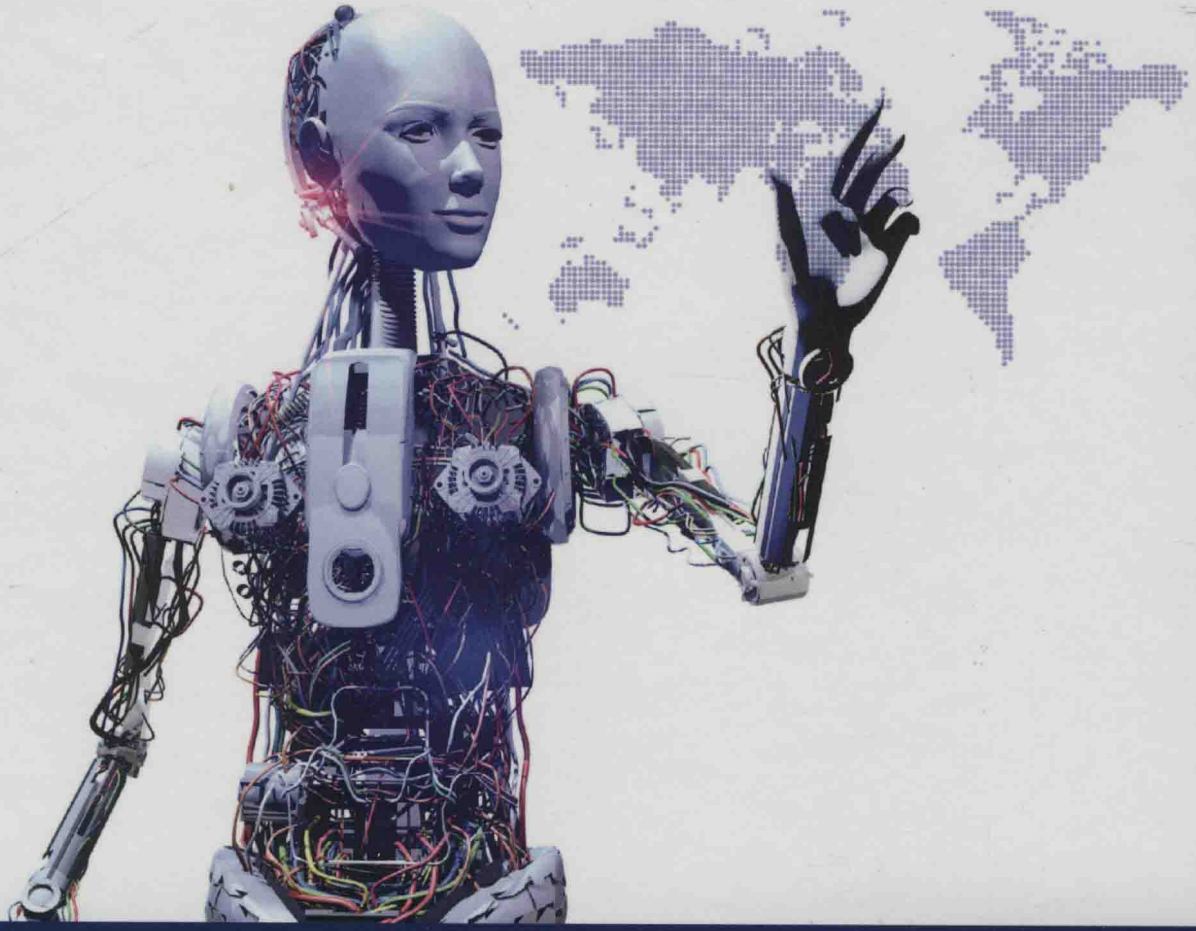

Introduction to Robotics

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Julian Evans

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Introduction to Robotics

Preface

Robotics is an amalgamation of fields like computer science, mechanical engineering and electrical engineering. It is concerned with the design, construction and programming of robots. It is also used to control, process information and obtain sensory feedback from computer systems. Most of the topics introduced in this book cover new techniques and the applications of robotics. It is compiled in such a manner, that it will provide in-depth knowledge about the theory and practice of this subject. The book studies, analyses and uphold the pillars of robotics and its utmost significance in modern times. As this field is emerging at a rapid pace, the contents of this textbook will help the readers understand the modern concepts and applications of the subject. It will serve as a reference to a broad spectrum of readers.

