Robotics: Advanced Concepts & Analysis

Information for Students and Teachers

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Information for Students

- There are **10 modules** – Introduction (Module 1), Elements of robots (Module 2), Kinematics of serial and parallel robots (Module 3 and Module 4), Velocity and static analysis of robots (Module 5), Dynamics of robots (Module 6), Motion planning and control (Module 7), Flexible manipulators (Module 8), Wheeled mobile robots (Module 9) and Advanced concepts & topics (Module 10).
- **What to and not to expect** – The material is **not** for a first course in robotics or for beginners wishing to get a *general* understanding of the subject! Treatment is mathematical and a knowledge of matrix analysis, solution of non-linear equations, ordinary differential equations and its solution, MATLAB® or equivalent, and general familiarity with computation using a computer is **essential**.

Information for Students

- The material is ideally suited for final year Undergraduate or Masters students.
- Modules and lectures marked with a '$*$' are **advanced** and can be skipped by undergraduate students.
- For best use and understanding of the material in the Modules and Lectures, the text book *Robotics: Fundamental Concepts and Analysis*, Oxford University Press, 2006 is suggested as an accompanying material.
- Every effort has been made to verify the correctness of the material including the URL of the websites mentioned in the text. Any error pointed out by readers will be gratefully acknowledged. Please send email to **asitava@mecheng.iisc.ernet.in**.
- The URL's of the website is marked in the usual manner. For example, the NPTEL website can be accessed by clicking here (Please see **Known Bugs** Slide #10).

Information for Teachers

- The modules and lectures are used by the author in a Master's course on Robotics at IISc Bangalore.
- Most of the material in these modules are from the book by the author – *Robotics: Fundamental Concepts and Analysis*, Oxford University Press, 2006. It is suggested that this book be used with the Lectures. The book was written after almost 15 years of teaching robotics to masters and undergraduate students, and scientists from industry and R& D labs in continuing education courses at IISc.
- Each lecture is roughly for one hour – In some instances, depending on the student group, part of a lecture may overflow to the next hour.
- The URL's of the website is marked in the usual manner. For example, the NPTEL website can be accessed by clicking here (Please see **Known Bugs** Slide #10).

Information for Teachers

- The material was prepared in PDF to enable its free viewing on any computer or for projection in a classroom. A free Adobe Acrobat PDF reader can be downloaded for any Windows/Linux system from this website.
- At the end of each module, a number of exercise problems and references are provided for self learning.
- Every attempt has been to make the contents of the Lectures error free. Any errors pointed out by the reader will be gratefully acknowledged. Please inform author by email to **asitava@mecheng.iisc.ernet.in**.
- The videos and movies in the lectures should play in any Windows/Linux system.
- A copy of the simulation videos and movies from Internet is available here as a compressed file (large file, **435 Mb**!). Please download this file and play the movies/simulation videos if Internet connection is not stable or easily available.

Notation Used in Slides

- Symbols such as a, x, P denote *scalars*.
- *Boldfaced symbols* such as $\mathbf{p}$, $\mathbf{q}$ denote *vectors*.
- The *components* of a 3D vector $\mathbf{p}$ is denoted by $(p_x, p_y, p_z)^T$ or $(p_1, p_2, p_3)^T$.
- Vectors are described *with respect to a coordinate system*, and the *leading superscript* A as in ${}^A\mathbf{p}$ denotes the coordinate system in which $\mathbf{p}$ is described.
- A *coordinate system* named A or *Tool* is denoted by the symbol $\{A\}$ or $\{Tool\}$. The *origin* of the coordinate system $\{A\}$ will be denoted by O_A and it is located by a vector $\mathbf{O}_A$. The *unit vectors* along the three coordinate axes of $\{A\}$ will be denoted by $\hat{\mathbf{X}}_A$, $\hat{\mathbf{Y}}_A$, $\hat{\mathbf{Z}}_A$. A rigid body i, in the context of kinematics, is *equivalent* to a coordinate system $\{i\}$, and will be used interchangeably.

Notation Used in Slides

- The *subscript* with a vector distinguishes one object out of many — ${}^{0}\mathbf{O}_1$ denotes a point $\mathbf{O}_1$ with respect to the coordinate system $\{0\}$.
- Symbols enclosed in *square brackets* such as $[J]$ or $[T]$ denote *matrices*. Matrices are often *associated* with coordinate systems indicated by the leading superscript and subscript — The orientation of a rigid body (or coordinate system) B with respect to another rigid body (or a coordinate system) A can be defined with the help of a rotation matrix ${}^{A}_{B}[R]$.
- *Trigonometric functions* such $\sin\alpha$ and $\cos\theta$ are denoted by s_α and c_θ. Sometimes the symbol for the angle is dropped: $\cos\theta_1$, $\sin(\theta_1+\theta_2)$ are denoted by c_1, s_{12}, respectively.
- The derivative of a vector $\mathbf{q}$ with respect to time will be denoted by $\dot{\mathbf{q}}$ and the second derivative by $\ddot{\mathbf{q}}$, respectively.
- Other symbols will be explained as and when they are introduced.

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- The Modules and Lectures were prepared using open source software **MikTeX** and **Beamer** class files. The figures were drawn using open source graphics software **XFig**.

Known Bugs and Way Around

- The modules contain external links such as NPTEL website generated using the **href** command in **MikTex**.
- The external URL's and links can be accessed in the usual way by *"clicking"* on them. On *"clicking"*, the browser displays the content pointed to by the link.
- Unfortunately, *after viewing* the external URL or document, one **cannot** go back to the place in the module where the link was clicked!
- On using the *Back* button, the **first** page of the Module appears!
- **To avoid** this problem,
  - Click link using **right mouse button** or equivalent.
  - Copy link and paste in a New Window or Tab.
  - After viewing external URL, close New Window or Tab.