
For most people the word *robot* is associated with the image of sophisticated machines having an anthropomorphic shape with functions that are similar, or even go beyond, those of human kind. This misleading perception is sustained by a profusion of books and movies which present the astounding performances of those imaginary machines. In fact, the word *robot* is derived from the Czech word *robota* which means “forced labor” or “slavery”. It has been introduced in 1921 by the Czech play writer Karel Kapek in his play R.U.R. (*Rossum’s Universal Robots*). The story was about robots built to serve their master that finally rose up against the humans and threatened them. Even at the early beginning of robotics, the popular perception of robots was quite negative since they were seen as a threat for humans. Fortunately some artistic works, such as the texts from Isaac Asimov, brought the perception of robots to be more peaceful. The introduction of very strict laws that must be followed by robots brought a new perception in which those machines were aimed to help and protect their masters, the human beings. Here are the three fundamental laws of robotics from Asimov:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings, except where such orders would conflict with the first law.
- A robot must protect its own existence as long as such protection does not conflict with the first and second laws.

Today, robots that we build and use are still extremely different from the androids that one can find in science fiction stories, and this is true both for

their external appearance and for their performances. Machines having a superior intelligence as compared to humans that we see in futuristic movies are as unreal as the young and bright guys who build and program these machines. In spite of that, successful and impressive projects are abundantly found in the history. Actually, the evolution of robotics has been and is still intimately related to the expansion of computers' capabilities.

The study of robotics is a consequence of the interest that we have in reproducing given aspects of the human machine by using various mechanisms, sensors, actuators and computers. Of course, this project is very ambitious and requires that ideas from very different fields are put together. From a high level of abstraction, robotics can be split in five specific fields that are: mechanisms, movement, control, sensing and artificial intelligence. Making all those fields to interact and work together is far from being a simple task. That is why robotic research and development is conducted almost independently within each of these domains. When robots are placed in contact with human beings, the aspects of perception and psychology are also heavily implied.

In order to begin the study of robotics, we will now present a quick overview of the evolution of this science before introducing more formal definitions from the point of view of engineering. We will also examine the operation of a robotic system as a sequence of steps and will look at various applications where robots of different types might be found. The social and economical impact of robotics on the society also deserves to be considered. Indeed, many people are still opposed to the integration of industrial robotic systems. Human beings feel vulnerable in front of this potential replacement tool that is extremely robust and can execute a task with a very high accuracy and constancy.

1.1 History of robotics

Up to the middle of the twentieth century, programmable automata were largely used for entertainment. But the development of the technology, the introduction of the computer, of feedback control, of gear-based transmission systems and of numerous reliable sensors allowed to develop robotic systems that were sufficiently flexible and robust to be used in industrial applications. At the beginning, industrial robots were and are still today mainly used for more or less flexible and complex automated tasks, depending on the field of activity. The rule of the four *D* (dull, dirty, dangerous and difficult) and of the four *H* (hot, heavy, hazardous and humiliating) gives a good overview of the kind of tasks in which robots were intended to be used during the first part of their introduction into the industry. Over the time other concerns were taken into account (time, money, safety at work, technology advancement) and this resulted in more diversified fields of application for autonomous systems.

The cost of labor, especially in the automotive industry, stimulated the development of robot manipulators capable to precisely execute repetitive tasks. Previously these tasks were executed by workers who were not capable of always ensuring the same constancy in the quality. Some security problems and the necessity to decontaminate polluted sites after incidents in nuclear reactors also motivated and accelerated the development of mobile robots and telemanipulator arms (remote manipulation). These robots were first aimed at very specific needs and applications.

In the same context, some robotic systems have been developed with the objective to allow humans to reach places in harsh environment. For example, submarines have been built to inspect the flooded side of dams or ship wrecks on the sea bed, e.g. the *Titanic*. Spatial probes have been built and sent in space to explore other planets. Some mechanisms equipped with sophisticated control systems have been developed to serve as artificial limbs that provide a better autonomy to amputees. In parallel, numerous funny projects took place with goals more oriented towards entertainment than usefulness.

