# Design Aspects for Advanced Robot Hands: Sensory System

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## 1 Introduction

Dexterous manipulation requires devices provided with a suitable mechanical structure as well as an adequate sensory system. In fact, manipulating an object needs precise information about the configuration of the hand and the state of the interaction with the environment (typically the grasped object), and often the success (or simply the completion time) of the task depends on the level of this information.
Starting from the observation of the human hand, in Sec. 2 we outline the desirable features of a dexterous robot end-effector, in terms of manipulation capabilities. In Sec. 3 we inspect the sensing technologies currently available, and in particular, in Sec. 4, we focus on force and tactile sensors, which at the moment are the most debated topic in the field of sensors for robotic manipulation. In Sec. 5 and 6 we describe some tangible examples of this kind of transducers, as well as their application in dexterous manipulation in order to accomplish slip detection of grasped objects. Finally, we draw some conclusions about the choice of a suitable sensory equipment for a robot hand by means of a comparative analysis of the solutions adopted in some noticeable examples of dexterous end-effectors.

## 2 From human to robot hands

The human hand is the best example of dexterous end-effector we deal with and therefore it is often used as model and benchmark for robot hands. It is not an accident that the term *anthropomorphic* is so widely used in robotics. Not only the structure of the human hand but also its sensory system appears to be very effective. As a matter of fact, many researchers tend to adopt similar sensory configurations in devices, which are often quite simple from the mechanical point of view and not anthropomorphic at all; this is the case of the ROTEX Gripper [1], whose equipment includes position, force and tactile sensors. In this sense it is possible to extend the meaning of term *anthropomorphism* to the sensory system; a dexterous manipulation device can not be considered fully anthropomorphic, despite its shape and its mechanical structure mimic the human hand, if not equipped with an adequate sensing apparatus.
The internal state of the human hand (position, velocity and force) is known by means of receptors collocated in the muscles, tendons, and joint capsule. But one of the reasons of the dexterity of our hand are cutaneous information (high-frequencies vibrations, small scale shape or pressure distribution, thermal properties). As a matter of fact, it has been shown that the lack of touch sensation, due for example to thick gloves (e.g. in space) degrades the human ability and prolongs the task completion time up to 80%, [23].

Two are the main skills of a human hand:

- *prehension*, such as the hand's ability to grasp and take hold of objects;
- *apprehension*, or the hand's ability to understand through active touch.

In this sense the human hand is both an *input* and *output* device [see [16]]. As output device, it can apply forces in order to obtain stable grasps or perform some procedures of manipulation, while as input device, besides providing information about the state of the interaction with the object during the task, the hand is capable to explore an unknown environment. The same characteristics should be desirable in advanced robot hands; as a matter of fact, the application of robotic systems in unstructured servicing environments requires dexterous manipulation abilities and facilities to execute complex operations in a flexible way. Moreover, considering the possibility of

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**Design Aspects For Advanced Robot Hands:**

**ROMANSY 21 - Robot Design, Dynamics and Control** Vincenzo Parenti-Castelli,Werner Schiehlen,2016-06-29 This proceedings volume contains papers that have been selected after review for oral presentation at ROMANSY 2016 the 21th CISM IFToMM Symposium on Theory and Practice of Robots and Manipulators These papers cover advances on several aspects of the wide field of Robotics as concerning Theory and Practice of Robots and Manipulators ROMANSY 2016 is the 21st event in a series that started in 1973 as one of the first conference activities in the world on Robotics The first event was held at CISM International Centre for Mechanical Science in Udine Italy on 5 8 September 1973 It was also the first topic conference of IFToMM International Federation for the Promotion of Mechanism and Machine Science and it was directed not only to the IFToMM community Theoretical Biomechanics Vaclav Klika,2011-11-25 During last couple of years there has been an increasing recognition that problems arising in biology or related to medicine really need a multidisciplinary approach For this reason some special branches of both applied theoretical physics and mathematics have recently emerged such as biomechanics mechanobiology mathematical biology biothermodynamics This first section of the book General notes on biomechanics and mechanobiology comprises from theoretical contributions to Biomechanics often providing hypothesis or rationale for a given phenomenon that experiment or clinical study cannot provide It deals with mechanical properties of living cells and tissues mechanobiology of fracture healing or evolution of locomotor trends in extinct terrestrial giants The second section Biomechanical modelling is devoted to the rapidly growing field of biomechanical models and modelling approaches to improve our understanding about processes in human body The last section called Locomotion and joint biomechanics is a collection of works on description and analysis of human locomotion joint stability and acting forces

