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QUO VADIS ROBOTICS?

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Abstract. Robotics is an extremely dynamic field with thriving advancement in its technology. The capabilities of trusted robots will grow and evolve over time. Robots will be able to explain what they do and why. This will enable people to better understand what we trust in machines and where and how we can use them, and will lead to a better understanding of the new technology and, in particular, confidence in secure use. It remains in the hands of humans how we want to use these machines and robots. The article explains what a robot is made of, where we stand with robots, robot vehicles, robot intelligence, industrial robots, aspects of legislation, legal consequences, artificial intelligence and robots, deep learning systems, the businessman's problem, and the economic model.

Keywords: *Industrial and agricultural robotics, Defence and security robotics, Service and personal robotics, sensors, software, Turing's test, artificial intelligence, legal aspects.*

Introduction

Robot comes from the Czech *robota*, which means "forced labour". It was first used by the author Karel Čapek in his theatre play R. U. R. (Rossum's Universal Robots) in 1920.

A succinct definition of robotics is given in *The Chamber's Dictionary* [1]: "The branch of technology dealing with the design, construction and use of robots". The full scope of robotics lies at the intersection of mechanics, electronics, signal processing, control engineering, computing and mathematical modelling.

Robotics is a vast and composite technological field. It has been undergoing extraordinary development for several decades; it has revolutionized our industry and is called upon to do the same with our society. Robotics is often presented as one of the main developments in our society for the 21st century.

The robot can be defined as an intelligent, autonomous, mobile and communicating system. Each of these qualifiers induces a set of technological bricks, often of a high level [2].

The robotics sector can be divided into 3 markets very distinct:

(1) Industrial and agricultural robotics;
(2) Defence and security robotics;
(3) Service and personal robotics.

These three markets have reached very high levels of maturity different and are operated by companies with different profiles very far away.

Robots produce cars and other goods, play in films and appear almost daily in the news. Robots and automation form the basis of effective production facilities and thus make a significant contribution to the entire value chain. And yet robots are still subject to a flaw of the opaque, even dangerous or even uncontrollable, whereas in Japan things and machines are animated and cause astonishment as soon as they do something themselves, speak or move [3].

Since the drones (UAVs) are often equipped with autonomous piloting systems and artificial intelligence, they are one of the first examples of these robots from the defence world. Today, they constitute a specific market, initially military and increasingly aimed at civilians. Today there is a wide variety of these devices, ranging from the size of an aircraft to that of insects. Today, drones are able to operate at very high altitudes, as well as at ground level, on the ground or in water. Their applications range from observation in combat, to dropping missions or reconnaissance of dangerous environments (radiation, toxic gases, etc.). UAVs are the first assets to evolve in the public space and enjoying an autonomy (however very limited) to have been the subject of a framework specific legal. Their connectivity, their capacity interaction and, in the long run, their autonomy could lead to their being described as flying robots or robots airborne [4]. Japan, South Korea and the United States are major players in robotics. Japan and South Korea lead in technology for robot mobility, humanoid robots, and some aspects of service and personal robots including entertainment. Japan has the largest population of humanoid systems. The only question is: when will these future humanoids become viable. There is a second reason for the inevitability of humanoids: they encompass a large set of robotics domains. The United States leads in such areas as robot navigation in outdoor environments, robot architectures, and in applications to space, defence, underwater systems, and some aspects of service and personal robots. Europe leads in mobility for structured environments, including urban transportation. Europe also has significant programs in eldercare and home service robotics.

What is a robot made of?

The robot is equipped with sensors that collect information in its environment: cameras filming people, roads, landscapes; microphones that capture voices and perceive noises; lasers that measure the distance at which possible obstacles are located. Unlike data that an Internet search engine retrieves from computer files, data extracted from the real world are "noisy". This term, which is well understood for an acoustic signal, actually applies to all sensor signals. Just as a voice recorded in the street may be covered by the sound of cars passing by, the wind blowing or the barking of dogs, an image taken by a robot's camera in a daily environment may be "noisy" by a back-light, a shadow cast on a face, a blurred motion. Before starting to analyze the information it has retrieved, the robot must clean it up to extract what will be useful for its reasoning.