Here are some important dates in the history of robotics (adapted from *Spong and Vidyasagar*, 1989, *McKerrow*, 1991 and *Keramas*, 1999).

- 1921 Introduction of the word *robot* in a play by Czechoslovakian Karel Kapek.
- 1946 The first large electronic computer, ENIAC is built by J. Presper Eckert and John Mauchly at the University of Pennsylvania.
- 1947 Goertz develops the first master-slave teleoperator.
- 1948 First teleoperator with force feedback.
- 1950 Isaac Asimov publishes his first work “I Robot” which will change the image of robotics with the introduction of the three fundamental laws of robotics.
- 1954 George C. Devol designs the first programmable robot and calls it “Universal Automation”. Its first application was TV lamps handling.
- 1956 Joseph F. Engelberger buys the rights from Devol and founds UNIMATION (a shortened version of “Universal Automation”) which will become one of the largest robot builders many years later.
- 1962 A UNIMATE robot is installed for the first time on a production line at General Motors in Trenton, New Jersey. The 4000 pounds robot manipulator follows step-by-step a sequence of commands previously registered on a magnetic drum. The robot is used to move and stack pieces of cast metal
- 1963 Development of the first computer vision system for robotics.

- 1968 First walking robot (Walking Truck, General Electric).
- 1970 Lunokhod 1, a Russian exploration vehicle, visits the surface of the moon while being guided from the earth.
- 1971 The STANFORD manipulator is introduced at Stanford University.
- 1973 The first commercially available minicomputer-controlled industrial robot is introduced by Cincinnati Milacron Corporation. It is called the T³ (The Tomorrow Tool).
- 1973 The first computer-type robot programming language (WAVE) is developed at Stanford University. It is followed by the language AL which will gain in popularity the year after.
- 1975 Unimation makes its first profits and many companies start to commercialize some manipulators designed for industrial tasks: Kawasaki, Asea Brown Boveri, Vicarm.
- 1976 The first spatial robotic arms used on the Viking probe in order to collect samples of Martian soil.
- 1978 Unimation introduces the PUMA (Programmable Universal Machine for Assembly) robot on the market. This robot is based on the STANFORD manipulator technology.
- 1978 Parallel robotic architectures are introduced.
- 1979 Development of the SCARA (Selective Compliance Assembly Robot Arm) type robot at the Yamanashi University in Japan.
- 1980 A first grabbing system based on a manipulator guided by means of machine vision is demonstrated at the University of Rhode Island.
- 1982 Development of the STANFORD-JPL articulated hand, also known as the Salisbury hand, introduces the concept of dexterity.
- 1982 The first use of the Canadian space telemanipulator CANADARM installed on the Columbia spacecraft.
- 1984 Development of the articulated hand UTAH/MIT.
- 1990 After a rapid growth, the robotics industry is reorganizing itself. Asea Brown Boveri buys Cincinnati Milacron, Fanuc Robotics buys out its parts in General Motors.
- 1998 The first Mars exploration mission with the Mars Rover mobile robot.
- 1998 Honda demonstrates its first humanoid robot, P3.
- 2000 The Space Station Remote Manipulator System (SSRMS) is starting to work on the new international space station.
- 2005 DARPA Grand Challenge contributes to the evolution of autonomous ground vehicles.

- 2010 BP's oil spill in Gulf of Mexico demonstrates severe limitations in current underwater robots that solely rely on remote operation by human operators.
- 2011 A massive destruction in Japan results from a 8.9 magnitude earthquake that generates a tsunami. Search and rescue robots are used, among other things to inspect leaking nuclear reactors at Fukushima Daiichi power plant. Again, severe limitations of robotic technology are observed.
- 2012 Curiosity rover lands on Mars and turns into a great success for space exploration.

1.2 Definitions of a robot and of robotics

It is possible to define the word “**robot**” in many ways given the diversity of the technologies implied and the various tasks that might be done by these systems.

Soska proposed in 1985 a basic and very general definition of a robot that is based on a rather negative point of view of this technology: “Any device which replaces human labor.”

