setting and to banking, but this idea clearly has a huge application potential. In his Conclusions chapter, the author emphasizes that complex systems are ubiquitous: they occur in areas ranging from manufacturing to communications to transportation to finance. In all these areas, fuzzy networks can be useful.

The book presents an important stage in the development of an idea, when the idea has been formulated and mathematically developed, when its first applications have proven this idea to be practically useful – and when researchers and practitioners are encouraged to apply this idea to other application areas.

This book is not an easy reading: its mathematics may not be very complicated, but it is rather abstract and somewhat unusual. A reader may struggle to get through this book – especially a reader who is more accustomed to books and papers in which every abstract concept is made easy by illustrating how it works on numerous practical examples. However, a reader who does successfully "struggle through" will be rewarded with knowledge of new innovative tools, tools which are extremely promising in the challenging area of the analysis of real-life complex systems.

We hope that the readers will be encouraged by the existing applications and successfully apply the new promising techniques of fuzzy networks to new areas. Exciting results are ahead!

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