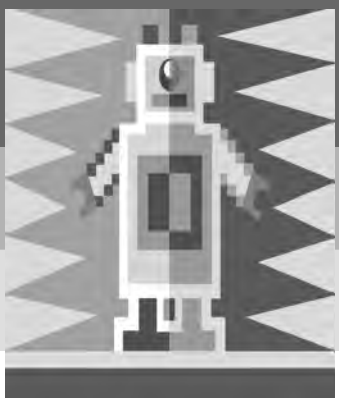

Preface

Robotics is a subject that attracts many young minds, mainly due to the exhaustive portrayal of robots in many science fiction stories and popular movies. From the sixties onwards, robots have mostly been used in industrial applications, particularly, in auto industries for the welding of car bodies. Even today, the major users of robots are the automobile giants. Robots are also finding increasing applications in medical surgeries, mining and space explorations, and even at homes to take care of elderly people.

Introduction to Robotics is a book which aims to understand the underlying concepts used in designing and building a robot, and to make it work. There are a number of books available in the market which typically cater to either researchers working mainly on the analyses aspects of robots, e.g., kinematics, dynamics, control, etc., or practicing engineers interested in the feasibility study of using robots for particular applications, procurement of robots, their programming, economics, etc. In an undergraduate curriculum of Robotics, it is important that the students are exposed to both the aspects of analyses and applications. Hence, the need was felt for a book which would cover both the aspects in a lucid manner.

The inspiration to write this kind of a book, however, came almost a decade ago (April, 1999) when Prof. Gayatri Kansal from Indira Gandhi National Open University (IGNOU), New Delhi, requested me to write some instructional materials on Robotics for their students. At the same time, I found no textbook on Robotics available in India at affordable prices. Hence, I felt the urge of writing one which should have an international quality but an Indian price. This would not only help

Indian students to own a robotics book but also others from countries of similar economic conditions.

Even though the book primarily targets the undergraduate students of Mechanical and Electrical Engineering, and Computer Science disciplines registering in a course on Robotics, it can also cater to the need for an advanced-level course on Robotics for the Master's and PhD students focusing on, say, Robot Kinematics, Dynamics, and Control. The material provided in this book can be used by practicing engineers as well who may or may not have any earlier exposure to the subject of robotics for the purposes of adopting, maintaining, and even designing a robot. In fact, with many examples and exercises provided in this book, one can prepare himself or herself for any competitive examination having Robotics as a topic.

This book is meant to cater to both the undergraduate (UG) and postgraduate (PG) level students for their courses on Robotics. The following roadmap is presented as a guide to the teachers concerned:

For UG-level course

At introductory level (preferably 2nd and 3rd year students)

For Mechanical discipline, use chapters 1–6.

For Electrical and Computer Science disciplines, use chapters 1–5, 12.

At senior level (preferably 3rd and 4th year students)

For Mechanical discipline, use chapters 2, 6–8, 11.

For Electrical and Computer Science disciplines, use chapters 2, 5–6, 8, 10–11.

For PG-level (Master's and PhD students) Course

Without any exposure to a course on Robotics

For Mechanical discipline, use chapters 1–8.

For Electrical discipline, use chapters 1–5, 10, 12.

With exposure to UG-level courses on Robotics

For Mechanical discipline, use chapters 5–11.

For Electrical and Computer Science disciplines, use chapters 5–8, 10–11.

Besides, the book is suitable for courses on Mechatronics and Multibody Dynamics. For example, chapters 3–6, 8, and 10 would constitute about 75–80% of a course on Mechatronics, whereas chapters 5–6, 8–9 can cover up to 80% of a course on Multibody Dynamics with only rigid-body treatment, and about 60% of a course on Multibody Dynamics with flexible body treatment.

Several special features are introduced in this book to make it different from any other contemporary books on Robotics:

- **Natural flow of the contents**, i.e., the topics are arranged in a way so that a student can grasp the subject logically. For example, once we hear about any new thing we are curious about how it looks or how it functions. Hence, the aspects of different robots and classifications are covered in chapters 1 and 2.

Next, one would be interested to know the components of a robot. Hence, actuators and sensors are explained in chapters 3–4. Having learnt about the robot structure and its components, it is natural to be curious about how a robot moves and what are the forces causing it. Here comes the necessity of transformation, kinematics, statics, and dynamics. They are covered in chapters 5–9, respectively. This is followed by the control laws in Chapter 10. Now, the robot is ready for practical use, and a user has to decide how to move it for a particular task. Motion planning of Chapter 11 is the one which explains robot movement. Finally, it is the hardware and the software that drives the robot, which are taken up in Chapter 12.

- **Textboxes** are given to highlight historical, contemporary, and other interesting information that would help the reader to complement his or her theoretical knowledge gained from the contents of the chapters.
- **Web-/MATLAB-based exercises** are given at the end of each chapter. These exercises will help a student to keep him or her abreast with what is happening on Robotics around the world, and to get practically acquainted with how to implement the mathematical concepts for real applications.

The complete organization of the book is as follows:

Chapter 1: Introduction In this chapter, different types of robots are introduced with their application areas, population, etc.

