Robotics

١.١ Introduction

Robotics means the study and application of robot technology. The goal of robotics is to mimic natural world as closely as possible. The main elements in the robot are the moving elements and the sensors. The basic structure of a robot is the robotic arm. No matter if they are used to work in industry or at our homes, mimic some of the human capabilities, or used to access dangerous environments, launched to space, or simply used to play with, robots are always a source of interest and admiration. Here the focus is in robots used to work on industrial environments, i.e., robots built to substitute man on certain industrial manufacturing tasks being a mechatronic coworker for humans.

In fact, actual manufacturing setups rely increasingly on technology. It is common to have all sources of equipment on the shop floor commanded by industrial computers or PLCs connected by an industrial network to other factory resources.

Also, manufacturing systems are becoming more autonomous, requiring less operator intervention in daily operations. This is a consequence of today's market conditions, characterized by global competition, a strong pressure for better quality at lower prices, and products defined in part by the end-user. This means producing in small batches, never risking long stocks, and working to satisfy existing customer orders. Consequently, concepts like flexibility and agility are fundamental in actual manufacturing plants, requiring much more from the systems used on the shop floor. Flexible manufacturing systems take advantage of being composed by programmable equipment to implement most of its characteristics, which are supported by reconfigurable mechanical parts. Industrial robots are good examples of flexible manufacturing systems. Using robots in actual manufacturing platforms is, therefore, a decision to improve flexibility and to increase the agility of the manufacturing process. If the manufacturing processes are complex, with a low cycle time, and have a lot of parameterization due to the diversity of products, then using robots is the correct decision, although it isn't enough for a complete solution. In fact, engineers need to Industrial Robots Programming integrate other technologies with the objective of extracting from robots the flexibility they can offer. That means using computers for controlling and supervising manufacturing systems, industrial networks, and distributed software architectures. It also means designing application software that is really distributed on the shop floor, taking advantage of the flexibility installed by using programmable equipment. Finally, it means taking special care of the humanmachine interfaces (HMI), i.e., the devices, interfaces, and systems that enable humans and machines to cooperate on the shop floor as coworkers, taking advantage of each other's capabilities.

A Brief History of the Industrial Robot

The word *"robof* comes from the Czech *"robota"* which means tireless work It was first used in ١٩٢١ by the novelist *Karel Capek* in his novel *"Rossum's Universal Robots"*. Capek's robots (Figure ١.١) are tireless working machines that looked like humans and had advanced capabilities even when compared with actual robots. The fantasy associated with robotics offered by science fiction movies, and printed and animated cartoons is so far from reality that actual industrial robots seem primitive compared with the likes of *C٣P٠* and *R٢-D٢* (from the movie *Star Wars), Cyber dyne*

TIOOO (from the movie *Terminator ۱۱) Bishop* (from the movie *Alien II)* and *Sonny* (from the *movie Q I Robot),* for example.

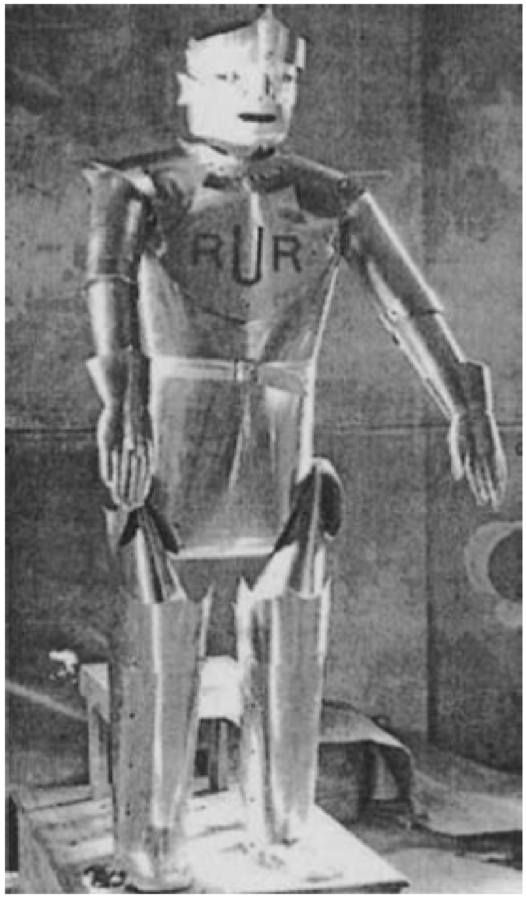

Figure ۱.۱ A robot from *Karel Capek's* novel *"Rossum 's Universal Robots"*

But robotics was a special concern of the most brilliant minds of our common history, since many of them took time to imagine, design, and build machines that could mimic some human capabilities. It is one of the biggest dreams of man, to build obedient and tireless machines, capable of doing man's boring and repetitive work.