To facilitate a deeper understanding of the contents of this book a short introduction of every chapter is written below:

Chapter 1- The branch of science that involves mechanical engineering, computer science and similar subjects for the manufacture of robots and other computer systems that have advanced sensory capabilities and some form of artificial intelligence is known as robotics. This chapter will provide an integrated understanding of robotics.

Chapter 2- Robotics has a number of branches; some of these branches are artificial intelligence, android science, nanorobotics, laboratory robotics, cognitive robotics and robot locomotion. The intelligence displayed by machines is known as artificial intelligence. Nanorobotics is a technology used for creating machines or robots. The section is a compilation of the various branches of robotics that form an integral part of the broader subject matter.

Chapter 3- The principles and laws of robotics are degrees of freedom, roboethics, humanoid, cyborg, laws of robotics and three laws of robotics. Robot ethics, also known as roboethics, deals with the ethical questions such as for example, whether robots pose a threat to humans or not. The topics discussed in the chapter are of great importance to broaden the existing knowledge on robotics.

Chapter 4- Robotics deals with the design and the use of robots. The significant aspects of robotics are telerobotics, behavior-based robotics, evolutionary robotics, developmental robotics and rehabilitation robotics. This section is a compilation of the significant aspects of robotics that form an integral part of the broader subject matter.

Chapter 5- Bionics, shadow hand and robot-assisted surgery are some of the main applications and prototypes of robotics. Bionics is the applicability of the systems

that are found in nature, these systems are mostly applied to the study and design of engineering whereas dexterous hand is a robot system created in the form of a hand and is used commercially. The chapter serves as a source to understand the applications and prototypes of robotics.

Chapter 6- Robots are best understood in confluence with the major topics listed in the following chapter. Some of the types of robots discussed are autonomous robots, humanoid robots, androids, industrial robots and mobile robots. Mobile robots are robots that are capable of moving themselves. Humanoid robot, as the name also suggests is built to look exactly like the human body. This section helps the reader in understanding all the types of robots and their functions.

Chapter 7- ASIMO is a humanoid robot. The basic purpose of ASIMO was to help people who lack movement. It is also used to exhibit and encourage the study of science and mathematics. The chapter encourages the reader to understand and to know about the popular robots of our time.

Chapter 8- Robots may seem as a new invention, but they can be traced back to ancient times. Artificial intelligence being used in robots has existed since the 1960s. This text provides an account of the evolution and growth of robotics.

Finally, I would like to thank the entire team involved in the inception of this book for their valuable time and contribution. This book would not have been possible without their efforts. I would also like to thank my friends and family for their constant support.

Editor

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Introduction to Robotics

The branch of science that involves mechanical engineering, computer science and similar subjects for the manufacture of robots and other computer systems that have advanced sensory capabilities and some form of artificial intelligence is known as robotics. This chapter will provide an integrated understanding of robotics.

Robotics is the branch of mechanical engineering, electrical engineering and computer science that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing.

The Shadow robot hand system

These technologies deal with automated machines (robots for short) that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behaviour, and or cognition. Many of today's robots are inspired by nature, contributing to the field of bio-inspired robotics.

The concept of creating machines that can operate autonomously dates back to classical times, but research into the functionality and potential uses of robots did not grow substantially until the 20th century. Throughout history, it has been frequently assumed that robots will one day be able to mimic human behavior and manage tasks

in a human-like fashion. Today, robotics is a rapidly growing field, as technological advances continue; researching, designing, and building new robots serve various practical purposes, whether domestically, commercially, or militarily. Many robots are built to do jobs that are hazardous to people such as defusing bombs, finding survivors in unstable ruins, and exploring mines and shipwrecks. Robotics is also used in STEM (Science, Technology, Engineering, and Mathematics) as a teaching aid.

Etymology

The word *robotics* was derived from the word *robot*, which was introduced to the public by Czech writer Karel Čapek in his play *R.U.R. (Rossum's Universal Robots)*, which was published in 1920. The word *robot* comes from the Slavic word *robota*, which means labour. The play begins in a factory that makes artificial people called *robots*, creatures who can be mistaken for humans – very similar to the modern ideas of androids. Karel Čapek himself did not coin the word. He wrote a short letter in reference to an etymology in the *Oxford English Dictionary* in which he named his brother Josef Čapek as its actual originator.

