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Abstract

Previously separated from humans behind a fence, the new advanced robots (or cobots) are sharing our workspace and collaborating with us. The perception of robotics technology is improving, as we experience more ways it can positively affect our lives. In this scenario, the terms Artificial Intelligence (AI) and Robotics are liberally used, and frequently interchanged today. However, the physical nature of a robotic system distinguishes it from the pure abstraction of AI. We are experiencing a transition from Information Technology (IT) to InterAction Technology (IAT). The paradigm of convergence between physical entity and digital twin (phygital twin) will guide with 5G the development of new robotic applications making a natural transition from the Internet-of-Things (IoT) to the Internet-of-Skills (IoS). Armed with these skills, robots can be controlled dynamically in real time and be connected to people and machines locally and globally. In a future scenario in which humans and machines are called to coexist, the socialization process of robotics will conform to an anthropocentric approach, for the benefit of the community, towards a technological and digital humanism that can help us reaffirm the least artificial feature of our world: our humanity.

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1 Information Technology

The increasingly rapid diffusion of digital technologies in all human activities is the phenomenon that best characterizes the 21st century. The computer, born as a calculation tool, has become, thanks to the Internet, a communication tool. In 1982, Time magazine dedicated its cover to the computer for its “great influence in our daily lives” by awarding its subject of the year title to a “machine” instead of a person for the first time [1]. With that iconographic image, technological progress—even before the advent of the Internet—promised in some way to revolutionise the life of the individual and of the community, a prediction in fact realized and enhanced by the development of *AI (Artificial Intelligence)*. With the convergence and integration between digital tools and data processing techniques, we have moved on to a new technological era, that of *IT (Information Technology)*, defined as those technologies used in information processing, i.e. in processes of acquiring, processing, storing and sending information. The term IT can be incorporated within the term *ICT (Information and Communication Technology)* with which we indicate the fusion of information technologies with communication technologies: information is not processed by stand-alone machines—systems capable of functioning by itself or independently of other systems with which they may interact—but is processed in multiple locations and exchanged within the network.

ICT defines the set of technologies that allow information to be processed and communicated through digital means. This area includes the study, design, development, creation, support and management of information and telecommunications systems, also with attention to software applications and the hardware components that host them. The ultimate goal of ICT is the manipulation of information data through the conversion, storage, protection, transmission and secure retrieval of information. ICT has come to shape society and the planet, becoming part of the challenges of the *Anthropocene*.

2 Automation and Robotics

Digital technologies entered industrial design and production in the 1960s. These are numerically controlled machine tools, in which software guides the processing that the intelligent machine performs to obtain the required product. The goal of industrial automation is to create a new way of conceiving and developing production, integrating manufacturing with the management information system and other company functions, such as the adaptation of the product to customer requests.

Robotics is a branch of industrial automation. The first robots have been widely used in industry since that decade. The first automatons dot an ancient history, from the Christian and Arab Middle Ages to the Italian Renaissance, with the ingenious designs of Leonardo da Vinci, up to the flourishing in the eighteenth century in Europe and Asia of creations such as Jaquet-Droz’s family of androids and *karakuri-ningyo* mechanical dolls. The playful dimension of the automatons was rooted in a

frontier technical knowledge for the time. In the industrial period, with the prevalence of the concept of utility of machines over any other function, the marvels of these automatons to be considered as the parents of modern robots become a memory of past eras [2].

The term *robot*, of Slavic origin and synonymous with subordinate work, comes from the pages of the Czech writer Karel Čapek in the drama R.U.R. (Rossum's Universal Robots) of 1920 to indicate an anthropomorphic machine designed and built with organic material to relieve the fatigues of humans. Twenty years later, we are in 1940, the image of the robot changes becoming a mechanical artifact with the Russian writer Isaac Asimov [2]. The main factors that have determined its diffusion in the manufacturing industry, especially the automotive industry, have been the reduction of production costs, the increase in productivity, the improvement of product quality standards and, last but not least, the possibility to eliminate harmful or repetitive tasks for the operator.

Compared to the past, today the robot's actions are no longer a pre-established sequence of movements, but they are performed automatically thanks to a control system that governs the motion in relation to what is happening in the environment. Hence, the commonly accepted definition since 1980 of Robotics as the "intelligent connection between perception and action" with a cognitive dimension, in relation to the possibility of decision and planning of the actions to be carried out; a sensory dimension, understood as knowledge of reality through the analysis of data; finally, an implementation dimension with the actions to be taken to achieve the desired goal.