Robot Grippers Gareth J. Monkman,Stefan Hesse,Ralf Steinmann,Henrik Schunk,2007-02-27 Since robotic prehension is widely used in all sectors of manufacturing industry this book fills the need for a comprehensive up to date treatment of the topic As such this is the first text to address both developers and users dealing as it does with the function design and use of industrial robot grippers The book includes both traditional methods and many more recent developments such as micro grippers for the optolectronics industry Written by authors from academia industry and consulting it begins by covering the four basic categories of robotic prehension before expanding into sections dealing with endeffector design and control robotic manipulation and kinematics Later chapters go on to describe how these various gripping techniques can be used for a common industrial aim with details of related topics such as kinematics part separation sensors tool excahnge and compliance The whole is rounded off with specific examples and case studies With more than 570 figures this practical book is all set to become the standard for advanced students researchers and manufacturing engineers as well as designers and project managers seeking practical descriptions of robot endeffectors and their applications **5th Kuala Lumpur International Conference on Biomedical Engineering 2011** Hua-Nong Ting,2011-06-17 The Biomed 2011 brought

together academicians and practitioners in engineering and medicine in this ever progressing field This volume presents the proceedings of this international conference which was hold in conjunction with the 8th Asian Pacific Conference on Medical and Biological Engineering APCMBE 2011 on the 20th to the 23rd of June 2011 at Berjaya Times Square Hotel Kuala Lumpur The topics covered in the conference proceedings include Artificial organs bioengineering education bionanotechnology biosignal processing bioinformatics biomaterials biomechanics biomedical imaging biomedical instrumentation BioMEMS clinical engineering prosthetics **The Human Hand as an Inspiration for Robot Hand Development** Ravi Balasubramanian,Veronica J. Santos,2014-01-03 The Human Hand as an Inspiration for Robot Hand Development presents an edited collection of authoritative contributions in the area of robot hands The results described in the volume are expected to lead to more robust dependable and inexpensive distributed systems such as those endowed with complex and advanced sensing actuation computation and communication capabilities The twenty four chapters discuss the field of robotic grasping and manipulation viewed in light of the human hand s capabilities and push the state of the art in robot hand design and control Topics discussed include human hand biomechanics neural control sensory feedback and perception and robotic grasp and manipulation This book will be useful for researchers from diverse areas such as robotics biomechanics neuroscience and anthropologists **Flexible Robotics** Mathieu Grossard,Nicolas Chaillet,Stephane Regnier,2013-08-05 The objective of this book is to provide those interested in the field of flexible robotics with an overview of several scientific and technological advances in the practical field of robotic manipulation The different chapters examine various stages that involve a number of robotic devices particularly those designed for manipulation tasks characterized by mechanical flexibility Chapter 1 deals with the general context surrounding the design of functionally integrated microgripping systems Chapter 2 focuses on the dual notations of modal commandability and observability which play a significant role in the control authority of vibratory modes that are significant for control issues Chapter 3 presents different modeling tools that allow the simultaneous use of energy and system structuring notations Chapter 4 discusses two sensorless methods that could be used for manipulation in confined or congested environments Chapter 5 analyzes several appropriate approaches for responding to the specific needs required by versatile prehension tasks and dexterous manipulation After a classification of compliant tactile sensors focusing on dexterous manipulation Chapter 6 discusses the development of a complying triaxial force sensor based on piezoresistive technology Chapter 7 deals with the constraints imposed by submicrometric precision in robotic manipulation Chapter 8 presents the essential stages of the modeling identification and analysis of control laws in the context of serial manipulator robots with flexible articulations Chapter 9 provides an overview of models for deformable body manipulators Finally Chapter 10 presents a set of contributions that have been made with regard to the development of methodologies for identification and control of flexible manipulators based on experimental data Contents 1 Design of Integrated Flexible Structures for Micromanipulation Mathieu Grossard Mehdi Boukallel St phane R gnier and Nicolas