According to the *Oxford English Dictionary*, the word *robotics* was first used in print by Isaac Asimov, in his science fiction short story "Liar!", published in May 1941 in *Astounding Science Fiction*. Asimov was unaware that he was coining the term; since the science and technology of electrical devices is *electronics*, he assumed *robotics* already referred to the science and technology of robots. In some of Asimov's other works, he states that the first use of the word *robotics* was in his short story *Runaround* (Astounding Science Fiction, March 1942). However, the original publication of "Liar!" predates that of "Runaround" by ten months, so the former is generally cited as the word's origin.

History of Robotics

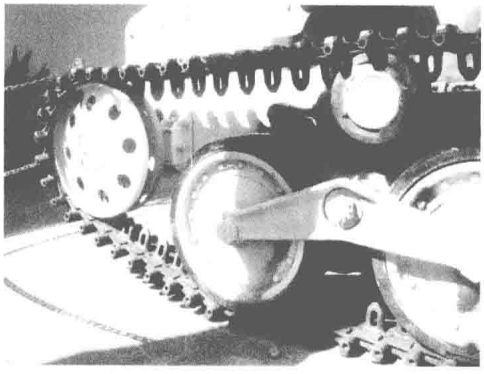
In 1942 the science fiction writer Isaac Asimov created his Three Laws of Robotics.

In 1948 Norbert Wiener formulated the principles of cybernetics, the basis of practical robotics.

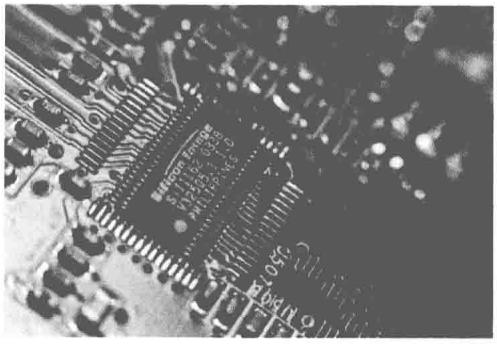
Fully autonomous robots only appeared in the second half of the 20th century. The first digitally operated and programmable robot, the Unimate, was installed in 1961 to lift hot pieces of metal from a die casting machine and stack them. Commercial and industrial robots are widespread today and used to perform jobs more cheaply, more accurately and more reliably, than humans. They are also employed in some jobs which are too dirty, dangerous, or dull to be suitable for humans. Robots are widely used in manufacturing, assembly, packing and packaging, transport, earth and space exploration, surgery, weaponry, laboratory research, safety, and the mass production of consumer and industrial goods.

Date	Significance	Robot Name	Inventor
7000 BC	In Mohanjo-daro, the Dravidian civilization was using bow drills for dentistry. The recent unearthing of the fossil also opens up questions why early Tamils (Thamizh People) needed dentistry. The answer could be the starch, from the cooked ground flour-based food they were consuming.	Dentist bow driller	Early Tamils
Third century B.C. and earlier	One of the earliest descriptions of automata appears in the *Lie Zi* text, on a much earlier encounter between King Mu of Zhou (1023–957 BC) and a mechanical engineer known as Yan Shi, an 'artificer'. The latter allegedly presented the king with a life-size, human-shaped figure of his mechanical handiwork.		Yan Shi (Chinese: 偃师)
First century A.D. and earlier	Descriptions of more than 100 machines and automata, including a fire engine, a wind organ, a coin-operated machine, and a steam-powered engine, in *Pneumatica* and *Automata* by Heron of Alexandria		Ctesibius, Philo of Byzantium, Heron of Alexandria, and others
c. 420 B.C.E	A wooden, steam propelled bird, which was able to fly		Archytas of Tarentum
1206	Created early humanoid automata, programmable automaton band	Robot band, hand-washing automaton, automated moving peacocks	Al-Jazari
1495	Designs for a humanoid robot	Mechanical Knight	Leonardo da Vinci
1738	Mechanical duck that was able to eat, flap its wings, and excrete	Digesting Duck	Jacques de Vaucanson
1898	Nikola Tesla demonstrates first radio-controlled vessel.	Teleautomaton	Nikola Tesla
1921	First fictional automatons called "robots" appear in the play *R.U.R.*	Rossum's Universal Robots	Karel Čapek
1930s	Humanoid robot exhibited at the 1939 and 1940 World's Fairs	Elektro	Westinghouse Electric Corporation
1946	First general-purpose digital computer	Whirlwind	Multiple people
1948	Simple robots exhibiting biological behaviors	Elsie and Elmer	William Grey Walter
1956	First commercial robot, from the Unimation company founded by George Devol and Joseph Engelberger, based on Devol's patents	Unimate	George Devol
1961	First installed industrial robot.	Unimate	George Devol
1973	First industrial robot with six electromechanically driven axes	Famulus	KUKA Robot Group
1974	The world's first microcomputer controlled electric industrial robot, IRB 6 from ASEA, was delivered to a small mechanical engineering company in southern Sweden. The design of this robot had been patented already 1972.	IRB 6	ABB Robot Group
1975	Programmable universal manipulation arm, a Unimation product	PUMA	Victor Scheinman

