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Science and Engineering

Maria Isabel Aldinhas Ferreira
Sarah R. Fletcher *Editors*

The 21st Century Industrial Robot: When Tools Become Collaborators

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Preface

I am C-3PO, human/cyborg relations. And you are?
in Star Wars

The disruption caused by the Covid-19 pandemics on economy and society as a whole has accentuated existing problems of an ongoing social and economic crisis,[1] mainly caused by the evolution of a global neo-liberal economic framework, with its speculative financial models, plus the destructive effects of a growing climate/environmental emergency. The dynamics of this very complex situation, that the sanitary crisis has deeply aggravated, calls for a fast, objective and ethically- guided strategic planning in order to reshape economies,[2] by placing equity and the well-being of individuals as their goals, and to restore the lost environmental equilibrium. To achieve these goals that, in a certain way, were already defined as a priority in the Development Sustainable Goals Framework,[3] the technological innovation brought about by the so-called 4th Industrial Revolution, namely the embodied and non-embodied artificial intelligent systems, will be essential tools. However, having intelligent systems producing tangible or non-tangible forms of work, and coexisting with human beings at the workplace or even co-operating, raises fundamental ethical and societal concerns. By addressing the complexities of this human/robot co-existence and co-operation in industrial settings, this book aims to contribute to their harmonious integration .

According to Deloitte[4], automation will remain a strategic priority for all countries over the next ten years. As 2014–2019 saw an estimated 85% global rise in factory deployment of industrial robots[5], it is clear that fast development and deployment of

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[1] The so-called 2008 Great Recession.

[2] Cf. Emerging Stronger and Better: 12 Months, Twelve Lessons from the Pandemics: https://feature.undp.org/emerging-stronger-and-better/?utm_source=web&utm_medium=sdgs&utm_campaign=12lessonsfromCOVID19.

[3] https://www.undp.org/content/undp/en/home/sustainable-development-goals.html.

[4] Deloitte.uk- Robots are Coming. https://feature.undp.org/emerging-stronger-and-better/?utm_source=web&utm_medium=sdgs&utm_campaign=12lessonsfromCOVID19.

[5] International Federation of Robotics: World Robotics Report 2020. https://ifr.org/ifr-press-releases/news/record-2.7-million-robots-work-in-factories-around-the-globe.

ICTs and intelligent systems, either embodied or non-embodied, will remain a technological target of developed and developing societies. Despite early assumptions that industrial automation would just replace human operators, evidence has long shown that it simply cannot replace many complex human skills, particularly those involving flexible and intelligent responses.[6] The Global Partnership on Artificial Intelligence report on the Future of Work[7] refers to evidence that shows intelligent systems are not intended to automate entire processes but rather to improve the performance of human workers. This means that natural and artificial cognition/intelligence will not only coexist at the workplace but will co-operate, i.e. act in order to achieve a common productive outcome. This co-operation has been commonly referred to as human-robot 'collaboration'. However, artificial systems lack the true agency/free will features inherent to the semantics of that concept. Consequently, artificial systems need to be "made collaborative" through human-centric purposeful design. A human-centric approach to developing technology means applying design principles that respect human factors and follow strict ethical guidelines, so that systems are compatible for effective human-robot co-operation, work for human benefit and respect fundamental human values. Production processes cannot only be designed to achieve the expected productive outcome goals, but with respect to the nature, specificities and reasonable expectations of all the users involved. However, as the abovementioned GPAI report points out, putting the human at the centre is an incantatory discourse, it must not just be said, it must be accomplished.

A human-centric approach requires a robust understanding of, and reliable methods to examine, human behaviour and requirements. Social science, and particularly human factors (ergonomics), has a fundamental role to play in providing this knowledge, though its inputs have traditionally been neglected. But, in fact, until fairly recently, the size and payload of industrial robots was so hazardous, they were completely separated from the workforce in production processes and, understandably, there has been, until recently, no need to consider human issues (other than segregation protocols) in the design and engineering of systems. However, as customary boundaries between people and robots are progressively being removed and the deployment of collaborative systems advances at pace, this fundamental change brings a pressing need to gather and integrate human factors into system design. Consequently, engineering and social science disciplines are beginning to merge towards development of a rich field of research that not only seeks to develop technical systems but to also take account of human factors in order to promote worker well-being, both physical and mental.