The action is offered by a mechanical system equipped with locomotion organs to move (wheels, tracks, mechanical legs) and/or manipulation organs to intervene on the objects present in the surrounding environment (mechanical arms, artificial hands, tools). Perception is entrusted to a sensory system capable of acquiring information on the mechanical system and on the environment (position sensors, cameras, force and tactile sensors). The intelligent connection is entrusted to a control system that governs the motion in relation to what happens in the environment, according to the same principle of feedback that regulates the functions of the human body [3].

3 InterAction Technology

Digital is not merely a tool but a mediator between humans and their environment. It not only redesigns the latter—think of modern factories, and those of the future in which the massive presence of robots will completely redesign spaces—but it reinvents the way we work, study, and socialize.

We are the protagonists of a technological revolution in which Robotics is destined to play a driving role for a new generation of autonomous devices which, through the ability to learn, will be able to collaborate with human and interact with the external environment. Hence the neologism *IAT* (*InterAction Technology*) introduced to explain how the convergence between Robotics and AI will project us towards a

new generation of intelligent devices that will be the missing link between the digital world and the physical one [4]. In this sense, IAT represents the natural evolution of ICT and lays the foundations for a real symbiosis between human and machine thanks to an increasingly intuitive technology, which will make it possible to use robots with the same ease with which we use today common *devices*.

If previously robots were confined for safety reasons to spaces far from humans, in the new generation factories they have effectively become *cobots*, which cooperate together with the worker in a safe and reliable way, or they are equipped with autonomy to move and work even in presence of uncertainty and variability of the environment. We will have a technology capable of revolutionizing not only the production approach, but also our daily life. Reduction of risks and work fatigue, improvement of the production processes of material goods and their sustainability, safety, efficiency and reduction of the environmental impact due to the transport of people and goods, physical assistance to the disabled or elderly, progress in diagnostic techniques and surgeries are all examples in which the new technologies of interaction can be a tool at the service of humans.

4 From Internet-of-Things to Internet-of-Skills

5G is expected to contribute to promoting the efficiency of robotic systems, which will pave the way for a new generation of robots controlled via wireless communication and at the same time equipped with new processing and data storage resources via the cloud. Robots operating in environments co-inhabited by humans in the near future will need to have the ability to interact, make decisions and react flexibly to unexpected events. To do this, a robot must be able to probe the environment and gain awareness of its surroundings. Improving sensory skills and processing of information from the outside is essential and this will be possible through the use of exteroceptive sensors such as distance, vision and contact sensors which will have to be increasingly sophisticated. Deep learning-based image and sound processing techniques have increased the need for high computational resources. Even if the computing capacity and the miniaturisation of processors has improved in recent years, one cannot think of housing all the necessary computing capacity in a robot. Being able to connect a robot via a wireless connection with one or more external computers represents an enormous wealth that can open the door to a new generation of robots with unprecedented characteristics of autonomy, safety and reliability. That said, in order for a robot to work correctly, the connection must allow for the transfer of a large number of data per second and that the time taken to transfer the data be sufficiently small and above all predictable, i.e. with constant latency.

With 5G, robots will eventually be able to be controlled dynamically in real time and be connected with people and machines both locally and globally. It is therefore understandable how *IoT* (*Internet-of-Things*) can be overcome by *IoS* (*Internet-of-Skills*), a “tactile internet” to allow a remote physical experience through haptic

devices that combine with the skills, for example, of the drone operator or the surgeon dealing with an operation performed using a remote robotic system.

Ultimately, the new paradigm of interpenetration between the emulation of the digital twin and the operation of physical reality (phygital twin) redesigns in an extraordinary way not only the industrial field but also promises to have an impact in other fields of application: agri-food, medical-health, urban mobility, hostile or poorly structured environments [5].

