Control, Robotics and Sensors Series 99

Practical Robotics and Mechatronics

Marine, Space and Medical Applications

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Practical Robotics and Mechatronics

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Preface

The world is experiencing the beginning of a revolution in robotics and mechatronics. A key part of this revolution is integration with IoT (Internet of Things), this networking of robotics and mechatronics will represent significant market opportunities.

The author engages in developing technologies using IoT-based intelligent robotics using several effective applications as examples. The successful development of practical robotics and mechatronics must begin from consideration of IoT and/or the M2M (Machine To Machine) interface.

The author has developed many world-class practical examples of robotics and mechatronics during his 30 years of experience as an engineer and a professor. The author's experience comprises working with Mitsubishi Heavy Industries Ltd. (20 years), JAMSTEC (3 years), and as a professor at Kyushu, Kitakyushu, and Nagasaki University (10 years). Most of the robotics and mechatronics developed continue to be used safely. Such an experience of development inherently creates new ideas for robotic applications. Based on the author's experience, important ways of thinking and technologies essential to produce successful robotics and mechatronics are summarized in this book.

The author hopes that this book can provide fruitful hints for developing new robotics and mechatronics that will lead to new and successful business opportunities.

Ikuo Yamamoto, Dr. Eng.,
Nagasaki, Japan

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Chapter 1
Introduction

There is a high demand for developing robotics and mechatronics around the world. The market for robotics and mechatronics continues to expand, and is expected to be an increasing business field. The market needs practical robotics and mechatronics, which meet societal demands.

How can we develop a new practical robotics and mechatronics?

The author has developed practical robotics and mechatronics during his 20 years or so at Mitsubishi Heavy Industries, Ltd., and has invented many products, such as a 10000-m operating depth capable unmanned remotely operated vehicle (ROV), called Kaiko; a manned underwater vehicle, the Shinkai 6500; a hydrofoil catamaran called Rainbow; an air cushion surface effect ship, the Techno Super Liner; the intelligent ship, the Super Joy; a dynamic positioning system (DPS) of offshore platform, like the bridge construction vessels UMASHIMA and CHIKYU; a riser entry system, robotic fish; the B787 main wing, a regional jet. The author was the project leader of the autonomous underwater vehicle (AUV) Urashima, which established a world record for autonomous continuous cruising in 2005. In addition, as a university professor for over 10 years, the author has developed intelligent robotics such as robotic fish, a multirotor aviation system, medical robotics, and space robotics. Particularly – true story! – one of the author's robotic fish swam in space.

This book can provide hints for solutions to developing new robotics and mechatronics which are intelligent and practical.

Robotics is defined as 'an intelligent machine system which consists of sensors, actuators, and a controller'. If robotics is compared to humans, the relationship of sensors, actuators, and a control device can be summarized as shown in Figure 1.1.

Sensors are the devices that feel or sense the outer and inner states of the robot, similar to the eyes, ears, nose, and pressure/temperature points of the skin in a human body. Actuators are the devices that actuate parts of the body, just like the hands, feet, and mouth. A controller is the device that makes decisions according to the sensor information and other data, and gives commands to the actuators to move (or stop), as in the brain of a human.

Mechatronics is defined as 'mechanics with an electrical circuit'. Mechatronics is originally a Japanese-made English word, which is a mixture of mecha(nics) and (elec)tronics. Robotics is composed of mechatronics, as shown in Figure 1.2.