Where are we with the robots?

With the advent of electronics, robots - as we see them today - are really making their appearance. Thanks to it, then to computer technology, it is possible to "intelligently" move a mechanism. Joseph Engelberger[1], the father of robotics, said: "I don't know what a

[1] American engineer (July 26, 1925 - December 1, 2015); in 1956, he met George Devol, who had designed and patented the ancestor of the industrial robot; together they founded Unimation, the first robotics company, which produced the Unimate robot, the first of which was installed in 1961 in a General Motors plant. Soon, Chrysler and Ford also equipped themselves with Unimates robots. In 1982, Engelberger sold Unimation to Westinghouse for $107 million and focused on

robot is, but I recognize one when I see it." To go beyond this joke, it is possible to consider that a robot is a mechanism whose movements take into account information from sensors. This mechanism can include wheels, tracks, legs, arms and even hands. Its motors can be electric, pneumatic, hydraulic, and piezoelectric. However, to be more than an automaton, the robot must also be equipped with sensors that provide it with information not only about its own state (the position of its joints, its inclination) but also about that of the world around it (cameras, microphones, rangefinders). Finally, it must have a computer that determines the movement of each joint.

In addition to these robots, there are also robots that are not (software used by search engines that explore in the same way as robots sent to distant planets); they explore the web to record information collected on the sites they visit. This review is carried out automatically: the programs define rules that allow these programs to locate words, sentences, expressions and carefully arrange them by noting the address at which they were found. Engelberger does not recognize them as robots since they do not have a physical incarnation. This is why these purely computer-based robots are sometimes called "bots" to distinguish them from "real" robots, characterized by their physical presence in a world of digital intelligence.

Robots are everywhere: in factories and fields, at the bottom of the sea and in space, in gardens and living rooms. They are of growing economic importance, and some predict that they will be in the 21st century what the car was in the 20th century. In addition, they have not only penetrated the industrial world, they are also penetrating our daily lives and culture, and some of them are participating nowadays to the renewal of the vision we have of ourselves (see Figure 1).

While classical and industrial robotics was articulated around the three D's, "dull, dirty, and dumb" characterizing boring work and dirty for which robots had to replace men, a new robotics system is developing around the three E's, "education, entertainment, every day" in which robots are present to accompany us on a daily basis to help us, to stimulate us, and have fun. That's why we're talking about company robotics and of personal robotics.

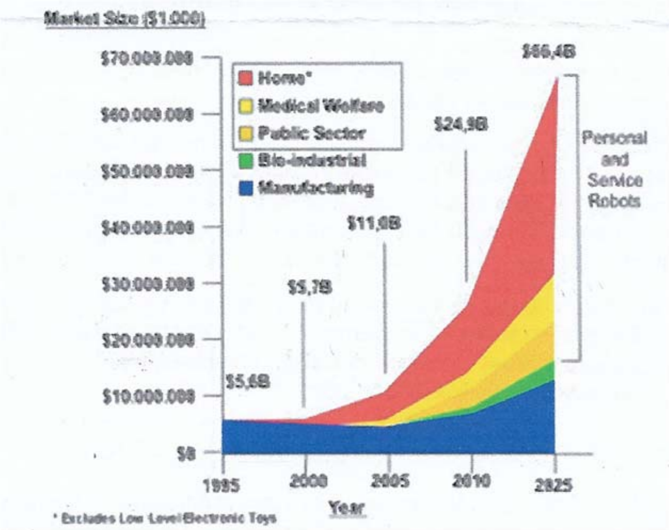

Figure 1. Projection of the evolution of the robotics market (source: Japan Robotics Association).

