

Preface

The book presents a comprehensive treatment on a novel design theory that fosters innovative thinking and creativity essential for addressing wicked problems. Wicked problems are ill-defined, ambiguous in both their aims and solutions, and complex with interconnected and intertwined (coupled) factors. While being ubiquitous and difficult, however, wicked problems share characteristics common to science and design in three regards; namely, agent finitude, system complexity, and problem normativity. These fundamental attributes allow a core cognitive process common to design and science to be identified and a strategic problem-solving conception of methodology to be formulated as a result. The novel theory presented in the book facilitates new opportunities for synergetic cross-disciplinary research and practice by incorporating the essences of the theory of Extenics to Axiomatic Design. Innovative thinking is enabled by exploring Extenics for problem reframing, paradigm shift, and abductive reasoning and by engaging Axiomatic Design in the co-evolution (iteration) of the need and viable design concept.

The theory is unique in that it is a framework for quantifying imprecise and vague design information available during the conceptual design stage as mathematical expression and algorithm early in the design effort and enables the objective evaluation and emergence of an optimal design concept from the multitude of viable ones. The principles of the theory help one articulate fundamental questions essential to tackling difficult design problems with regards to innovative design concept generation, proper thinking procedure, and guidance that drive design iteration. The principles are manifestations of Chinese philosophical thinking of abstraction using mathematical expression, functional mapping, and physical parameters. Through encouraging creative imagination, fostering broad abstraction, and promoting logical and structured inference, innovative design solutions are warranted.

A comprehensive investigation into the Axiomatic Design (AD) and Extenics allows the basis of the synergy of the two theories to be found that renders the mathematical description of the novel theory that is elaborated in the book. Functional requirement, design parameter, and design coupling as defined in the AD theory are described using the affair-element model, matter-element model, and relation-element model in Extenics. The issue of lacking unified and precise expressions

in AD for elements in the problem domain and coupling description is resolved. Moreover, basic-element models for the process that maps the functional domain to the physical domain in AD are established. The search for initial conceptual design is transformed into one that addresses the feasibility of the design problem. Mapping from the functional domain to the physical domain is also made explicit. The needs for evaluating the independence of the elements in the design matrix, mapping and decomposing between domains, and expanding design solution space are also addressed. A general framework viable for proper design decoupling is also developed that allows viable decoupling methods to be formulated with ease in the context of the AD theory.

The book is conceived for students and real-world practitioners in engineering, natural and social sciences, business, and fine arts who seek to develop powerful design thinking for solving problems in a creative and innovative way. The principles presented in the present volume are universally applicable to problem-solving. They are not limited to specific disciplines or levels of studies. While the many illustrative examples included in the core chapters may seem suggesting that the book is designed for project-based engineering design courses, it is recommended that the methodologies be incorporated into teaching design thinking early in the curriculum, be it engineering or non-engineering.

The design principles of the book can be adopted as materials for a comprehensive coverage of conceptual design or for developing broad design thinking skill and capability effective for addressing tough problems that are wicked, difficult, and of a high degree of complexity. The book is arranged as follows. Chapter 1 introduces the essences of design thinking and contemporary engineering design methodologies. Chapter 2 defines the fundamentals including the definition for function structure, performance, constraint, and design requirements. Chapter 3 reviews the theory of Axiomatic Design and Chapter 4 gives a comprehensive account of the Extenics theory. In addition to investigating the complementary properties of the two design theories, the features and synthesis of the two powerful design theories are performed in Chapter 5. Drawing upon the creative synergy, Chapter 6 presents the innovative design methodology with the subsequent chapters, Chapter 7 documents the novel design decoupling methodology and Chapter 8 projects in brevity the bright outlook that the theory promises.

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