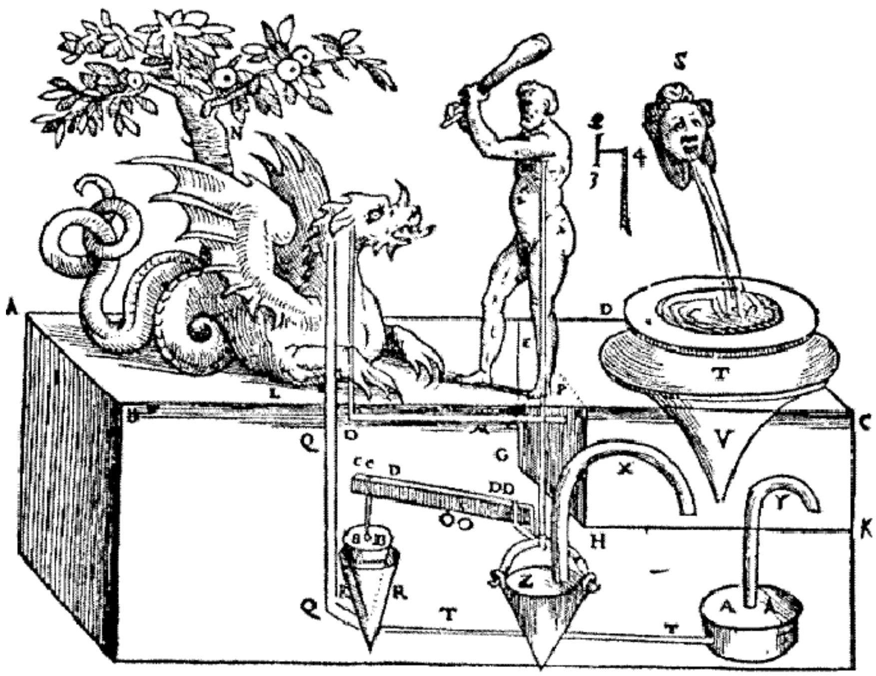

Figure ١.٢ Water clocks designed by *Ctecibius { ١١ ()* B.C.)

Today's challenge is to consider robots as human coworkers and companions, extending human capabilities to achieve more efficient manufacturing and to increase the quality of our lives. This book focuses on industrial robotic coworkers. Nevertheless, the social perspective of using robots not only as coworkers, but also as personal assistants, is very promising. In fact, due to several social and economical factors, we are required to work until very late in life: It is common in Europe to only allow retirement when a person is near seventy years old. Since our physical and mental capabilities decrease with time, the possibility of having mechanical assistants that could help us in our normal routine has some valuable interests.

Theory and Application

❖ Sensors

Sensors are the perceptual interface between robots and their environment. On the one hand we have passive sensors like cameras, which capture signals that are generated by other sources in the environment. On the other hand we have active sensors (for example sonar, radar, laser) which emit energy into the environment. This energy is reflected by objects in the environment. These reflections can then be used to gather the information needed.

Generally active sensors provide more information than passive sensors. But they also consume more power. This can lead to a problem on mobile robots which need to take their energy with them in batteries.

We have three types of sensors (no matter whether sensors are active or passive). These are sensors that either

- record distances to objects or
- generate an entire image of the environment or

- measure a property of the robot itself.

Many mobile robots make use of range finders, which measure distance to nearby objects. A common type is the sonar sensor (see [٦] for an example). Alternatives to sonar include radar and laser (see Figure ١.(
Some range sensors measure very short or very long distances. Close-range sensors are often tactile sensors such as whiskers, bump panels and touch-sensitive skin. The other extreme are long-range sensors like the

- ❖ **Global Positioning System (GPS)**

The second important class of sensors is imaging sensors. These are cameras that provide images of the environment that can then be analyzed using computer vision and image recognition techniques. The third important class are proprioceptive sensors. These inform the robot of its own state. To measure the exact configuration of a robotic joint motors are often equipped with shaft decoders that count the revolution of motors in small increments. Another way of measuring the state of the robot is to use force and torque sensors. These are especially needed when the robot handles fragile objects or objects whose exact shape and location is unknown. Imagine a ton robot manipulator screwing in a light bulb.