The present book takes a multidisciplinary stance, where the insights and experience of academia and industry merge to highlight the need for an accurate vision of how the design, development and deployment of intelligent tools can incorporate fundamental knowledge about human behaviour and present societal values. In the

[6] de Winter, J. C. F., Dodou, D., 2014. Why the Fitts list has persisted throughout the history of function allocation. *Cognition, Technology & Work.* 16, 1, 1–11.

[7] The Global Partnership on Artificial Intelligence report on the Future of Work-November 2020-GPAI, the Future of Work https://gpai.ai/projects/future-of-work/.

following chapters, a range of contemporary issues and approaches demonstrate how emerging industrial human-robot collaboration challenges are being tackled.

In chapter "On Human Condition: The Status of Work", Ferreira refers both to the universal existential circumstances that human beings share with all the other life forms and to those that are human specific. The author claims that the capacity for work, in all its tangible and non-tangible forms, is a unique essential human attribute, responsible for the evolution of humankind as a species and for the development of their world. According to the author, being intrinsically human and not the result of a temporary condition or state, [work], i.e. [productive goal-oriented action] has been, throughout times, improved, enhanced and augmented by the creation of rudimentary, and then progressively more sophisticated, man-made tools. Ferreira refers that contemporary societies have become hybrid environments, where the physical is permeated by the digital, human interaction is mediated by advanced forms of virtual communication and work is being replaced, in many sectors, by task performance and decision making by artificial intelligent systems. This present context and its predictable development in the near future demands the emergence of a deep awareness on the part of different stakeholders: research and development institutions, policy makers and governance, business and on the part of society in general, so that intelligent technology remains a human tool for enhancing and augmenting [work], respecting its fundamental twofold dimension as: (i) a generative endowment for the creation of human reality and (ii) a means for the fulfilment and existential satisfaction of every human being.

Michalos, Karagiannis, Dimitropoulos, Andronas and Makris, in chapter "Human-Robot Collaboration in Industrial Environments", present a thorough exploration of the current state of *Human-Robot Collaboration in Industrial Environments*, arguing that the advancement of robotics technology in recent years and the parallel evolution of the AI, big data, Industry 4.0 and Internet of things (IoT) paradigms have paved the ground for applications that extend far beyond the use of robots as mindless repetitive machines. The number of technical configurations/solutions grows exponentially when considering factors such as (a) the particularities of the task to be performed (e.g. type of part, weight, dimensions, process to be carried out, etc.), (b) the type of robots that can address these requirements (fixed or mobile robots, high/low payload, exoskeletons, aerial robots, etc.), (c) the type of collaboration and interaction that would be appropriate for the task and (d) the special requirements of the production domain where such tasks are needed. The authors aim to identify the existing approaches on the implementation of human-robot collaborative applications and highlight the trends towards achieving seamless integration of humans and robots as co-workers in the factories of the future.

In chapter "Managed Systems Approach to Commissioning Collaborative Industrial Robot Systems", Quinlan-Smith describes how the field of collaborative robotics has expanded significantly over the past ten years, such that it is now the fastest growing segment of the global industrial robotics market with advances in robot software technology allowing robots and workers to work "hand-in-hand" to achieve higher levels of efficiency and productivity. This new relationship leverages the strength of the robot to perform dull, dirty and repetitive tasks (e.g. palletizing, painting, packaging, polishing, etc.) while combining the higher cognitive abilities and flexibility of the human colleague; a winning combination of brawn and brains that is clearly transforming traditional ways of working. Quinlan-Smith points out that, when properly executed, the partnership between the human and robot has the potential to improve safety while keeping up with forever changing customer requests and productivity demands, e.g. a robot that performs a repetitive task may help improve health by reducing injury incidence while also improving productivity at the same time. However, despite these claims, research has shown that this new technological introduction into our workplace will bring forth ethical issues. Sudden, coerced introductions of a robotic colleague into our work space, whom we have long been separated from by means of strategically placed "fencing", will threaten the adoption of such technology on the plant floor. Evidence presented in one study showed that improper attention to the "human aspects" is believed to be a primary cause of significant failures in the implementation of advanced manufacturing technology in the USA. Based on lessons learned in this study, organizations must learn to understand how changes in work tasks or the working environment that are made without consultation with, or involvement of, a worker can significantly impact the human experience and overall productivity.

