Preface

Interpretation of algebraic inequalities: Practical engineering optimisation and generating new knowledge [ISBN: 9781032059174] / by Michael Todinov (CRC Press, 2021).

Algebraic inequalities are an ideal tool for handling deep uncertainty associated with components, properties and control parameters. A formidable advantage of algebraic inequalities is that they *do not require knowledge related to the values or distributions of the variables entering the inequalities*. This advantage permits ranking of systems and processes with unknown performance characteristics of their components.
A treatment related to the applications of algebraic inequalities for risk and uncertainty reduction was presented in a book, recently published by the author, focused exclusively on the *forward approach* to generating new knowledge by using algebraic inequalities. This approach starts with the competing physical systems/processes and compares their performance by deriving and proving algebraic inequalities. The forward approach was demonstrated through many application examples from various unrelated domains. However, the potential of the forward approach for generating new knowledge is somewhat limited because it is confined only to specific performance characteristics or specific systems.
The focus of this book is on the *inverse approach*, which was developed to expand the capabilities of the forward approach. Instead of comparing systems and processes and deriving and proving algebraic inequalities demonstrating the superiority of one of the solutions, the inverse approach operates in the opposite direction. The inverse approach starts with a correct algebraic inequality and progresses towards deriving new knowledge about a real system or process, which is subsequently used for enhancing its performance.

The inverse approach is based on the principle of non-contradiction: *if the variables and the different terms of a correct algebraic inequality can be interpreted as parts of a system or process, in the physical world, the system or process exhibits properties or behaviours that are consistent with the prediction of the algebraic inequality.*

The book demonstrates that powerful quantitative knowledge about systems and processes, locked in abstract inequalities, can be *released through their meaningful interpretation*. Furthermore, depending on the specific interpretation, knowledge, applicable to different systems from different domains, *can be released from the same starting inequality*. In this respect, the inverse approach *does not require or imply any forward analysis* of pre-existing systems or processes. The new properties discovered about real systems or processes are solely a result of meaningful interpretation of the variables and the different parts of the inequalities.

This book is firmly rooted in the practical applications of algebraic inequalities. In engineering design, design inequalities have been widely used to express design constraints guaranteeing that the design will perform its required functions.
As will be shown in this book, the application potential of algebraic inequalities in engineering is far-reaching and certainly not restricted to specifying design constraints. Interpretation with the purpose of deriving new knowledge, subsequently used for system/process optimisation, is a new dimension in the application of algebraic inequalities. Thus, in Chapter 3, meaningful interpretation of algebraic inequalities was used to (i) construct a parallel–series system with superior reliability, (ii) select a complex system with superior reliability in the absence of knowledge related to the reliabilities of the separate components and (iii) rank

alternative mechanical assemblies in terms of equivalent stiffness in the absence of data related to the stiffness of the individual components.
Practical applications of interpretation of algebraic inequalities are featured in the domains of reliability engineering, risk management, mechanical engineering, electrical engineering, economics, operational research and project management. The meaningful interpretation of algebraic inequalities, however, is not restricted to these areas only. Chapters 4 and 5 demonstrate an important class of algebraic inequalities based on sub- and super-additive functions which *can be used for optimising systems and processes in any area of science and technology, as long as the variables and the separate terms in the inequalities are additive quantities*.

By interpreting inequalities based on sub-additive functions in Chapters 4 and 5, new knowledge is derived and subsequently used to (i) produce light-weight designs, (ii) maximise the total power output from a voltage source, (iii) maximise the energy stored in a capacitor, (iv) maximise the accumulated elastic strain energy during tension and bending, (v) maximise the accumulated kinetic energy during inelastic impact and (vi) maximise the profit from investment. The same classes of algebraic inequalities have also been used to minimise the drag force during motion in viscous fluid and the formation of undesirable brittle phase during phase transformation.
In addition, the meaningful interpretation of a new algebraic inequality led to a method for maximising the mass of deposited substance during electrolysis.

Chapter 6 presents interpretation of algebraic inequalities for (i) maximising the probability of selecting high-reliability items from suppliers with unknown proportions of high-reliability items, (ii) optimal assignment of devices to tasks to maximise the probability of successful accomplishment of a mission and (iii) assessing the likelihood of unsatisfied demand from users placing random demands on a time interval.

Chapter 7 features interpretation of algebraic inequalities for (i) ranking the magnitudes of sequential random events, (ii) determining the lower bound of the probability of reliable assembly, (iii) determining tight lower and upper bound for the fraction of faulty components in a pooled batch and (iv) avoiding overestimation of profit.

Finally, Chapter 8 introduces interpretation of algebraic inequalities as potential energy to determine the equilibrium state of systems and sum of distances.

This book is the first publication introducing generation of new knowledge by meaningful interpretation of algebraic inequalities. It can be a primary source for a course on algebraic inequalities and their applications and a primary reading for researchers wishing to make a fast and po knowledge about systems and processes through interpretation of algebraic inequalities. This book can be an excellent source of applications for courses and projects in mathematical modelling, applied mathematics, reliability engineering, mechanical engineering, electrical engineering, operational research and risk management.

Finally, by demonstrating the principle of non-contradiction on numerous examples, this book sheds some light on the deep connection between the physical reality and mathematics. The results presented in this book support the view that physical phenomena and processes seem to take (follow) paths that are consistent with the predictions of correct abstract algebraic inequalities whose variables and different parts correspond to the controlling variables and factors driving these phenomena and processes.

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