Robotic Aspects



Robotic construction



Electrical aspect

There are many types of robots; they are used in many different environments and for many different uses, although being very diverse in application and form they all share three basic similarities when it comes to their construction:

1. Robots all have some kind of mechanical construction, a frame, form or shape designed to achieve a particular task. For example, a robot designed to travel across heavy dirt or mud, might use caterpillar tracks. The mechanical aspect is mostly the creator's solution to completing the assigned task and dealing with the physics of the environment around it. Form follows function.

2. Robots have electrical components which power and control the machinery. For example, the robot with caterpillar tracks would need some kind of power to move the tracker treads. That power comes in the form of electricity, which will have to travel through a wire and originate from a battery, a basic electrical circuit. Even petrol powered machines that get their power mainly from petrol still require an electric current to start the combustion process which is why most petrol powered machines like cars, have batteries. The electrical aspect of robots is used for movement (through motors), sensing (where electrical signals are used to measure things like heat, sound, position, and energy status) and operation (robots need some level of electrical energy supplied to their motors and sensors in order to activate and perform basic operations)

3. All robots contain some level of computer programming code. A program is how a robot decides when or how to do something. In the caterpillar track example, a robot that needs to move across a muddy road may have the correct mechanical construction, and receive the correct amount of power from its battery, but would not go anywhere without a program telling it to move. Programs are the core essence of a robot, it could have excellent mechanical and electrical construction, but if its program is poorly constructed its performance will be very poor (or it may not perform at all). There are three different types of robotic programs: remote control, artificial intelligence and hybrid. A robot with remote control programing has a preexisting set of commands that it will only perform if and when it receives a signal from a control source, typically a human being with a remote control. It is perhaps more appropriate to view devices controlled primarily by human commands as falling in the discipline of automation rather than robotics. Robots that use artificial intelligence interact with their environment on their own without a control source, and can determine reactions to objects and problems they encounter using their preexisting programming. Hybrid is a form of programming that incorporates both AI and RC functions.

Applications

As more and more robots are designed for specific tasks this method of classification becomes more relevant. For example, many robots are designed for assembly work, which may not be readily adaptable for other applications. They are termed as "assembly robots". For seam welding, some suppliers provide complete welding systems with the robot i.e. the welding equipment along with other material handling facilities like turntables etc. as an integrated unit. Such an integrated robotic system is called a "welding robot" even though its discrete manipulator unit could be adapted to a variety of tasks. Some robots are specifically designed for heavy load manipulation, and are labelled as "heavy duty robots."

Current and potential applications include:

- Military robots
- Caterpillar plans to develop remote controlled machines and expects to develop fully autonomous heavy robots by 2021. Some cranes already are remote controlled.
- It was demonstrated that a robot can perform a herding task.
- Robots are increasingly used in manufacturing (since the 1960s). In the auto industry they can amount for more than half of the "labor". There are even "lights off" factories such as an IBM keyboard manufacturing factory in Texas that is 100% automated.

- Robots such as HOSPI are used as couriers in hospitals (hospital robot). Other hospital tasks performed by robots are receptionists, guides and porters helpers,
- Robots can serve as waiters and cooks., also at home. Boris is a robot that can load a dishwasher.
- Robot combat for sport – hobby or sport event where two or more robots fight in an arena to disable each other. This has developed from a hobby in the 1990s to several TV series worldwide.
- Cleanup of contaminated areas, such as toxic waste or nuclear facilities.
- Agricultural robots (AgRobots,).
- Domestic robots, cleaning and caring for the elderly
- Medical robots performing low-invasive surgery
- Household robots with full use.
- Nanorobots