Haninger, in chapter "Robot Inference of Human States: Performance and Transparency in Physical Collaboration", addresses the topic of *Robot Inference of Human States: Performance and Transparency in Physical Collaboration.* This refers to the need for a human-robot partnership to not only be designed for the human to monitor and anticipate forthcoming events but how, in order for a robot to flexibly collaborate towards a shared goal in human-robot interaction (HRI), it must also be appropriately designed to respond to changes in their human partner. The robot can realize this flexibility by responding to certain inputs or by inferring some aspect of their collaborator and using this to modify robot behaviour; these distinct approaches reflect design viewpoints of robots that regard robots respectively as tools or as collaborators. Independently of this design viewpoint, the robot's response to a change in the collaborator's state must also be designed. In this regard, HRI approaches can be distinguished according to the scope of their design objectives: whether the design goal depends on the behaviour of the individual agents or the coupled team. Haninger synthesizes work on physical HRI, largely in manufacturing tasks, according to the design viewpoint. HRI is posed as the coupling of two dynamic systems; a framework which allows a unified presentation of the various design approaches and, within which, common concepts in HRI can be posed (intent, authority, information flow). Special attention is paid to predictability at various stages of the design and deployment process: whether the designer can predict team performance, whether the designer can predict team performance, whether the human can predict robot behaviour, and to what degree the human behaviour can be modelled or learned.

Eimontaite, Chapter "Human-Robot Collaboration using Visual Cues for Communication" presents recent studies that have examined *Human-Robot Collaboration using Visual Cues for Communication*, in order to begin building a foundational knowledge of what type(s) of cues a robot should present to most effectively promote human awareness and anticipation of a robot's forthcoming actions. Thus, following on from chapter "Robot Inference of Human States: Performance and Transparency in Physical Collaboration" attention to robot capabilities, Eimontaite addresses another important aspect of communication and mutual awareness between robot and human partners. This chapter reviews how traditional industrial robots in the manufacturing sector have been used for repetitive and strenuous tasks for which they were segregated due to their hazardous size and strength and so are still perceived as threatening by operators in manufacturing. This means that successful introduction of new collaborative systems where robotic technology will be working alongside and directly with human operators depends on human acceptance and engagement. The chapter discusses the important reassuring role played by communication in human-robot interaction and how involving users in the design process increases not only the efficiency of communication, but provides a reassuring effect. After presenting findings to date, Eimontaite identifies remaining challenges that affect the development of productive and stimulating communication between manufacturing operators and robots, thereby highlighting future work needed in this area.

Chapter "Trust in Industrial Human-Robot Collaboration" explores the specific issue of workers' *Trust in Industrial Human-Robot Collaboration.* Here, Charalambous and Fletcher not only emphasize how trust is a vital component for successful co-operation within any team, regardless of the entities that form it, but how there is a need to identify and understand the specific characteristics of a system or context that influence trust. In the context of human-automation teaming, an ideal level of trust needs to be achieved to optimize performance because too much trust can cause over-reliance and confidence, but not enough trust can cause timidity and poor response. Therefore, the authors describe how the different attributes of robots, e.g. degree of autonomy, mobility, anthropomorphism, size, types of physical embodiments, etc., and the task for which the application is being used, may cause different impacts on trust. As these attributes have the potential to tease out different human/user responses, the authors emphasize the importance of designers and integrators being able to evaluate trust in relation to robot attributes. Having identified that no existing measure to evaluate trust in industrial human-robot collaboration, Charalambous and Fletcher describe research work they conducted to specifically identify relevant robot attributes and, at the same time, develop a new psychometric measure of Trust in Industrial Robots intended to aid design of future systems.