Chaillet 2 Flexible Structures Representation and Notable Properties in Control Mathieu Grossard Arnaud Hubert St phane R gnier and Nicolas Chaillet 3 Structured Energy Approach for the Modeling of Flexible Structures Nandish R Calchand Arnaud Hubert Yann Le Gorrec and Hector Ramirez Estay 4 Open Loop Control Approaches to Compliant Micromanipulators Yassine Haddab Vincent Chalvet and Micky Rakotondrabe 5 Mechanical Flexibility and the Design of Versatile and Dexterous Grippers Javier Martin Amezaga and Mathieu Grossard 6 Flexible Tactile Sensors for Multidigital Dexterous In hand Manipulation Mehdi Boukallel Hanna Yousef Christelle Godin and Caroline Coutier 7 Flexures for High Precision Manipulation Robots Reymond Clavel Simon Henein and Murielle Richard 8 Modeling and Motion Control of Serial Robots with Flexible Joints Maria Makarov and Mathieu Grossard 9 Dynamic Modeling of Deformable Manipulators Fr d ric Boyer and Ayman Belkhiri 10 Robust Control of Robotic Manipulators with Structural Flexibilities Houssem Halalchi Lo c Cuvillon Guillaume Merc re and Edouard Laroche About the Authors Mathieu Grossard CEA LIST Gif sur Yvette France Nicolas Chaillet FEMTO ST Besan on France St phane R gnier ISIR UPMC Paris France *Shape Memory Alloys* Corneliu Cismasiu,2010-10-18 In the last decades the Shape Memory Alloys with their peculiar thermo mechanical properties high corrosion and extraordinary fatigue resistance have become more popular in research and engineering applications This book contains a number of relevant international contributions related to their properties constitutive models and numerical simulation medical and civil engineering applications as well as aspects related to their processing *Dextrous Robot Hands* Subramanian T. Venkataraman,Thea Iberall,2012-12-06 Manipulation using dextrous robot hands has been an exciting yet frustrating research topic for the last several years While significant progress has occurred in the design construction and low level control of robotic hands researchers are up against fundamental problems in developing algorithms for real time computations in multi sensory processing and motor control The aim of this book is to explore parallels in sensorimotor integration in dextrous robot and human hands addressing the basic question of how the next generation of dextrous hands should evolve By bringing together experimental psychologists kinesiologists computer scientists electrical engineers and mechanical engineers the book covers topics that range from human hand usage in prehension and exploration to the design and use of robotic sensors and multi fingered hands and to control and computational architectures for dextrous hand usage While the ultimate goal of capturing human hand versatility remains elusive this book makes an important contribution to the design and control of future dextrous robot hands through a simple underlying message a topic as complex as dextrous manipulation would best be addressed by collaborative interdisciplinary research combining high level and low level views drawing parallels between human studies and analytic approaches and integrating sensory data with motor commands As seen in this text success has been made through the establishment of such collaborative efforts The future will hold up to expectations only as researchers become aware of advances in parallel fields and as a common vocabulary emerges from integrated perceptions about manipulation *Approaching Human Performance* Markus Grebenstein,2014-01-24 Humanoid