When you look at it carefully, the robot combines, in the same object, four main faculties: versatility, interaction capacity, decision-making autonomy, and learning ability. Each of them can be found individually in other objects [5]. But their combination makes the robot unique and justifies society's questions about the consequences of its arrival in our daily lives.

mobile robotics. In 1984 he founded the Transistion Research Corporation where he created HelpMate - a mobile wheeled robot for the distribution of drugs in hospitals. In ten years, about a hundred hospitals bought the robots from his company, which he renamed HelpMate Robotics Inc. At the age of 80, he left his company but remained an ardent defender of the robotics cause, particularly for the assistance of the elderly.

Robot vehicles

The most distinctive characteristic of the last century or so might seem to be the enormous amount of change that has occurred. Dozens, if not hundreds, of advances are said to have revolutionized our lives. The list includes automobiles, air travel, television, the personal computer, the Internet, and cell phones. Change is everywhere. We have harnessed the atom, flown into space, invented antibiotics, eliminated smallpox, and sequenced the genome.

Soon our cars will be robots. Already, like planes controlled by automatic pilots, driverless buses are appearing in some cities in Europe and Asia on circuits reserved for them. Autonomous baggage and equipment transport cars are also present in airports. How can an automated car detect, perceive, understand and anticipate human behaviour on the roadside? Interactions between cars (semi-automated) and those that are fully controlled by a human being are also problematic.

Would it be worth it if the roads were systematically" increased" for automated cars? How to operate the transition, i.e. to be able to continue to integrate cars" in an environment designed for smart cars? Localisation is a fundamental aspect of any autonomous mobile robot. Without an accurate estimate of where it is, a robot cannot successfully navigate in its environment and is thus by definition not mobile, at least not in any controlled sense [6].

Given the progress of satellite wave location/wifi/gprs, advances in satellite imagery, and the development of connections high bandwidth mobile internet, one could imagine by these means of providing each car with the information it has without resorting to physical transformations of our networks truck drivers?

The intelligence of robots

The classic experiment proposed for determining whether a machine possesses intelligence on a human level is known as *Turing's test*[2] (Figure 2). This experiment has yet to be performed seriously, since no machine yet displays enough intelligent behaviour to be able to do well in the test.

Turing's test consists of presenting a human being, *A,* with a typewriter-like or TV-like terminal, which he can use to converse with two unknown (to him) sources, *B* and *C* (see Figure 2). The interrogator *A* is told that one terminal is controlled by a machine and that the other terminal is controlled by a human being whom *A* has never met. *A* is to guess which of *B* and C is the machine and which is the person. If *A* cannot distinguish one from the other with significantly better than 50% accuracy, and if this result continues to hold no matter what people are involved in the experiment, the machine is said to *simulate* human intelligence.

Alan Turing, proposed a test called "The Imitation Game" (1951) that might finally settle the issue of machine intelligence [7]. Robots are often referred to as autonomous: it is the ability of a machine to modify its movements on its own according to the data transmitted by its sensors that makes it a robot.

So much so that, formally, the remotely operated robots used by deminers to inspect a trapped package usurp the name of robot. They are only a few sophisticated remote-controlled cars, which have robots only in appearance.

[2] After A. M. Turing, who pioneered research in computer logic, undecidability theory, and artificial intelligence