5 Roboethics

What has been described belongs to a future dimension towards which the world of research is heading. But the promise of the pervasiveness of robots and intelligent machines in our society cannot fail to refer to a different range of ethical problems and moral dilemmas on which we all have to reflect, as scientists and as humans. What will be the social impact in terms of the labor market if the use of the progress of Robotics and AI further concentrates power and wealth in the hands of a few? In psychological terms, what will be the repercussions that could derive from human–robot relationships? How can we deal with addiction to such tools? In legal terms, we should consider whether robots deserve to be recognized as “people” and what the legal and moral implications of this choice are. There are many questions and they must be asked starting from the assumption that human is a “technical subject” and has always equipped himself/herself with tools of freedom and liberation with which he has been able to evolve. In the future Robotics and AI will be two tools with a high gradient of development, and therefore it goes without saying that a profound reflection must be opened on the constraints that will have to be placed on progress, so that technology does not become dangerous and alienating but, like politics and economy, take charge and always have in view the needs and the centrality of human in his becoming.

The anthropisation of robots cannot ignore the resolution of those ethical, legal, social, economic (ELSE) problems which have so far slowed down their diffusion in our society. Italian robotics has been the cradle of reflections on these problems and in Italy the term *Roboethics* was born to indicate ethics applied to robotics, on the occasion of an international symposium in which philosophers, jurists, sociologists, economists together with the robotics community, laid the foundations of an ethics in the design, construction and use of robots. An opportunity that proved to be decisive for creating awareness of the need for such ethics and which in the future is essential for coping with the digital transition.

Roboethics primarily deals with a series of issues related to the growing diffusion of robots in society, in particular the dual use of technology (virtuous or harmful), the impact on the labor market, on people’s psychology, on the environment, the digital divide between rich and poor regions of the world, the problem of dependence on technology, understood as personal dependence and social dependence. Roboethics

is in this sense a human ethics that treats robots as machines and discusses their social role [6].

At a later level and in a more strictly human–robot interaction context, the concept of autonomy and responsibility for the actions of the robotic system comes into play. The growing ability of robots to perform autonomous actions and complex tasks raises issues of liability and acceptability in a wide range of applications. In some military, industrial and service fields, critical analyzes of these problems are mostly oriented towards the development of ethical policies that require substantial *MHC* (*Meaningful Human Control*) over autonomous robots whereby humans, and not machines and their algorithms, should ultimately maintain control, and therefore moral responsibility, of the relevant decisions that impact humans. More generally, we can say that developing the growing autonomy of robotic systems in harmony with the moral autonomy and assumption of responsibility of human beings is one of the great technological and, at the same time, ethical challenges of our time [7].

6 Towards a Technological Humanism

The new generation of robots will actively cooperate with humans; beyond agility, necessary for effective manipulation, some strategic capabilities appear to be safety, reliability and aesthetics, necessary for effective human–machine interaction.

Safety is of paramount importance so that the robot can react and learn from the stimuli coming from the environment it interacts with. The first and obvious concern with respect to robot safety is the possible harm from an unwanted collision between human and machine. Damage usually means physical injury or damage to human health, or even to property or the environment—where property includes the robot itself. The quantification of the damage, and therefore of the safety of a robotic system, passes through appropriate biomechanical analyzes on human–robot contact.

Reliability is defined as the ability to perform a task in a manner that can legitimately be trusted. To prevent failures from being more frequent and serious than admissible, reliability proposes four tools: prevention, removal, error prediction and error tolerance.

Regarding aesthetics, the appearance of a robot and its way of interacting with humans is of paramount importance. Until a few years ago, the asymmetry between the usually excellent performance of industrial robots and their ugly and disharmonious bodies, with rough manners and potentially dangerous movements for the human environment, was clearly evident. Now that robots are starting to be an integral part of our lives, they need to be aesthetically pleasing. A robot designed in collaboration with artists, designers and architects can be as harmonious and beautiful as a biological machine—through an electronic microscope even a gnat shows its extraordinary symmetry and beauty—and can be as harmonious and beautiful as a work of plastic art, which in turn may be as good as the nature that inspired it, if not more so [8]. In this scenario, the key role of design with respect to robotic technologies should

be clear in their becoming part of our daily life and in essentially modifying them in responsible and beneficial ways. It is designers who shape the interfaces between humans and machines and, as a result, help make robots as widespread as computers and smartphones.

We are the protagonists of a technological revolution that brings with it an extraordinary connectivity between humans and machines from which derive new languages, ways of knowing, working and participating in collective life, and which can turn into a new push: that of affirming the least artificial characteristic of our world: our humanity [2].

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