robotics have made remarkable progress since the dawn of robotics So why don t we have humanoid robot assistants in day to day life yet This book analyzes the keys to building a successful humanoid robot for field robotics where collisions become an unavoidable part of the game The author argues that the design goal should be real anthropomorphism as opposed to mere human like appearance He deduces three major characteristics to aim for when designing a humanoid robot particularly robot hands Robustness against impacts Fast dynamics Human like grasping and manipulation performance Instead of blindly copying human anatomy this book opts for a holistic design methodology It analyzes human hands and existing robot hands to elucidate the important functionalities that are the building blocks toward these necessary characteristics They are the keys to designing an anthropomorphic robot hand as illustrated in the high performance anthropomorphic Awiwi Hand presented in this book This is not only a handbook for robot hand designers It gives a comprehensive survey and analysis of the state of the art in robot hands as well as the human anatomy It is also aimed at researchers and roboticists interested in the underlying functionalities of hands grasping and manipulation The methodology of functional abstraction is not limited to robot hands it can also help realize a new generation of humanoid robots to accommodate a broader spectrum of the needs of human society Scientific and Technical Aerospace Reports ,1995 Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database Grippers in Motion Andreas Wolf,Ralf Steinmann,Henrik Schunk,2006-02-08 Grippers in Motion provides a comprehensive practice oriented guide to the fascinating details of automation processes involving gripping and manipulation This intriguing and colorful book leads the reader from the history of automation and robotics to the fundamentals of the gripping process as well as the interaction of the gripping process with individual workpieces Boundary conditions and initial situation of the gripping process are defined and how subsequent motion follows gripping is shown The implementation of these motion processes from simple linear motions to the kinematics of multiple axes is illustrated in a practical way This practical introduction motivates students and even professionals to learn more about the world of robotic grippers Grippers in Motion includes a spectrum of real world applications demonstrating the possibilities and varieties of automation in practice **Intelligent Computing Techniques and Applications** Tusharkanta Samal,Ambarish Panda,Manas Ranjan Kabat,Ali Ismail Awad,Suvendra Kumar Jayasingh,Deepak K Tosh,2025-08-19 This Taylor Francis CRC Press volume contains the papers presented at the International Conference on Emerging Trends in Intelligent Computing Techniques ICETICT 2024 held during 27th and 28th December 2024 organized by DRIEMS University Tangi Cuttack Odisha India A lot of challenges at us and no words of appreciation is enough for the organizing committee who could still pull it off successfully The conference draws the excellent technical keynote talk and many papers The keynote talks by Prof Sanjeevikumar Padmanaban University of South Eastern Norway and Prof Bidyadhar Subudhi Director NIT Warangal are worth mentioning We are grateful to all the

speakers for accepting our invitation and sparing their time to deliver the talks Robotic Mechanical Systems Fundamentals Shridhar Shastri,2025-02-20 Robotic Mechanical Systems Fundamentals serves as a comprehensive guide to understanding the core principles and technological intricacies of robotic systems in today s rapidly evolving landscape We offer an in depth exploration of the mechanical foundations that drive the design control and functionality of robots making it an essential resource for students researchers and industry professionals Our journey begins with a thorough examination of the fundamental concepts and historical developments that shape robotics Readers will gain insights into the dynamics of robotic systems through the Newton Euler equations paving the way for a deeper understanding of the Lagrange formulation which offers a powerful framework for analyzing robot motion Focusing on dynamic modeling we provide a detailed look at the mechanisms governing the behavior of manipulators emphasizing the complexities involved in designing and controlling robotic arms Additionally we address control forces and torques highlighting strategies to ensure precision and efficiency in robotic actions With a holistic approach that considers the ethical and societal implications of robotics Robotic Mechanical Systems Fundamentals balances theoretical foundations with practical applications making it accessible for beginners and valuable for seasoned professionals Authored by experts our book equips readers to navigate the fascinating world of robotics inspiring a deeper appreciation for the technologies that shape our future Springer Handbook of Robotics Bruno Siciliano,Oussama Khatib,2016-07-27 The second edition of this handbook provides a state of the art overview on the various aspects in the rapidly developing field of robotics Reaching for the human frontier robotics is vigorously engaged in the growing challenges of new emerging domains Interacting exploring and working with humans the new generation of robots will increasingly touch people and their lives The credible prospect of practical robots among humans is the result of the scientific endeavour of a half a century of robotic developments that established robotics as a modern scientific discipline The ongoing vibrant expansion and strong growth of the field during the last decade has fueled this second edition of the Springer Handbook of Robotics The first edition of the handbook soon became a landmark in robotics publishing and won the American Association of Publishers PROSE Award for Excellence in Physical Sciences Mathematics as well as the organization s Award for Engineering Technology The second edition of the handbook edited by two internationally renowned scientists with the support of an outstanding team of seven part editors and more than 200 authors continues to be an authoritative reference for robotics researchers newcomers to the field and scholars from related disciplines The contents have been restructured to achieve four main objectives the enlargement of foundational topics for robotics the enlightenment of design of various types of robotic systems the extension of the treatment on robots moving in the environment and the enrichment of advanced robotics applications Further to an extensive update fifteen new chapters have been introduced on emerging topics and a new generation of authors have joined the handbook s team A novel addition to the second edition is a comprehensive collection of multimedia references to more than 700 videos which bring valuable insight into the contents