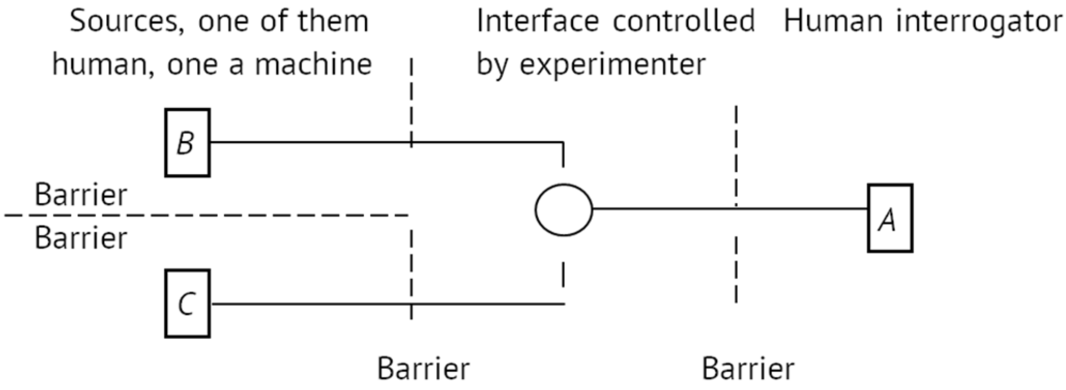

Figure 2. A diagram of Turing's test.

However, even these remote-controlled machines can have some autonomy: some automatically stop in front of a hole or obstacle that the pilot did not see; others are able to automatically retrace their steps when they have lost the radio link to their control station. Still others, such as space exploration robots sent to Mars, are more independent: engineers assign them, from Earth, a territory to explore and they perform, defining their trajectory, avoiding obstacles, managing the energy of their battery. The robot performs its task without continuous control of a pilot. He is therefore autonomous but this does not mean that he is "without a master" for all that.

Industrial robots (IR)

In the last decade the industrial robot (IR) has developed from concept to reality [8], and robots are now used in factories throughout the world. In lay terms, the industrial robot would be called a mechanical arm. This definition, however, includes almost all factory automation devices that have a moving lever. The *Robot Institute of America* (RIA) has adopted the following working definition: A robot is a programmable multifunction device designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. It is generally agreed that the three main components of an industrial robot are the mechanical manipulator, the actuation mechanism, and the controller.

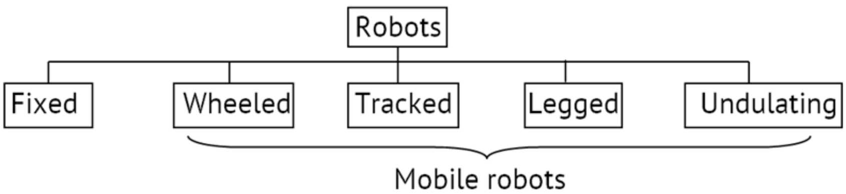

Figure 3. The robots family.

As it can be seen from the figure 3, robots cover a wide variety of types and a unified approach to robotics focusing on the two leading classes of robots, the fixed and the wheeled types. The full scope of robotics lies at the intersection of mechanics, electronics, signal processing, control engineering, computing and mathematical modelling, and the fundamental aspects concern modelling, planning and control.

The largest class of robots existents today is that of the fixed robot which does repetitive but often precise mechanical and physical tasks. These robots pervade many areas of modern industrial automation and are mainly concerned with tasks performed in a structured environment. It seems highly likely that as the technology develops, the number of mobile robots will significantly increase and become far more visible as more applications and tasks in an unstructured environment are serviced by robotic technology. However, industrial robots still do not have the sensing, control, and decision-making capabilities that are required to operate in unstructured, 3D environments.

Legislation aspects [9-11]

Yesterday the drones, today the autonomous vehicles..... All of them, because of their particularities and the uses envisaged, have pushed our legal system to adapt. But should a new standard be adopted for each new robotic product, at the risk of quickly making our legislation look like a patchwork of technical regulations? Would it not be appropriate to embrace robotics as a whole and propose a global approach in order to avoid putting the work back on the legislative profession each time a new robot appears?

This leaves the liability regime for things. It applies only in a residual manner in relation to the product liability regime defective, already mentioned. Schematically, in this system, if damage is caused, the person responsible is the guardian of the robot. The responsibility of the producer can be brought into play every time that there is a manufacturing defect, for example. The owner, in the event that it is different from the guardian, may be held liable if he has not properly maintained the robot, if it has not made the necessary updates or, why not, if the learning provided to the robot is at the origin of the damage.