The Robotic Industries Association (RIA) proposes a definition that is more focused: “An industrial robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or special devices through variable programmed motions for the performance of a variety of tasks.”

The International Standards Organization (ISO) describes an industrial robot in the following way: “A machine formed by a mechanism, including several degrees of freedom, often having the appearance of one or several arms ending in a wrist capable of holding a tool, a workpiece, or an inspection device. In particular, its control unit must use a memorizing device and it may sometimes use sensing or adaptation appliances to take into account environment and circumstances. These multipurpose machines are generally designed to carry out a repetitive function and can be adapted to other functions.”

Another very lengthy definition of a robot comes from the Association Française de Normalisation (AFNOR): “A manipulator controlled in position, reprogrammable, polyvalent, with many degrees of freedom, capable of handling materials, pieces, tools and other specialized devices, following variables and preprogrammed displacements in order to execute various tasks. Often it looks like one or many arms ending into a wrist. Its control unit uses, among other things, a memorizing device and eventually sensing and adaptation devices which take into account the environment and the circumstances. These multipurpose machines are designed to repeat the

same function in a cycle while being adaptable to other functions without permanent modifications of the environment.”

One characteristic that appears into these definitions is the limitation on the type of robots that are considered. Only manipulators are taken into account. Mobile systems are completely excluded from the class of robots, making many people unsatisfied with these definitions. A more general definition including the various kinds of technology currently available can be set as follows: “A robot is a machine which can be programmed to do a variety of tasks and having eventually the capability of adapting itself to the variations that occur into the environment.” (adapted from *McKerrow*, 1991).

The study of robots is called “**robotics**”. A first definition of robotics that is very general and representative of the current and future reality would be: “Robotics is the intelligent connection of perception to action.” (*Brady*, 1985).

From a more technical and specific viewpoint, robotics can also be defined as: “Robotics is the discipline which involves (i) the design, manufacture, control and programming of robots; (ii) the use of robots to solve problems; (iii) the study of the control processes, sensors and algorithms used in humans, animals and machines; and (iv) the application of these control processes and algorithms to the design of robots.” (*McKerrow*, 1991).

We note in these two definitions the significance of the perception aspect. In spite of the fact that, at the early times of this science, the objectives were rather to build machines that would allow to extend the limited capabilities of human beings, the reality of robotics has significantly evolved over the years. Now, there is a strong interest in building machines which have some intelligence. This leads to the necessity to implement perception functions in the system in order for it to be able to adapt to the environment. This is why numerous sensors are now integrated in the robotic structure. These sensors ensure simultaneously an internal supervision of the robot status while continuously taking measurements on the environment characteristics in order to adjust the robot’s displacements with its working space. In this way, robotics research has recently experienced a transformation and is now more focused towards the development of autonomous systems of any types.

1.3 From perception to action

Like any other design process, the development of a robotic system satisfying given constraints must be done step by step. First, the nature of tasks to perform must be defined. Then this task is decomposed into a series of actions to execute. Next the devices required to execute the actions are selected and integrated into a global system that becomes the desired robot. Performances of this system must then be evaluated and the design process is iterated until a good compromise between the cost, the performances and the human impact is reached.

In opposition to computer systems which are basically interested in the transformation of an information between an input and an output, robotics is concerned with the transformation of the real physical world between an initial state and a final state. This transformation is obtained by means of manipulation of real objects.

If we define robotics as an intelligent integration of components from perception to action, it becomes possible to decompose the physical transformations to be executed into a sequence of simpler processes. These processes correspond to the main steps that a robotic system has to go through in order to complete a task: measurements gathering, perception, modeling, planning and action.

1.3.1 Measurements gathering

The robot measures the parameters of the task and of the objects on which it will have to act by means of various sensors. The robot must also measure its own current configuration (position and velocity) in the environment and with respect to the area in which the objects are located.

1.3.2 Perception

Starting from the measurements that it gathered, the robot must determine its own state as well as the state of the environment. It must then analyze the measurements with appropriate algorithms in order to make an interpretation of these informations.