The videos can be viewed directly augmented into the text with a smartphone or tablet using a unique and specially designed app Springer Handbook of Robotics Multimedia Extension Portal http handbookofrobotics org **Human and Robot Hands** Matteo Bianchi,Alessandro Moscatelli,2016-02-24 This book looks at the common problems both human and robotic hands encounter when controlling the large number of joints actuators and sensors required to efficiently perform motor tasks such as object exploration manipulation and grasping The authors adopt an integrated approach to explore the control of the hand based on sensorimotor synergies that can be applied in both neuroscience and robotics Hand synergies are based on goal directed combined muscle and kinematic activation leading to a reduction of the dimensionality of the motor and sensory space presenting a highly effective solution for the fast and simplified design of artificial systems Presented in two parts the first part Neuroscience provides the theoretical and experimental foundations to describe the synergistic organization of the human hand The second part Robotics Models and Sensing Tools exploits the framework of hand synergies to better control and design robotic hands and haptic sensing systems tools using a reduced number of control inputs sensors with the goal of pushing their effectiveness close to the natural one Human and Robot Hands provides a valuable reference for students researchers and designers who are interested in the study and design of the artificial hand

**Advances in Mechatronics and Biomechanics towards Efficient Robot Actuation** Jörn Malzahn,Navvab Kashiri,Monica Daley,Nikos Tsagarakis,2019-06-28 *Human-Like Advances in Robotics: Motion, Actuation, Sensing, Cognition and Control* Tadej Petric,Kosta Jovanovic,Toshiaki Tsuji,Calogero Maria Oddo,2019-12-24 *Intelligent Robotic Systems* Spyros G. Tzafestas,2020-08-27 A multiplicity of techniques and angles of attack are incorporated in 18 contributions describing recent developments in the structure architecture programming control and implementation of industrial robots capable of performing intelligent action and decision making Annotation copyright Book *The Mechanical Systems Design Handbook* Yildirim Hurmuzlu,Osita D.I. Nwokah,2017-12-19 With a specific focus on the needs of the designers and engineers in industrial settings The Mechanical Systems Design Handbook Modeling Measurement and Control presents a practical overview of basic issues associated with design and control of mechanical systems In four sections each edited by a renowned expert this book answers diverse questions fundamental to the successful design and implementation of mechanical systems in a variety of applications Manufacturing addresses design and control issues related to manufacturing systems From fundamental design principles to control of discrete events machine tools and machining operations to polymer processing and precision manufacturing systems Vibration Control explores a range of topics related to active vibration control including piezoelectric networks the boundary control method and semi active suspension systems Aerospace Systems presents a detailed analysis of the mechanics and dynamics of tensegrity structures Robotics offers encyclopedic coverage of the control and design of robotic systems including kinematics dynamics soft computing techniques and teleoperation Mechanical systems designers and engineers have few resources dedicated to their particular and often

unique problems The Mechanical Systems Design Handbook clearly shows how theory applies to real world challenges and will be a welcomed and valuable addition to your library **Advancements in Automation, Robotics and Sensing** B Vinod,Richard Voyles,Prahlad Vadakkepat,M. Sundaram,K S Sujatha,J Joe Brislin,2016-10-22 This book constitutes the thoroughly refereed proceedings of the First International Conference of Advancements in Automation Robotics and Sensing ICAARS 2016 held in Coimbatore India in June 2016 The 83 revised selected papers were selected from 159 submissions and focus on industrial robotics mobile robotics adaptive control vision system smart materials and teleoperation

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**Table of Contents Design Aspects For Advanced Robot Hands**

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