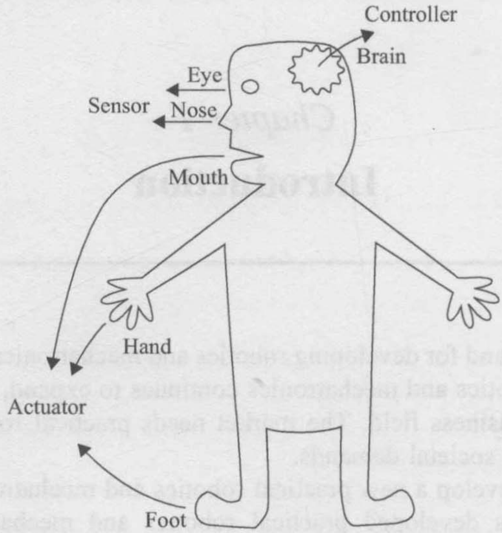

Figure 1.1 Robotic functionality compared to humans

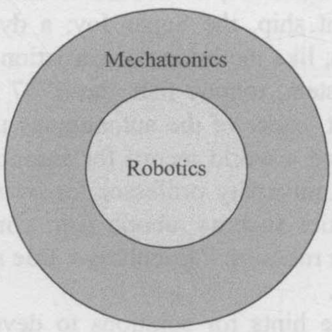

Figure 1.2 Relationship between robotics and mechatronics

Robotics and mechatronics consist of many fundamental technologies, such as mechanics, electronics, electrical engineering, and information technology. Fundamental technologies sometimes come from economics, medicine, agriculture, fishery, literature, and other scientific subjects. The author refers to such technologies as 'universal knowledge', where 'universal' provides the root word of 'university'. That is, the knowledge important for robotics and mechatronics are subjects which students learn during their undergraduate terms at university.

The basic procedure to create new robotics and mechatronics can be summarized as shown in Figure 1.3.

Fundamental technologies and their integrated systems produce seeds for robotic and mechatronic inventions. Customers outline their needs, and the result is the development of new robotics and mechatronics.

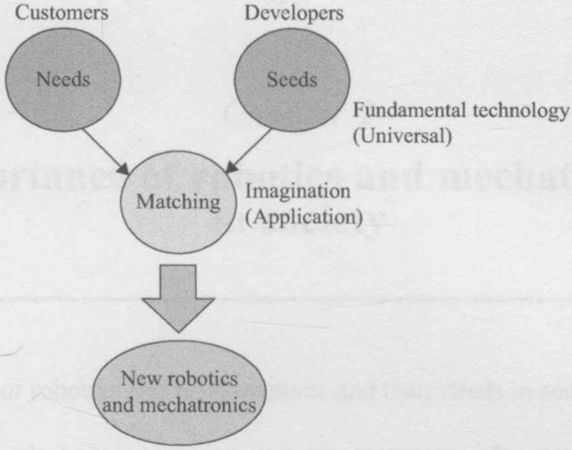

Figure 1.3 Basic procedure to create new robotics and mechatronics

It is important to develop new robotic and mechatronic mechanisms to meet customers' requests, and to be creative and highly functional. In addition, the Japanese methods of manufacturing are well suited to the development of new robotics and mechatronics.

There is a Japanese word, *osekkai*, which means 'interference and meddlesomeness from goodwill'. Development of robotics and mechatronics usually involves group work, and it is important that each engineer is not only professional in one element of technology but also mindful of other fields of technology, and entirely covers all fields of robotic and mechatronic development in the group.

Chapter 2

Importance of robotics and mechatronics in society

Classification of robotics and mechatronics, and their needs in society are outlined in this chapter.

Robotics and mechatronics penetrate into every part of society. The definition of robotics is as follows: 'Robotics is a system of intelligent machinery which consists of sensors, actuators, and a controller.' The definition of mechatronics is 'mechanics including an electrical circuit'.

You can find various robotics and mechatronics in society. If you look around the room, you can find several examples of robotics and mechatronics. For example, an air conditioner is robotic. It is an intelligent machine which has a sensor (thermometer), actuator (air emission machine), and controller (microcomputer for adjustment of temperature). Similarly, a vacuum cleaner is robotic, or at least mechatronic. Some recent vacuum cleaners can avoid obstacles automatically by sensing and conduct a cleaning mission by itself.

If you go to an airport, you sometimes find a human-like robotic guide. The boarding gate, which does not look like a human, is very robotic. It can sense barcode information of boarding slips and guide passengers to the airplane automatically.

There are various types of robotics and mechatronics in society, and robotics and mechatronics help people with their daily lives. Generally, robotics can be classified into the following categories:

- 'Service robots', which focus on providing convenience. Robotic navigation for local directions, car navigation guidance robots in town, and in-vehicle navigation robots belong to this category.
- 'Amusement robots', which entertain people. Humanoid robots, dog robots, and fish robots, which were created earlier in Japan, belong to this category.
- 'Industrial robots', which work in factories carrying out hazardous manufacturing operations and monotonous work in place of people. A welding robot on an automobile manufacturing line is representative of this category. Industrial robots that focus on specific tasks, such as a welding robot, provide only a human arm- and hand-like function.

Chapter 3

How to create practical robotics and mechatronics

The experiential methods and basic ideas to create practical robotics and mechatronics are presented in this chapter.