Legal consequences [12]

The robot's extraordinary ability to adapt over the course of its experience will not be without legal consequences: the multiplication of interactions proportionally increasing the risks of potential damage. This raises the question of liability. Should the producer's use of the robot evolve, knowing that it is almost unpredictable, almost unlimited? If a robot is able to perform any task at the request of its owner, should the owner himself have the knowledge and skills to supervise the requested task? Should certain functions or actions be prohibited, supervised? Should a "user license" be introduced for certain robot models or for the use of certain features? If so, this probably justifies legal reflection and the eventual adoption of certain rules. What are the existing possibilities? What legal system could capture the unique nature of robots? But legal issues also raise ethical and social questions about the appropriateness of entrusting machines with increasingly sophisticated tasks that have hitherto only been possible by human beings. In complex situations, how can the robot have a notion of good and evil, in order to evaluate the actions it is asked to perform?

Artificial intelligence and robots [13-15]

In the 1980s, research in artificial intelligence aimed to enable computers to recognize elements in an image (for example, a red ball), or even to have certain human reasoning skills, by implementing a system of rules. We imagined then that it would be possible for them to formulate a diagnosis, like doctors do: "if the patient coughs, if he has a runny nose and no fever, then he has a cold"; "if he is tired and if he has a fever, then he has the flu"... The great advance of the time was that the computer no longer dealt only with numerical values but also abstract ones: "have a fever", "be tired"... A first level of rules allowed the passage from the first to the second: "if the temperature is higher than

38 °C, then the patient has a fever." However, what should be considered when assessing patient fatigue? Of course, the computer can ask the patient if he is tired, as a doctor would do; but the answer can be very subjective. The doctor will rely on the patient's general attitude, his way of responding, the energy with which he gets up and sits down to form his own opinion. This is where true intelligence comes into play: how to extract meaningful information from a set of signals that are difficult to measure explicitly? Applying rules once you have the right information is not the most complicated. It is the very retrieval of relevant information that is often the main obstacle to truly intelligent thinking.

Not only are robotics and AI changing the world of work and education, they are also capable of providing new insights into the nature of human activity as well. The challenges related to understanding how AI and robotics can be integrated successfully into our society have raised several profound questions, ranging from the practical (*Will robots replace humans in the workplace? Could inhaling nanoparticles cause humans to become sick?*) to the profound (*What would it take to make a machine capable of human reasoning? Will "grey goo" destroy mankind?*).

Thanks to planning algorithms, he is able to analyze every conceivable move to the end of all possible parties. All he has to do is choose those who take him to victory. Is it really true-proof of intelligence?

The experts on various topics make predictions about the future that are not just a little different, but that are dramatically different and diametrically opposed to each other. So, why do Elon Musk, Stephen Hawking, and Bill Gates fear artificial intelligence (AI) and express concern that it may be a threat to humanity's survival in the near future? Each group's members are as confident in their position as they are scornful of the other side. With respect to robots and automation, the situation is the same. The experts couldn't be further apart. Some say that all jobs will be lost to automation, or at the very least that we are about to enter a permanent Great Depression in which one part of the workforce will be unable to compete with robotic labour while the other part will live lavish lives of plenty with their high-tech futuristic jobs. Others roll their eyes at these concerns and point to automation's long track record of raising workers' productivity and wages, and speculate that a bigger problem will be a shortage of human labourers [1].

