Preface

The load capacity of human itself is limited. However, on many occasions, the human body needs to bear large load, such as earthquake relief, mountain land exploration, and building in mountains. In this case, only relying on the ability of human itself, problems often can not be solved, which has restricted human activities. In order to solve this problem, in addition to minimizing the weight and the size of load, we will naturally consider using external auxiliary devices to help people with heavy load to reduce human's energy consumption. Now, human has developed a lot of auxiliary devices, generally referred to as "exoskeleton", "power-assisted robot", "mechanical leg", "auxiliary leg", etc. Because the exoskeleton is similar to the invertebrates' exoskeleton that can be worn on human body like clothes, so it can be called "exoskeleton suit" very vividly.

The most remarkable characteristics of exoskeleton suit are wearable, operability, and intellectualization. The basic idea of its design is to combine human's intelligence with the strength of machinery: human sends control instruction to exoskeleton suit, and the exoskeleton suit provides the energy for the movement. The man–machine interaction intelligent device is different from the traditional robot, whose control system is controlled by human's consciousness, and by the complementation of people's intelligence and machinery's strength, not only can avoid the mechanical structure's complexity produced when the traditional robot simulates human's intelligence, but also can greatly expand the human body's ability. The ultimate goal of designing exoskeleton suit is to increase the wearer's speed, strength and endurance, and the wearer bearing heavy load can easily complete such actions as walking, running, jumping, squatting, and turning off, also the heaviness felt by the wearer being reduced significantly, the load of dozens of kilograms being felt like a few kilograms. The perfect coupling between human and exoskeleton suit conforms to the human body's engineering standard, safe and reliable, easy to operate and achieved the harmony and complementation of human and the machine. The appearance of exoskeleton suit is the innovation of transportation modes, which breaks through the limitation of traditional vehicles affected by terrain conditions easily. In the regions not suitable for marching of motor vehicles, such as rugged mountains and dense jungle, the exoskeleton suit can help

people carry heavy load. Because it can significantly reduce the wearer's heaviness and save the wearer's physical power, so it can effectively improve human's mobility and continuous movement capacity; therefore, it will have a broad application prospect.

Although it has been for more than 50 years since the concept of exoskeleton suit was put forward and the birth of the first set of exoskeleton system, it is in the late 1990s that the exoskeleton system research was in full swing. Internationally, the United States, Japan, France, South Korea, Israel, and etc. have developed prototypes for demonstration, and many other countries have researched in some key technology areas of exoskeleton suit. Among them, the United States, Japan, and South Korea are most outstanding, whose technologies are most advanced, closest to the practical. Domestic study in exoskeleton suit began in about 2004, and Zhejiang University, Harbin Industrial University, Naval Aeronautical Engineering Institute, Soldier Systems Center of PLA General Logistics Department, and East China University of Science and Technology are the institutes that have started the research earlier. Then, Southeast University, Beijing Institute of Technology, Nanjing University of Science and Technology, Ordnance Industry Group, Tengzhong Aviation Electronics co. Ltd., and some other scientific research and teaching institutions have entered this field. Because the system involves the mechanical design, drive mode, control method, intelligent sense, power conversion, signal analysis, and some other disciplines and fields, and especially, the system is a complex man–machine coupling system, so it has played an important role in the teaching and scientific research. But due to a late start, compared with the research level of developed countries, we have been left behind.

Naval Aeronautical Engineering Academy in which the book's authors work is one of the institutes that have started the research earliest. And the authors have been in the research group, having a comprehensive understanding in the research of exoskeleton suit, and having got some certain research results on the research of exoskeleton suit's control methods. The publication of the book is desired to promote the development of the exoskeleton suit system.

This book introduces one of the key technologies of exoskeleton suit, namely the control method, and focuses on the force control theory and method based on multidimensional force/torque sensor. This book consists of eight chapters. Chapter 1, the introduction, introduces the concept and background of exoskeleton suit and analyzes the research status of exoskeleton suit home and abroad, the development status of exoskeleton suit's control method. Chapter 2 is the modeling basis of this book, in which the exoskeleton suit's mathematical models of kinematics and dynamics have been established. Chapter 3 introduces and analyzes the sensitivity amplification control methods of exoskeleton suit. From Chaps. 4 to 8, the force control methods of exoskeleton suit based on multidimensional force/torque sensors have been introduced. Among them, Chap. 4 analyzes the direct force control method of exoskeleton suit; Chap. 5 analyzes the force control method of exoskeleton suit based on the inner position loop; Chap. 6 analyzes the impedance control method of exoskeleton suit; Chap. 7 analyzes the impedance control method of exoskeleton suit

with uncertainty; and Chap. 8 introduces the impedance control method of using neural network to estimate the exoskeleton suit's reference trajectory.

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The research on exoskeleton suit system is an important and continuously developing research direction. The research of this book on exoskeleton suit concentrates on its force control technology, and for the comprehensive and practical research on the whole system, we still have a lot of work to do. We hope there are more scholars paying attention to the challenging research, having the related issues in this field studied further. Being constrained by authors' knowledge level, there must be many defects and mistakes in this book, and please do not spare your comments.

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