1.3.3 Modeling

Once the informations have been analyzed, it is appropriate to group and integrate the data into a coherent package. A widely used technique to get this package is to build a model of the environment and of the robot. This model offers a virtual representation, that might be more or less detailed, of the configuration of all the components that will be implied into the transformation process: the robot parts, the objects to manipulate, the objects to avoid.

1.3.4 Planning

Before the robot can be started, the control system must analyze the situation with respect to the goal that is pursued and must set a proceeding strategy. It will then plan each step of the transformation making sure that each displacement of the robot is feasible taking into account its mechanical constraints as well as those imposed by the environment. Under some circumstances where the operations must be done in a very safe way, it is usual to first simulate the behavior of the robot and its environment on a computer. In this way, many problems and dangerous situations can be

detected and avoided if some errors occurred with the measurements, the modeling or the planning algorithms.

1.3.5 Action

Once all the steps are properly defined and validated in the planning phase, the robot is started and the sequence of displacements is executed under supervision. As a general rule, in spite of the planning and the simulation previously executed, the robot control system must be equipped with an emergency stop device in order to avoid to damage the environment and the robot itself if the task does not execute as well as it was anticipated.

EXAMPLE 1.1

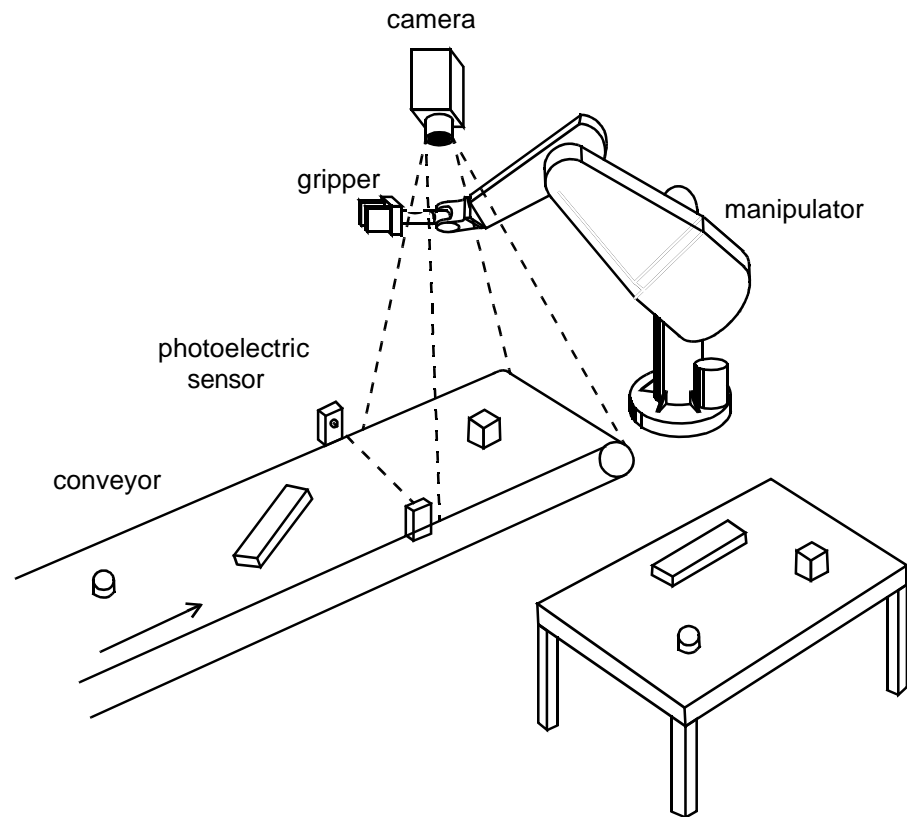
Steps of operation of a robotic system.

With the goal to illustrate the steps that we have just defined, let's consider the case of a robot equipped with a gripper that must grasp a set of pieces of various shapes and place them on a table. Pieces are arriving in the robot environment by means of a conveyor as shown in figure 1.1.