Inspired by how the brain works and how babies become aware of their environment, computer scientists have sought to reproduce the activity of a neural network. The systems model the interpretation of a sensor signal and the corresponding decision making using a combination of very simple operations. The neurons are spread over different layers. Each neuron in the first layer picks up part of the signal, transforms it and transmits the result to the neurons in the second layer. Each of them retrieves the results of several neurons from the first layer, combines them through a simple operation and transmits unique information to the neurons of the third layer, etc. Such a system can identify a sound, for example. The sound signal is transmitted to the neurons of the first layer... and on the last layer, one neuron is activated if the initial sound is a telephone ringing tone, another one if it is a fire alarm, yet another one for an applause... When the network has just been created, the operations performed by each layer are arbitrary and the output neurons are therefore activated in a completely random way. Training is necessary to ensure that the operations of each neuron and the connections between the different levels lead to the expected outputs. This adaptation of neural connections through learning is a bit like what happens in the brains of babies who discover the world around them. This has helped to give the artificial intelligence modelled by these neural networks a less artificial dimension and, at the same time, probably a little more worrying. It would be legitimate to ask the following question: "Now that computers have neurons like our brains, what's stopping them to be as smart as we are?"

A legal personality can no longer be granted to the robot as a whole, but to its artificial intelligence (AI). This presupposes that the AI can migrate from one robotic "body" to another. Some companies are working on the development of operating systems where artificial intelligence could be adapted to many robots. The physical part would only be a vehicle, a container, intended to receive - for a given time - a logical system.

The legal personality would be linked to this AI, and no longer to the body of the robot. This approach would make it possible to understand the case of the announced development of vocal assistants but also that of "robot swarms", these sets of machines acting and reacting together in order to achieve the same objective, and driven by a single artificial intelligence. It would seem justified here to recognize the legal personality not to each mechatronic object but to the AI that binds them. To legally distinguish the physical and logical aspect of the robot would also offer another advantage in terms of liability, as each party could be subject to a different regime.

Since, on the one hand, AI is at the origin of the robot's decision-making autonomy, versatility and some of its interaction capabilities and, on the other hand, the user can be involved in its learning, a differentiated approach could be appropriate. The producer responsible for the physical appearance and mechatronics of the robot would remain liable in the event of a defect related, for example, to the manufacture of a sensor, a battery, etc. The role of the robot user appears obvious and does not require any further development: he must be responsible for the orders given to the robot but also for the knowledge bricks he has been able to teach him and which could be at the origin of certain comments or actions. However, things are more complex with regard to AI, which is not currently specifically regulated by law. Everything is to be built.

Deep learning systems [16]

This new technology is now giving quite fascinating results. For example, in the case of image processing, neurons will be responsible for finding characteristic patterns in the images submitted to them. But we no longer tell them what these patterns are that they should look for (we don't say, as in the approaches mentioned above, that we should identify eyes, edges, points of interest characterized by shapes or changes in colour in a packet of pixels). The system simply has to identify repeating pixel patterns. The software identifies combinations of pixels on an image fragment and then searches them in the millions of visuals at its disposal to learn. After this first pass, he chooses the 100 most frequent combinations. Of course, he finds edges (which delimit two surfaces of different colours), patterns that resemble the points of interest of classical methods and other combinations. Then, he looks at how these first-level patterns most often aggregate to form pattern patterns. To do this, a new pass is made through the database to identify, say, the 100 most common patterns of patterns. And so on: we find a third level of patterns, then a fourth...

While the first neural networks had only three or four layers, advances in computing have made it possible to increase the number of neural networks and to obtain so-called *deep learning*[3] systems.

Just as a baby discovers that the red ball in front of his eyes moves when his hand touches it, artificial intelligence will learn to evaluate the consequences of the movements of the motors it controls, so that it can then trigger the right actions and achieve the desired objectives. If a baby finally gets there, why wouldn't a robot with the same learning mechanisms do it? This is one of the fundamental questions that concerns roboticians, but also neurologists and physiologists: if the robot has the same "mechanisms" of perception, decision and action as a human being, will we obtain an equally effective being (we avoid the word "intelligent" on purpose)? And if not, will it be because robotics has not succeeded in reproducing these mechanisms accurately enough? Or because the scientists who study man have not yet grasped the full subtlety of his functioning? Is there a transcendental ingredient in man that physiology cannot identify? Physiologists and roboticians have come together in recent years to try to answer these questions.

