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Book Reviews

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Multibody Dynamics and Visualization

Harry Dankowicz, Springer–Verlag, New York, 2005, 504 pp.

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This book's unique feature is its illustrations and geometric configurations in determining the kinematics of rigid bodies. The book is a recipe for mathematically and CAD-oriented students who have an appetite for the dynamics of multibody systems and articulated mechanical systems. The book provides the insight into how connectivity and bookkeeping is mathematically illustrated by means of nicely crafted visualization concepts that help students and engineers understand the kinematical knowledge needed in modeling mechanisms and multibody systems.

The author builds the concepts block by block, defining translation, rotation, and viewing the observers as different reference frames.

The notion of auxiliary observers is particularly important when dealing with multiple rigid bodies. The author demonstrates with clarity and exceptional talent how the number of transformations increases when relative frames are introduced. This concept is missing from our current teaching of dynamics and multibody dynamics (MBDs), in which relative motion is introduced without any conceptual description or geometrical descriptions that would enable the students to grasp the real meaning and use it to select the most convenient frames that best describe the kinematics.

The book goes into the heart of graphics and graphics manipulation using pure mathematics and provides a direct link to the fundamentals of position and orientation of objects. The tree concept as in parent-child relations is introduced in this book as a clever way of making a student think about the possible configurations and how to get from W to A_i ($i = 1 - n$). The thought process is put into the correct mode before any derivations of position and velocity are made.

The MAMBO toolbox interface developed by the author includes a graphical subroutine to represent an arbitrarily complex array of rigid bodies in a 3-D environment. I like the way the author tries to "provide a language to communicate a three-dimensional geometry and the structure of a multibody system." Chapter 3 is hands on and allows the reader to really interact with basic concepts such as vectors and their base frame.

In Chapters 4 and 5 the treatment of position and orientation are illustrated through object labeling, allowing for tracking the different sides of the object as well as defining the orientation with respect to different frames.

This is essential for developing realistic animations which have some meaningful geometrical descriptions. The labeling technique is similar to finite element methods, where both the nodes and the elements need to be labeled. This technique allows for a coupled derivation of the position vectors for all the points of an object. The MATLAB codes in Chapter 4 are well written and provide the tools necessary to build the animation of multibody systems. The book provides a summary of the MAMBO Toolbox and terminology for a quick reference.

Chapter 5 and 6 develop rotations using matrices to describe the relationship between different orthonormal bases. This treatment is done with vectors and dot products, which I found to be quite interesting if you are familiar with MATLAB or other similar codes. Students willing to be challenged will really enjoy learning how to deal with the orientation and graphics using MAMBO Toolbox.

Chapter 7 brings together all the tools developed in previous chapters with hands on applications to multibody systems. In particular, the author uses the bicycle as a complex multibody system and uses the modeling algorithm that is advocated throughout the first chapters that allows the reader to derive the essentials of a multibody system. This development is done by defining the reference frames and their orientations, defining the rigid bodies and their spatial relationships, and building the tree structure configuration that allows the system assembly to take place. The recipe leads to a detailed analysis of position vectors and appropriate transformations needed in the kinematics. Another example, modeling an articulated desk lamp, is provided to enforce the concepts developed. Students can use this chapter as a way to learn most of the concepts the book is trying to highlight.

Chapter 8 deals with both linear velocities and angular velocities. In particular, emphasis is made on describing the instantaneous state of motion of a rigid body or observer relative to an observer. Differentiation of vectors (positions) with respect to different observers is also fully described. The visualization is tackled by using the information from the angular velocities and linear velocities to reconstruct the configuration of the rigid body. A number of illustrations are given and a step-by-step solution is fully explained.

Chapter 9 is dedicated to constraints. The book describes the geometrical constraints and kinematical constraints that limit the motion of the mechanism and defines the independent velocity coordinates that satisfy the motion provided by the imposed geometrical constraints. The book also shows how one can derive the constraint equations at the velocity level. The author has a done a great job explaining the differences between system motion limitation and how constraints can be derived to make that happen, and how to apply a set of constraints on a mechanical system. The author looks at all types of constraints including redundancy or linear dependency between constraints, switching between constraints, and singularities. What is important is that one will understand how constraints are defined, their role in the dynamics, and what happens when they vanish, become redundant, or are imposed on the motion of the mechanism. There is a section devoted on how to implant constraints in the MAMBO Toolbox.

Chapter 10 is an overall review chapter and is followed by Chapter 11, which provides some insight into what happens when a rigid body is isolated from the inertial reference frame, and how mass distribution affects the inertia properties of a rigid body. The chapter leads to an introduction into dynamics and initiates the discussion on how forces are formulated in the context of the kinematics algorithms developed in the book.

This book can serve as a requirement to many of the advanced courses in dynamics, and, in particular, for those that require multibody dynamics in their curriculum. It is a powerful tool for providing beginning engineers, who may rely on existing dynamic codes, to develop the needed skills to formulate and solve complex dynamical problems.

The book is written for juniors and seniors and requires some skills of MATLAB or MAPLE. The textbook is full of examples and problems that are well selected for the materials described in each chapter. It will be interesting to see if intermediate dynamics or simply analytical dynamics first-semester classes can be taught using this book. I believe that once you try this book, the students' response will be positive, and it will become easily integrated into the curriculum. It is a unique book with a different twist and distinguishes itself from all of the classical books in dynamics, which generally do not provide any mathematical modeling or visualization techniques associated with the geometry configuration and reference frames. I hope that mechanical and aerospace engineering students give this book a serious chance and begin to see Dynamics as a fun course to learn and indeed to develop more interest in research in this area.

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