In this application, the first phase which consists in taking measurements is split into three steps. First, a photoelectric sensor is used to detect the arrival of a piece on the conveyor thus initiating the grasping process. Second, a computer vision system using a camera located above the scene allows to grab an image of the object on the conveyor. Finally, the robot controller provides the coordinates of each robot joint.

FIGURE 1.1

Robotic setup for objects handling.



The second phase consists in interpreting the available measurements, this is the phase of perception. Starting from the image of the object on the conveyor, various characteristic extraction algorithms might be used in order to recognize the nature of the object and to define its geometrical shape. This information will be essential when the gripper will have to grasp the object. Indeed, the way to interact with an object depends on its shape. For example, we do not grasp a cylinder in the same way that we grasp a cube if we want to make sure that the piece is tightly held. The robot must do the same. The best way to grasp the piece must be found depending on its nature. The other information that is essential to extract from the image is the object's position and orientation on the conveyor belt (making the assumption that the conveyor is temporarily stopped during the grasping procedure). This information on the *attitude* or the *pose* of the object is also essential to allow the robot to grasp the piece. Finally, the current robot configuration is determined as a function of the measurement taken on the joint coordinates of the manipulator. This way, it is possible to know where the robot will have to start from.

Once these informations are known, it is suitable to generate a model or a virtual symbolic representation of the situation in combining the data on the object to grasp with the robot configuration. This way, all the informations

will be defined with respect to the same reference frame in spite of the fact that they have been gathered from different sources. Indeed, as we will discuss later, it is extremely important to bring all the data into the same spatial reference frame when one works in robotics. For example, we need to define the exact position of the object with respect to the robot basis and the position of the gripper with respect to the same robot basis. We will study this problem extensively. The use of a single model for both the robot and the environment can significantly help in satisfying this fundamental condition.

Now that the global model is defined, the task planning module can begin its work. There are numerous ways to plan a task. Scientific literature is abundant in this field and provides a large set of bright ideas. We will have an overview of that in a following chapter. But in order to keep the presentation of this concept simple, let's make the assumption that we want to bring the manipulator's gripper next to the object following the minimum length path. The planner must then define a series of small displacements that will be juxtaposed one to each other to determine a complete path from the gripper's initial location and up to the object. This is the first planning step. The next step consists in planning the gripper displacement such that it arrives near the object with the proper orientation. This will ensure that the gripper will be able to grasp the object and ensure a tight holding. The final approach must also be controlled such that the grasp is smooth. Once the gripper holds the piece, the grasp can be validated by means of tactile sensors installed on the inside surface of the gripper. Finally, a second displacement needs to be planned to move the object from the conveyor to the table where it has to be placed. A new sequence of small displacements is then defined and the deposit of the object on the table is carefully supervised. The last step consists of validating the sequence of displacements that have just been defined in order to detect any problem that might occur during execution. A software simulation of the robot displacements in a virtual environment is an excellent way to proceed.

If after all these steps the performance of the robot executing the task is sufficient, the corresponding control sequence is sent to the robot control module and the system is started to execute the task.

With the help of this example, we realize that the development and the operation of a robot into an relatively simple industrial task is not that straightforward. The number of steps to go through and the complexity of the algorithms required in each step bring important constraints. And this does not include the problems related with the mechanical design of the robot. It is indeed important, when one needs to design a specific robotic setup, to choose the type of robot that will satisfy the requirements with respect to the precision, velocity, loading capability, cost, energetic efficiency, noise level, etc. But also to choose and integrate a complete set of sensors that will allow to gather the best possible information always taking into account the cost,

the precision and the ease of use. Designing a complete and operational robotic system requires that all aspects are considered with much care.

1.4 Social issues

As engineers, technical questions might seem to be the most relevant. But it is also important to consider the social issues which relate to the development and the exploitation of robots. The designer of a robotic system is usually able to compare the capabilities of the automatic system with those of human operators. In general, the main criteria taken into account is the overall performance. Does the robot allow to reach as good or even better performances as the human operator? But there are also many other criteria to examine: What is the global cost (installation and operation) of the robot? Does it correspond to the company politics and long term goals? Does the company have the expertise and the appropriate resources to maintain this equipment? What are the risks for the workers who have to stay nearby the robots? What will happen with the employees who will be replaced by the robots, will they be dismissed or will they be recycled in other functions? These are all important questions that an engineer must consider in the design process of a robotic system.