Finally, we would like to mention the widespread idea that robots will never be as intelligent as humans because they cannot perceive and express emotions. By this we mean that they will always lack an emotional dimension, and that true intelligence is not that of calculation but that of the heart. Different techniques, such as neurolinguistic programming for example, have proposed to model all this and, with a fairly efficient ability to perceive, the robot that uses them will be able to almost read the emotions of its interlocutor in an open book. They will be added to the programs that, from today, are able to detect joy, sadness, anger, even sarcasm, in the speaker's voice. The perception of emotions is therefore not what will long differentiate man from the robot. As the robot has no personal emotion, it is even easier for him to express the emotion that his interlocutor expects. The main advantage of emotion recognition is that it allows the robot to adapt to the user's state of mind. The more robots identify emotions and respond to them in a relevant way, the more fluid they will interact, and the more accepted they will be in our daily lives.

The businessman’s problem

"How am I going to succeed in making and selling this item without losing of money?" [3]. For now, the price of a robot enough evolved to be placed in a family is still too high, especially when compared to the services it can actually provide. Before to consider a generalized marketing to the general public, it is necessary to reduce the design and manufacturing costs and, most importantly, to increase the services provided. When the balance between the two will be reached, our businessman can hope to get an answer.

However, what makes the value of the robot is not only its manufacturing cost but also the service it provides and to whom it is provided. A robot may be sold with a service and it is the price of this service over time that will make it possible to support a possible selling price of the robot deliberately lower than its material value. Insurance companies, who would like robots to be able to look after their insureds that are losing their autonomy,

[3] The beauty of the deep learning lies in the fact that artificial intelligence understands by itself what it takes and how to find it, such as a child who would discover the world. We don't teach him how to recognize a cat; we tell him that this being he sees regularly is called a cat. Of the same way, it is necessary to indicate to the artificial intelligence that this bundle of pixels that it locates in a large number of pixels of photos is a chat, so that she can then to propose us pictures of cats when we propose it to him request, or that the robot is able to identify it one in front of his cameras and to act accordingly.

are willing to imagine this kind of business model [16-18]. An individual could thus subscribe to a warranty contract that would ensure access to a quick repair service and software updates. This contract, over time, would allow the robot vendor to offer lower purchase prices.

Economic model

Consumer society has already shown extraordinary inventiveness in ensuring that everyone can access new technologies at a cost they consider reasonable. The business models used are not new. The robot seller will be able to invent new ones. But the robot buyer, who has learned from his experiences, may well be more demanding and more attentive to the consequences of the economic model he will subscribe to at the time of purchase. After all, the field has potential to bring great economic impact.

Conclusions

AI's motivation for dealing with robotics is clear: it provides a useful test bed for computational models of agents that include perception, reasoning, and action, as robots allow them to be examined in full integration. This is similar to AI's long-term perspective for robotics: to develop methods and tools that will contribute to closed-loop controllers for smart autonomous robots.

It is clear that technology is progressing towards the construction of intelligent sensors, actuators, and systems on small scales. These will serve as both the tools to be used for fabricating future micro/nanorobots as well as the components from which these robots may be developed. Shrinking device size to these dimensions presents many fascinating opportunities such as manipulating nano-objects with nanotools, measuring mass in femtogram ranges, sensing forces at piconewton scales, and inducing GHz motion, among other new possibilities waiting to be discovered. The 21st century will see humanoids leave the pages of fiction and step, roll or run into our world. The current generation of robots is only able to operate in two-dimensional, even, indoor environments. However, we still lack the fundamental theory and algorithms for manipulation in unstructured environments and industrial robots currently lack dexterity in their end effectors and hands.

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