Components

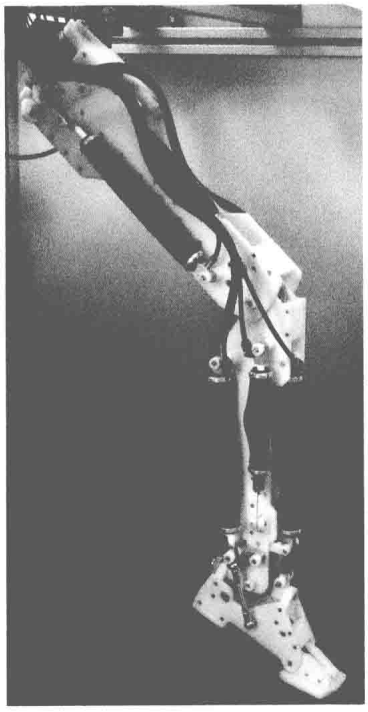
Power Source

At present mostly (lead–acid) batteries are used as a power source. Many different types of batteries can be used as a power source for robots. They range from lead–acid batteries, which are safe and have relatively long shelf lives but are rather heavy compared to silver–cadmium batteries that are much smaller in volume and are currently much more expensive. Designing a battery-powered robot needs to take into account factors such as safety, cycle lifetime and weight. Generators, often some type of internal combustion engine, can also be used. However, such designs are often mechanically complex and need fuel, require heat dissipation and are relatively heavy. A tether connecting the robot to a power supply would remove the power supply from the robot entirely. This has the advantage of saving weight and space by moving all power generation and storage components elsewhere. However, this design does come with the drawback of constantly having a cable connected to the robot, which can be difficult to manage. Potential power sources could be:

- pneumatic (compressed gases)
- Solar power (using the sun's energy and converting it into electrical power)
- hydraulics (liquids)
- flywheel energy storage

- organic garbage (through anaerobic digestion)
- nuclear

Actuation



A robotic leg powered by air muscles

Actuators are the "muscles" of a robot, the parts which convert stored energy into movement. By far the most popular actuators are electric motors that rotate a wheel or gear, and linear actuators that control industrial robots in factories. There are some recent advances in alternative types of actuators, powered by electricity, chemicals, or compressed air.

Electric Motors

The vast majority of robots use electric motors, often brushed and brushless DC motors in portable robots or AC motors in industrial robots and CNC machines. These motors are often preferred in systems with lighter loads, and where the predominant form of motion is rotational.

Linear Actuators

Various types of linear actuators move in and out instead of by spinning, and often have quicker direction changes, particularly when very large forces are needed such as with industrial robotics. They are typically powered by compressed air (pneumatic actuator) or an oil (hydraulic actuator).

Series Elastic Actuators

A spring can be designed as part of the motor actuator, to allow improved force control. It has been used in various robots, particularly walking humanoid robots.

Air Muscles

Pneumatic artificial muscles, also known as air muscles, are special tubes that expand(-typically up to 40%) when air is forced inside them. They are used in some robot applications.

Muscle Wire

Muscle wire, also known as shape memory alloy, Nitinol® or Flexinol® wire, is a material which contracts (under 5%) when electricity is applied. They have been used for some small robot applications.

Electroactive Polymers

EAPs or EPAMs are a new plastic material that can contract substantially (up to 380% activation strain) from electricity, and have been used in facial muscles and arms of humanoid robots, and to enable new robots to float, fly, swim or walk.

Piezo Motors

Recent alternatives to DC motors are piezo motors or ultrasonic motors. These work on a fundamentally different principle, whereby tiny piezoceramic elements, vibrating many thousands of times per second, cause linear or rotary motion. There are different mechanisms of operation; one type uses the vibration of the piezo elements to step the motor in a circle or a straight line. Another type uses the piezo elements to cause a nut to vibrate or to drive a screw. The advantages of these motors are nanometer resolution, speed, and available force for their size. These motors are already available commercially, and being used on some robots.

Elastic Nanotubes

Elastic nanotubes are a promising artificial muscle technology in early-stage experimental development. The absence of defects in carbon nanotubes enables these filaments to deform elastically by several percent, with energy storage levels of perhaps 10 J/cm^3 for metal nanotubes. Human biceps could be replaced with an 8 mm diameter wire of this material. Such compact "muscle" might allow future robots to outrun and outjump humans.

Sensing

Sensors allow robots to receive information about a certain measurement of the envi-