Unfortunately, the robotics history reveals numerous examples where social aspects have not been taken into account, e.g. the automotive industry. There has been many situations where the sole perspective of increasing benefits resulted in massive investments of companies into the robotic technology at the expense of experienced workers who found themselves unemployed. It is then very important for the robotic engineer to keep an eye on this reality and to try to find the equilibrium between the search for benefits and workers consideration. Nevertheless, we must remember how the introduction of computers first resulted in the lost of numerous jobs, especially in the field of administration. Over the years, these jobs have been transformed into operator positions, programmers, computer analysts and network managers. Overall, the balance is positive since these new jobs have largely compensated for the lost ones. But the transition has been difficult. Now that robots are entering the market, it might be justified to expect that similar consequences will result over the next few decades. Blue collar jobs will progressively be replaced by robot operator positions, robot programmers, robot installators and robot repairmen. This transformation might not be as dark as we believed at the beginning.

Many situations where robots were used to the benefits of human kind can be identified. For example, working in hazardous environments such as nuclear installations, mines or painting rooms is now significantly reduced. Some fields, like spatial exploration, experienced significant advancement due to the help of robotic probes and exploration vehicles.

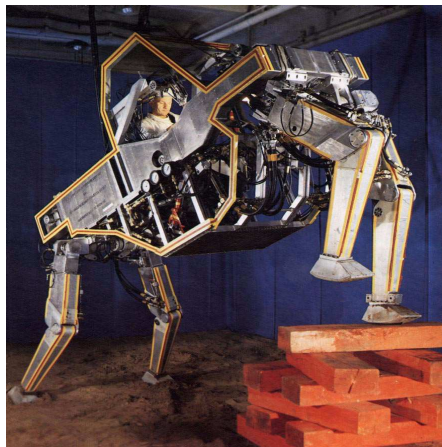
1.5 Applications

In order to complete this introductory chapter, we will enumerate some of the applications of robotics in various contexts. This will provide an idea of the diversity of tasks that these equipments can execute in spite of a level of sophistication that is still quite limited.

1.5.1 Automotive industry

The automotive industry has certainly been one of the most important partners in the development of robotic technologies. The use of spot welding robots has allowed to diversify the production of assembly lines that were previously dedicated to a single car model. The quality and the robustness of the assembly also increased significantly given the precision that can be achieved by a robot while welding two metal pieces. This was not possible with human operators who quickly became tired since the tools they had to manipulate were heavy. However, a supplementary difficulty had to be overcome. In order to successfully weld pieces one to each other, these pieces must be precisely positioned. Robots have then found another place into this industry as part handlers. They are also found in painting rooms where they are extensively used, preventing human painters from inhaling toxic fumes.

The social impact of this massive integration of robots resulted in significant job shortages in some American and Canadian cities. However, the statistics demonstrate that the number of new jobs that have been created as a result of the introduction of these technologies is larger than the number of jobs lost in various industrial sectors. An equilibrium state seems to take place even though these new sectors of activity require that the workers gain experience on tasks, such as robot installation, programming and maintenance, that are very far from what they were doing before.



1.5.2 Assembly

Another application having a strong potential for robotic technologies is the assembly of manufactured products. Indeed, the assembly of numerous commercial products requires a significant workforce. These workers usually execute repetitive, boring, demotivating and dangerous tasks. When these tasks are given to a robot, they can be executed with a constant performance since the robot never gets tired, bored or demotivated. It can repeat again and again the same sequence of movements.

However, the assembly of given products that are somewhat complex brings major problems for a robot. In order to put together all the parts that make a device, the robot must first be able to grasp the right pieces in the right order. It must also be able to align the pieces one with each others to perform insertion or screwing operations. Tools attached at the extremity of the manipulator robot must also be design to ensure stable and precise operations. As a result, specialized robotic tools design is an important area of robots development, as we are still very far from the capabilities of the human hand.