Robotics and mechatronics are based on several technologies. The most important technologies are mechanics, electronics, electrical engineering, and information technology. A prominent person sometimes creates and develops robotics and mechatronics alone; however, it is rare for a single person to produce them to a marketable level. Usually, a team is organized by engineers from mechanics, electronics, software, manufacturing, and business persons who direct the product development to the market. The author has experienced, that the optimal number of people to create new robotics and mechatronics is five.

The individual and team experience in developing robotics and mechatronics becomes 'treasure', which contains both successes and failures. The development of one field of robotics and mechatronics leads to the development of other fields; this means they produce cluster technologies that are an accumulation of technological development and result in increased business in various markets. Development of industrial products is divided into two groups, which are 'sustainable development' and 'evolutional development'. Sustainable development is intended to improve and modify established industrial products, whereas evolutional development creates new technologies to surpass conventional products.

Time histories of evolution of both developments can be summarized as in Figure 3.1. Sustainable development is based on significant knowledge and experience. It sometimes encounters failures during development, but they can be solved quickly with experience. Evolutional development has potential of high evaluation, but it involves risk of failure due to a lack of experience. If substantial failure occurs during development, the evaluation becomes zero and developers are compelled to suspend or stop the development. The important thing to do in this case is to maintain 'positive motivation' and carefully analyse the cause of failure.

The author invented a life-like sea bream robotic fish in 1995 (the first of its kind in the world), the first robotic coelacanth in 1997, and a robotic whale in 1998; however, we suffered a failure when the new robotic coelacanth was demonstrated to the public in 2000. We could not know the reason why it did not swim at the time of presentation, and the evaluation went down to zero. Afterwards, through failure analysis, we found that the reason was a heat problem in the battery

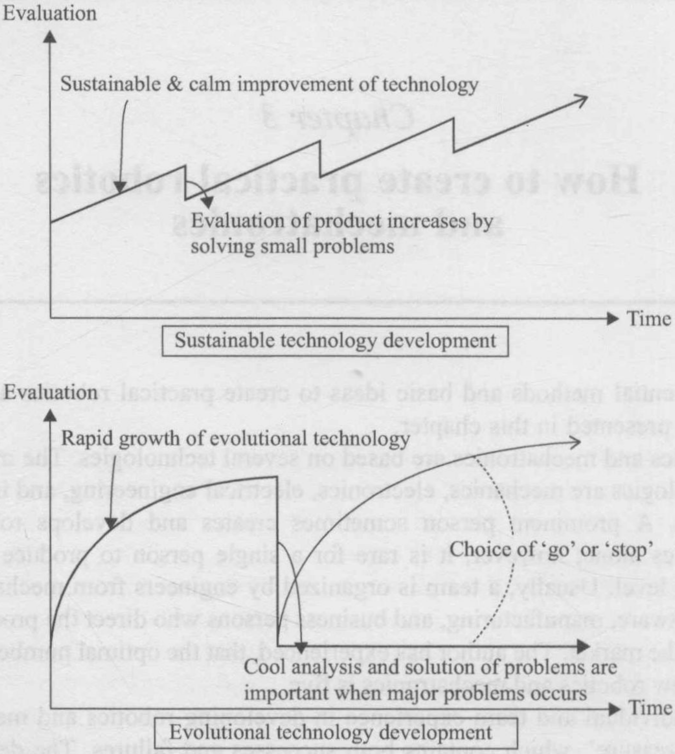

Figure 3.1 Sustainable technology and evolutional technology

caused by the TV cameras' strong light. The skin of the robotic fish around the battery was very thin and influenced by the heat of light. On the basis of this failure we have produced more robust robotic fish resulting in receiving a higher level of evaluation.

The author developed over 16 kinds of robotic fish and the fundamental mechanism went through four evolutions of change. The author encounters failures when a new mechanism is used; however, the problems can be overcome by positive motivation and a cool theoretical mind.

The newly developed robotics and mechatronics are called a 'prototype' model. Production of the actual products starts after confirmation of specification through practical tests of the prototype model. Most of the products which the author developed have been successful. The author has the experience and principles shown in Figure 3.2 according to the various successes and occasional failures.

That is, development of a new model starts over the wall of possibility (which is 3% of completeness), development of products is fully in progress over the wall of realization (which is 70% of completeness), and complete over the wall of reliance (which is 99% of completeness). The products are on the market after clearing all three walls. A feasibility study (FS) is conducted from the wall of possibility to that