- ❖ **Effectors**

Effectors are the means by which robots manipulate the environment, move and change the shape of their bodies. To understand the ability of a robot to interact with the physical world we will use the abstract concept of a degree of freedom (DOF). We count one degree of freedom for each independent direction in which a robot, or one of its effectors can move. As an example lets contemplate a rigid robot like an autonomous underwater vehicle (AUV). It has six degrees of freedom, three for its (x;y;z) location in space and three for its angular orientation (also known as yaw, roll and pitch). These DOFs define the kinematic state of the robot. This can be extended with another dimension that gives the rate of change of each kinematic dimension. This is called dynamic state. Robots with nonrigid bodies may have additional DOFs. For example a human wrist has three degrees of freedom – it can move up and down, side to side and can also rotate. Robot joints have ١, ٢, or ٣ degrees of freedom each. Six degrees of freedom are required to place an object, such as a hand, at a particular point in a particular orientation. Revolute joints generate rotational motion while the prismatic joints generates sliding motion. If you take your arm as an example you will notice, that it has more than six degrees of freedom. If you put your hand on the table you still have the freedom to rotate your elbow. Manipulators which have more degrees of freedom than required to place an end effector to a target location are easier to control than robots having only the minimum number of DOFs. Mobile robots are somewhat special. The number of degrees of freedom does not need to have corresponding actuated elements. Think of a car. It can move forward or backward, and it can turn, giving it two DOFs. But if you describe the car’s kinematic configuration you will notice that it is three-dimensional. On a flat surface like a parking site you can maneuver your car to any (x;y) point, in any orientation. You see that the car has ٣ effective DOFs but only ٢ controllable DOFs. We say a robot is nonholonomic if it has more effective DOFs than controllable DOFs and holonomic if the two numbers are the same. Holonomic robots are easier to control than nonholonomic (think of parking a car: it would be much easier to be able to move the car sideways). But holonomic robots are mechanically more complex. Most manipulators and robot arms are holonomic and most mobile robots are nonholonomic.

- **Movement**

For mobile robots a special group of effectors are the mechanisms the robot uses for locomotion, including wheels, tracks, and legs. The differential drive consists of two independently actuated wheels – one on each side. If both wheels move at the same velocity, the robot moves on a straight line . If they move in opposite directions, the robot turns on the spot. An alternative is the synchro drivn ,in which each wheel can move and turn around its own axis. This could easily lead to chaos. But if you assure the constraint that all wheels always point in the same direction and move with the same speed your robot is save. If you have ever tried to implement that (for example with a Lego Mindstorm) you know this can become hard especially with cheap hardware. Both differential and synchro drives are nonholonomic. Some more expensive robots use holonomic drives, which usually involve three or more wheels and can be oriented and moved independently.

- **Power Sources**

Robots need a power source to drive their effectors. The most popular mechanism for both manipulator actuation and locomotion is the electric motor.
Other possible ways are pneumatic actuation using compressed gas and hydraulic actuation using pressurized fluids. They have their application niches but are not widely used.

- **Bits and Pieces**

Most robots have some kind of digital communication like wireless networks. Especially today those modules get cheaper. They can be used for communication between robots or for some kind of back link
to the robots home station.
Finally you need a body frame to hang all the bits and pieces.

- **Robotic Perception**

A robot receives raw sensor data from its sensors. It has to map those measurements into an internal representation to formalize this data. This process is called robotic perception. This is a difficult process since in general the sensors are noisy and the environment is partially observable, unpredictable, and often dynamic.
Good representation should meet three criteria: They should

- contain enough information for the robot to make a right decision
- be structured in a way that it can be updated efficiently
- be natural, meaning that internal variables correspond to natural state variables in the physical world

Filtering and updating the belief state is not covered here as it was covered in earlier presentations. Some topics are Kalman filters and dynamic Bayes nets.