In chapter "Adapting Autonomy and Personalisation in Collaborative Human–Robot Systems", Marguglio, Caruso and Cantore point out why modern manufacturing systems need to be increasingly "adaptive" to an ever-changing environment, because evolving internal and external demands today require increasing flexibility, sustainability and human satisfaction. Adaptive automation is vital to meet these challenges but also so that systems can autonomously identify and apply best methods of employing the abilities offered by humans and automation, taking advantage of each other's strengths to balance flexibility and productivity requirements in an easy and cost effective way. The chapter describes a programme of work undertaken as part of the European Commission funded "A4BLUE" project to develop this "adaptive" robot architecture, and how a key objective was to integrate a degree of personalization and meet requirements of human operators to sustain their satisfaction.

The authors describe how this research fits into the wider context of the Europe 2020 strategy and its aims to promote market-oriented projects by bringing together private and public resources, and the role of the European Factories of the Future Research Association (EFFRA) which aims to promote development of new and innovative production technologies and pre-competitive research.

In chapter "Designing Robot Assistance to Optimize Operator Acceptance", Otero and Johnson present a real case study of *Designing Robot Assistance to Optimize Operator Acceptance* which was also conducted in Europe as part of the A4BLUE project. The chapter describes the main difficulties inherent to the implementation of an automated or robotic solution in a company, namely the doubts and concerns experienced by workers: "Will I be replaced by the robot? Is it safe to work collaboratively with an automated mechanism?" which reflect commonly held anxieties for workforces around the world as deployment of human-robot collaboration expands. At the same time, workers are asking these questions, there are usually economic concerns that the company are asking about the initially high investment and the expected benefits of such an innovative solution, where the risks can be higher than those traditional solutions which have been widely implemented and tested over the years. Otero and Johnson describe the process they undertook to involve operators in the development of the new system which was designed to both enhance design but also promote engagement and acceptance. The case study provides a real world example of successful implementation of a human-robot system in a Spanish aeronautical company in a production area where tasks are traditionally performed manually, including the assembly of complex aeronautical equipment and its auxiliary operations, and shows the benefits of involving the workforce in design and implementation of a new technology which will change their work methods.

In chapter The Role of Standards in Human-Robot Integration Safety", Franklin describes *The Role of Standards in Human-Robot Integration Safety* and specifically focuses on how standards have been developed for guiding the safe application of human-robot collaboration (HRC) in industrial settings standards. The chapter sets out the nature and purpose of standards, their utility and limitations, and how such standards are developed via voluntary industry consensus, i.e. how standards are constructed by international committees of volunteer experts. Franklin provides thoughts on how standards impact innovation in the marketplace and how standards provide safety requirements for industrial HRC and influence procedures, identifying ongoing challenges and limitations of voluntary industry consensus standards, both in general and specifically in the area of closer human-robot collaboration in industry. The history of industrial robot safety standards is also discussed, along with areas of potential future work.

In chapter "Engineering a Safe Collaborative Application", Dominguez provides a detailed account of risk assessment and design principles and procedures involved in the implementation or integration of a collaborative robot system. The chapter highlights the benefits brought by collaborative robotics when compared to the traditional robotic systems and points out that this new approach determines the priority of risk assessment when deploying collaborative systems at the workplace. In a collaborative context, risk assessment must identify all potential contact events, both intentional and unintentional. On the other hand, these contact events must be assessed in terms of probability of occurrence and the potential severity of injury, the definition of risk. If the risk level is not tolerable, then measures can be taken to either reduce the potential severity of injury or the probability of contact. The author identifies parameters involved, such as types of contact event and injury/pain threshold limits for force, and identifies the procedures respecting each of the steps concerning the assessment of risk in a collaborative context and in accordance with current standards.

Challenges in the Safety–Security Co-Assurance of Collaborative Industrial Robots explores existing approaches and best practices for ensuring the safety and security of collaborative robots; in chapter "Challenges in the Safety–Security Co-Assurance of Collaborative Industrial Robots", Gleirscher, Johnson, Karachristou, Calinescu, Law and Clark highlight the challenges posed by the complexity involved. In Sect. 1, the authors provide an overview of safety and security approaches applicable to collaborative robot systems, while in Sects. 2 and 3, they elaborate on particular methodologies in the context of a real industrial case study in the UK. Following the two perspectives—social and technical—of the Socio-Technical System (STS) design approach, Sect. 4 enumerates additional socio-technical and technical challenges arising from safety-security interactions. The chapter provides not only a thorough overview of current state of the art in safety and security assessment but also a real world example of application, presenting the foundations for a "preliminary research roadmap".

