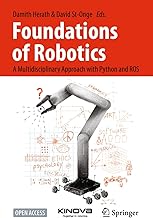
Foundations of Robotics - A Multidisciplinary Approach with Python and ROS



# Part I: Contextual Design

# 1. Genealogy of Artificial Beings: From Ancient Automata to Modern Robotics

# 2. Teaching and Learning Robotics: A Pedagogical Perspective

# 3. Design Thinking: From Empathy to Evaluation

# 4. Software Building Blocks: From Python to Version Control

# 5. The Robot Operating System (ROS1&2): Programming Paradigms and Deployment

## 5.1 Learning Objectives

The objective at the end of this chapter is to be able to:

• to know how to use (run and launch) ROS nodes and packages;

• to understand the messaging structure, including topics and services;

• to know about some of the core modules of ROS, including the Gazebo simulator, ROSbags, MoveIt! and the navigation stack.

## 5.2 Introduction

## 5.3 Why ROS?

## 5.4 What Is ROS?

5.4.1 ROS1&2: ROSCore Versus DDS

5.4.2 ROS Industrial

## 5.5 Key Features from the Core

5.5.1 Communication Protocols

5.5.2 Launch and Run

5.5.3 ROS Bags

5.5.4 Transforms and Visualization

## 5.6 Additional Useful Features

5.6.1 ROS Perception and Hardware Drivers

5.6.2 ROS Navigation and MoveIt!

5.6.3 Gazebo Simulator

## 5.7 Linux for Robotics

# 6. Mathematical Building Blocks: From Geometry to Quaternions to Bayesian

## 6.1 Learning Objectives

The objective at the end of this chapter is to be able to:

• use vector and matrix operations;

• represent translation, scaling, and symmetry in matrix operations;

• understand the use and limitation of Euler’s angles and quaternions;

• use homogeneous transformations;

• use derivatives to find a function optimums and linearize a function;

• understand the importance and the definition of a Gaussian distribution;

• use t-tests and ANOVAs to validate statistical hypothesis.

## 6.2 Introduction

## 6.3 Basic Geometry and Linear Algebra

### 6.3.1 Coordinate Systems

### 6.3.2 Vector/Matrix Representation

### 6.3.3 Basic Vector/Matrix Operations

## 6.4 Geometric Transformations

### 6.4.1 Basic Transformations

### 6.4.2 2D/3D Rotations

### 6.4.3 Quaternion

### 6.4.4 Homogeneous Transformation Matrices

## 6.5 Basic Probability

6.5.1 Likelihood

6.5.2 Bayes’ Theorem

6.5.3 Gaussian Distribution

## 6.6 Derivatives

### 6.6.1 Taylor Series

### 6.6.2 Jacobian

## 6.7 Basic Statistics

6.7.1 Variance

6.7.2 General Population and Samples

6.7.3 The Null Hypothesis

6.7.4 The General Linear Model

6.7.5 T-test

6.7.6 ANOVA

# Part II: Embedded Design

# 7. What Makes Robots? Sensors, Actuators, and Algorithms

# 8. How to Move? Control, Navigation and Path Planning for Mobile Robots

# 9. Lost in Space! Localisation and Mapping

# 10. How to Manipulate? Kinematics, Dynamics and Architecture of Robot Arms

## 10.1 Learning Objectives

The objective at the end of this chapter is to be able to:

• recognize the architecture and mobilities of a robot arm;

• solve the forward and inverse kinematics problem of serial and parallel manipulators;

• obtain the Jacobian relating the velocities of the joints to the end-effector;

• analyze the Jacobian to obtain the different singularities and understand their physical meaning;

• obtain the equations defining the dynamics of a robotic manipulator.

## 10.2 Introduction

## 10.3 Architectures

## 10.4 Kinematics of Serial Manipulators

### 10.4.1 Direct Kinematics

### 10.4.2 Denavit-Hartenberg Convention

### 10.4.3 Inverse Kinematics

### 10.4.4 Jacobian

### 10.4.5 Singularities

## 10.5 Kinematics of Parallel Manipulators

### 10.5.1 Direct and Inverse Kinematics

### 10.5.2 Jacobians

### 10.5.3 Singularities

## 10.6 Dynamics

### 10.6.1 Euler-Lagrange

### 10.6.2 Newton-Euler

# 11. Get Together! Multi-robot Systems: Bio-Inspired Concepts and Deployment Challenges

# 12. The Embedded Design Process: CAD/CAM and Prototyping

# Part III: Interaction Design

# 13. Social Robots: Principles of Interaction Design and User Studies

# 14. Safety First: On the Safe Deployment of Robotic Systems

# 15. Managing the World Complexity: From Linear Regression to Deep Learning

# 16. Robot Ethics: Ethical Design Considerations

# Part IV: Projects

# 17. Robot Hexapod Build Labs

# 18. Deployment of Advanced Robotic Solutions: The ROS Mobile Manipulator Laboratories