Chapter 2: Serial Robots In this chapter, different methodologies used for robot classification of serial robots are presented.

Chapter 3: Actuators Several types of actuators, namely, pneumatic, hydraulic and electric types are explained in this chapter, along with how to select them.

Chapter 4: Sensors Sensors, the important components of a robot system, are explained here.

Chapter 5: Transformations Architectures of a robot are defined in this chapter . Mathematical description of the robot's pose, i.e., the position and orientation of its end-effector, is presented, along with the definition of Denavit and Hartenberg (DH) parameters.

Chapter 6: Kinematics This chapter forms the fundamental basis for the design and control of a robot. Equations relating the joint coordinates with the Cartesian coordinates of the end-effector are derived.

Chapter 7: Statics When the robots move slowly, it is sufficient to consider the forces acting on the robots irrespective of what motion is caused due to them. This is called statics.

Chapter 8: Dynamics Dynamics is useful for control and virtual representation of a robot system. Different methodologies like Euler–Lagrange and Newton–Euler equations of motion are derived here.

Chapter 9: Recursive Robot Dynamics* Recursive robot dynamics, a set of modern and advance algorithms, are presented here. The star (*) mark next to the title indicates that this chapter can be skipped for a course in the UG- and preliminary PG-levels. It should be taken up only in the advanced level PG course meant for Master's

and PhD students or by those who want to take up a Master's project or PhD research in the area of robot dynamics.

Chapter 10: Control Linear control, P, PD, PID control laws, stability, etc., are covered in this chapter.

Chapter 11: Motion Planning Several motion-planning aspects are discussed. Joint and Cartesian-space-based trajectory planning equations are derived in this chapter.

Chapter 12: Computers for Robots Once the algorithms are developed, it is important to implement those in electronics hardware. Hence, different robot programs like ACL, etc. , are described.

References This section contains the list of books, papers, and other sources from where different materials are taken for the use in this book.

Appendix A: Mathematical Fundamentals In this appendix, many basic concepts from linear algebra, control theory, and others are introduced which will help the readers to understand the expressions used in different chapters, namely, chapters 5–10.

Appendix B: Use of MATLAB and RIDIM Software How to use the two software applications, namely, MATLAB, and the in-house developed RIDIM, is explained here.

Appendix C: Case Studies—Student Projects Several case studies, namely, the robots developed by the students for robotic competitions, and for their UG/PG projects are explained.

The book is accompanied by the following website where the RIDIM software will be available for the uses of this book. It will also contain the solution manual for the teachers. For the benefits of the students and teachers, the website will be updated at regular intervals.

`http:// www.mhhe.com/saha/robotics`

At the end, it is my duty to acknowledge the people without whose support the book would not have seen the light of day. It has been a long journey since April 1999. But I am happy that it is finally done, and it was surely a 'slow but steady' endeavour by me. After Prof. Gayatri Kansal, as mentioned earlier, I want to remember my PG students, Mr Mahesh Sharma, Mr Subhashis Pati, Mr T Gopala Rao, Mr Tamogna Das, Mr Naveen Sukumar, for typing some part of the chapters and drawing several diagrams for this book. I am grateful to Mr S S Petkar, Mr Arvind Patle, MTech students, and Mr Pankaj Marothiya and Mr Amit, BTech students, for generating the C++ code for the in-house developed RIDIM (Recursive Inverse Dynamics for Industrial Manipulator) software which is used to solve many examples of this book and also available through this book's website. I am indebted to two of my ex-PhD students, Dr Prasad Bhangale and Dr Himanshu Chaudhary, for their use of RIDIM during their research work and testifying it as a reliable one. I want to acknowledge many students of IIT Delhi, particularly those who have been participating in the ROBOCON competitions under my supervision and showed great enthusiasm in large numbers to build the many working robots that appeared in

Appendix C. Thanks are also due to Dr I N Kar, Associate Professor in the Department of Electrical Engineering at IIT Delhi, for readily agreeing to read Chapter 10 on Control and giving me timely comments on it. My special thanks to Mr Suril V Shah, a student currently doing his PhD, who painstakingly read the chapters and helped me to prepare the solutions of the problems given in the exercises of this book. I would like to thank the many reviewers for their valuable comments which have truly raised the standard of this book.

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My thanks will remain incomplete if I do not mention Tata-McGraw Hill for readily agreeing to publish this book, and their executives, Ms Vibha Mahajan, Ms Shukti Mukherjee, Ms Surabhi Shukla, Ms Sohini Mukherjee, Mr Baldev Raj, Ms Anjali Razdan and many others in the background, for their persuasion and help without whom the book would not have been a reality. Finally, it is my family—wife, Bulu and daughter, Esha—who have been waiting for long to get more attention from me, and to be able to spend some quality family time with me. I am grateful for their patience, understanding, support and cooperation.

I am confident that the readers will find this book truly valuable in terms of its quality and lucid presentation so that they can easily acquire the required knowledge. However, being the first edition, it may contain some inadvertent mistakes and typos, which I urge the readers to point out to me directly (saha@mech.iitd.ac.in) or write to the book's website the address of which has been mentioned earlier. Happy Reading!

IIT Delhi
February 14, 2008

SUBIR KUMAR SAHA