

# Preface

Large-scale complex systems, such as modern industrial processes, biological systems, and social networks, are interconnected by different units or elements; the system behavior is determined by the inter-relationship between every pair of the elements as well as the local dynamics within each element. It is essential to identify such inter-relationship, namely connectivity and causality, in order to analyze influence mechanisms, structural properties, and overall dynamic behavior.

In the control and automation community, connectivity and causality play a vital role in modeling and analysis, especially for fault detection and hazard analysis, because an abnormality can easily propagate within and between process units due to material and information flow paths. Thus the problem of fault detection and isolation for industrial processes is concerned with determination of root causes and fault propagation. Connectivity and causality, as the key features of process description, can be captured in two ways:

1. From process knowledge: Structural modeling based on first principles structural models can be merged with adjacency/reachability matrices or topology models obtained from process flow-sheets described in standard formats.
2. From process data: Cross-correlation analysis, Granger causality and its extensions, frequency domain methods, information-theoretic methods, and Bayesian networks can be used to identify pairwise relationship and network topology.

These methods rely on the notion of information fusion, whereby various types of process operating data are combined with qualitative process knowledge to give a holistic picture of the system.

In this book, we shall give an exhaustive overview of concepts and descriptions of connectivity and causality in complex processes and a tutorial guide to classical and recent research results on detection of connectivity and causality illustrated with example applications. A study of the fusion of different information resources for obtaining an acceptable process topology is also introduced.

Some details are omitted in this book due to space constraints. Interested readers should refer to the related literature. For questions, comments, and suggestions, please write to Fan Yang at yangfan@tsinghua.edu.cn.

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Fan Yang  
Ping Duan  
Sirish L. Shah  
Tongwen Chen

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Yang, F.; Duan, P.; Shah, S.L.; Chen, T.

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