The robot programming must also be done carefully in order to find the optimal sequence of operations, this is call sequencing or ordering. On the other hand, many sensor technologies recently developed now allow to enhance the adaptation capability of robots by providing them some means to examine their environment. This way the problem of alignment can be at least partially solved.

1.5.3 Medical laboratories

There is another place where repetitive tasks must be made. These are medical laboratories. Handling a large quantity of samples and the execution of analyses can be simplified by the use of robots. Indeed, automatic systems can easily fill in test tubes, place them on the stands and can even introduce them into some measurement apparatus. Small mobile units can also take charge of moving the samples between different parts of the room or services, thus eliminating the need for the technician to continuously have to walk. In such a context, the robots significantly contribute to improve the efficiency of human workers by unloading them of manual repetitive tasks.

As mentioned on the cover page, the mapping of the human genetic code was in part made possible, or at least accelerated, through the use of laboratory automation.

1.5.4 Medicine

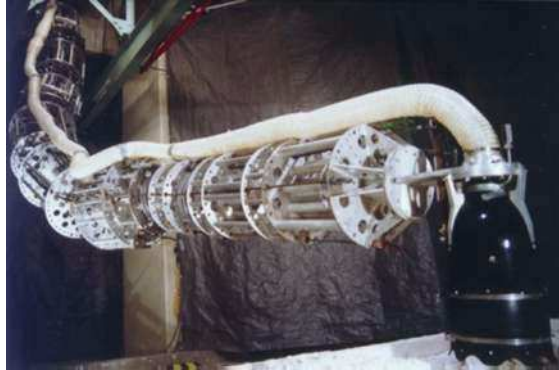
As robots are getting more and more accurate and modern surgery tends to be less invasive, robotic systems now start to be developed to assist surgeons in high precision manipulation of devices. By those days, the development of biomedical applications for robotics is becoming a very important field of research of development that is supported a social motivation to improve patient cares and by the fact that the technology now reaches a point where it can start to be applied to such systems.



1.5.5 Nuclear energy

Nuclear generator installations are places where a large number of robotic applications can be found. This industry supported the development of robotics systems from its early beginning because of the high risk associated with the exploitation of radioactive material. Today, robots are mainly used for maintenance of nuclear reactors and for the replacement of radioactive fuel tubes.

Unfortunate events where radioactive substances have been spilled, such as Three Miles Island in Pennsylvania in 1979 and Tchernobyl in URSS in 1986, have also contributed to the fast development of telemanipulator technologies. It was imperative under these circumstances to quickly find a way to seal off radioactive leakages in contaminated zones. Cleaning and decontaminating these areas without compromising the health of workers was also necessary. Some robots have then be adapted very quickly to these requirements and used to fix the problems. As a result, this technology experienced a fast growth that was afterwards transferred to other fields.



1.5.6 Agriculture

Robots have also found some applications in agriculture. For example, in Australia a robotic system has been developed for sheep shearing. Using a combination of vision and force feedback sensors, the robot has the ability to adapt itself in real-time to the shape of the sheep in spite of its movements, mainly resulting from the animal breathing. This technology demonstrated that less injuries were inflicted to the animal than if a man was doing the job. Some trials have also been conducted with robots to automatize field sowing and harvesting, as well as fruits gathering.



1.5.7 Space exploration

Spatial probes that have been sent for many years to explore and discover our universe are other examples of robots. Starting from the Viking I and II probes that were sent to explore Mars in 1976, space robots have combined flight systems, ground navigation and telemanipulation mechanisms to explore the surface of other planets and collect samples of soil that were locally analyzed.

The famous Canadian spatial manipulator, Canadarm, mounted on American spaceships and the new space station remote manipulator system

(SSRMS) that is used to assemble and maintain the international space station are all excellent examples of robotic technologies.



Starting from 1998, other successes in the field of mobile robotics have been the exploratory missions of several Mars rovers, including Spirit and Opportunity, that explored the surface of the planet while being teleguided from the Earth. These robots have provided an incredible amount of new information about this unknown environment.

1.5.8 Underwater robotics

Submersible robots have been used for many years to explore sea beds. For many important tasks such as rescuing ship-wrecked persons, retrieving black boxes of crashed planes or for exploring old wrecks in order to find their secrets, underwater robots have demonstrated a very strong potential.

Industrial applications of submarines are also developed. For example, Hydro-Québec designed a underwater robot, ROV 3, equipped with cameras to inspect the flooded side of water dams. In this way, the company can detect cracks and fix them before they present a risk for the structure without having to lower the level of water. This contributes to enhance the safety of people who live next to these large structures. Oil companies also take advantage of submarines to inspect and maintain their digging platforms as well as for the localization of new resources under the sea bed.



1.5.9 Unmanned aerial vehicles

A lot of interest has been recently put in the development of autonomous flying vehicles, known as unmanned aerial vehicles (UAVs). These systems present an obvious interest for military applications but also find numerous civilian purposes, including surveillance of coasts, monitoring of forest surfaces and detection of forest fires, and transportation. UAVs tend to mimic insects behavior to automatically avoid collisions. Their development implies the miniaturization of numerous sensors, actuators and navigation components given the low payload of most of these vehicles.



1.5.10 Service robotics

Various machines have been developed to serve customers in a semi-automatic or fully automatic way. One of the most popular applications of robotics in customer services is that of automatic banking that makes traditional banks significantly reduce the number of services they offer in person to their customers and thus save on their operating costs.

Some more sophisticated machines have also been developed, like the Shell SmartPump shown below but have not yet found a significant place on the market because of technical difficulties, an expensive investment required or simply because the market is not ready for it. An important challenge in developing services robots comes from the man-machine

interaction that must be established. Recent projects investigate nursing robots for disabled and elderly people. Introducing robotics in this kind of environment is far from being simple and introduces aspects that go far beyond engineering, such as psychological and medial issues.



Shell automated gas station



Pearl - the Nursebot

1.5.11 Arts and entertainment

As robotics is first known as being a field where people are “playing” with sophisticated toys, many original products and projects have emerged that are mainly dedicated for funny applications. Everybody has already seen one of these garbage can-like robots that are supposed to perform house cleaning or play with the kids. Companies, like Sony, successfully entered the market of “adult kids” who are ready to spend a few hundred dollars to buy a funny toy, such as the dog-robot called AIBO that is supposed to provide all the nice characteristics of a real dog but without its obvious disadvantages. Other projects have led to online artistic creations, while supporting the development of remotely controlled robots.

Of course, these products do not have direct industrial applications but their development often results in technologies that might later be used on more practical systems. For this reason, the development of entertaining robotic systems is usually considered as a very positive and innovative way of evolution in robotics.

In spite of all the applications developed in the past, the number of small problems that appear when a human operator is replaced by a robot is astounding. The adaptation capability of humans is far from being reproduced by automata. Also, in a given automatization process, it is important not to overestimate the capabilities of the robotic system, to select the technologies that best fit the needs and to take extreme care in the development of the strategy that the robot will follow during the execution of its tasks.



AIBO



1.6 Where are we going from now on?

By definition, robotics is a multidisciplinary science. It involves the collaboration of numerous participants from various fields of mechanical engineering, electrical engineering and computer science but also from physics, mathematics and psychology as well as some specialists who work in the fields where the robotic tools are to be implemented.

For the purpose of this course, we will not consider the aspects of robotics that are purely mechanical such as the design of robot structures and actuators which allow the systems to move. We will rather focus on the control of robots by means of computers. In order to do that in a properly structured way, we will nevertheless have to examine a given number of fundamental concepts. These will be required to understand the control techniques that we will discuss later on, such as the parameterization of the robot components with reference frames, or the geometrical transformations in position, velocity and acceleration which provide means to define the sequence of robot displacements. We will also examine various existing technologies which concern both the robots and their peripheral equipments that are meant to provide them a given level of autonomy. Sensors, perception and measurement techniques used in robotics will then be studied. Finally, technical aspects of actuators control as well as task and trajectory planning will be covered.