In chapter "Task Allocation: Contemporary Methods for Assigning Human-Robot Roles", Kousi, Dimosthenopoulos, Aivaliotis, Michalos and Makris propose that because human-robot collaboration (HRC) is now a major enabler for achieving flexibility and reconfigurability in modern production systems; it is vital to offer system designers an effective and systematic method of task and environment evaluation/optimization. The authors emphasize that the motivation for HRC applications arises from the potential of combining human operators' cognition and dexterity with the robot's precision, repeatability and strength that can increase system's adaptability and performance at the same time. The authors point out that to exploit this synergy effect on its full extent, production engineers must be equipped with the means for optimally allocating the tasks to the available resources as well as setting up appropriate workplaces to facilitate human-robot collaboration. The chapter discusses existing approaches and methods for task and process planning in collaborative work environments analysing the requirements for implementing such decision-making strategies, including modelling and visualization methods. The chapter also highlights future trends for progressing beyond the state of the art on this scientific field, exploiting the latest advances in artificial intelligence and digital twin techniques.

In chapter "Implementing Effective Speed and Separation Monitoring with Legacy Industrial Robots—State of the Art, Issues, and the Way Forward", Moel, Denenberg and Wartenberg present *Implementing Effective Speed and Separation Monitoring with Legacy Industrial Robots—State of the Art, Issues, and the Way Forward*, based on extensive work they have been conducting at VEO Robotics towards human-robot safety. The authors point out that collaborative applications using traditional industrial robots and Speed and Separation Monitoring (SSM per ISO/TS 15066) rely on safe stopping if a Protective Separation Distance (PSD per ISO/TS 15066) is violated. However, larger industrial robots have longer stopping times and their control architectures are not designed for flexible external interaction. Robot manufacturers also provide stopping time and distance data for calculating the PSD, but these data are often fragmented, hard to interpret and overly conservative. Hence, the "worst-case" PSD calculation for SSM is generally more conservative than warranted. The authors claim that truly fluid human-robot collaboration will be possible but will require a closer interlocking between the robot controller and the safety system and a more precise characterization of robot stopping times and distances. The present chapter describes techniques to improve latencies and response times using SSM with existing robot control architectures also proposing longer-term alternatives for consideration by the industry.

Chapter "Ethical Aspects of Human-Robot Collaboration in Industrial Work Settings" addresses the increasingly important topic of *Ethical Aspects of Human-Robot Collaboration in Industrial Work Settings*. Wynsberghe, Ley and Roeser review and expand upon the current ethical research on human-robot collaboration in industrial settings which primarily includes: job loss, reorganization of labour, informed consent and data collection, user-involvement in design, hierarchy in decision-making and coerced acceptance of robots. These wide-ranging issues are a useful starting point for discussion, yet as the number of robots designed and deployed as collaborators in industrial settings grows, ethical research must evolve to allow for more nuance in the previously listed issues as well as a recognition of novel concerns as they arise. The authors suggest a forthcoming emergence of new ethical aspects related to industrial human-robot collaboration, including: emotional impacts on workers; effects of limited movement; the potential effects of working with one's replacement; the "chilling effects" of performance monitoring; the possibility for disclosure of new and unintended information through data collection; and the inability to challenge computerized decisions. Individually these are all very concerning issues, and together they comprise a set of factors that will require new forms of moral learning for assessing the ethical acceptability of industrial human-robot collaborations.

Last but not at all least, the final chapter of this book, Chapter "Robots and the Workplace: The Contribution of Technology Assessment to Their Impact on Work and Employment", presents a comprehensive overview of *Robots and the Workplace: The contribution of Technology Assessment to their Impact on Work and Employment*. Here, Carvalho and Pereira address the challenges that automation/robotization poses for human labour and employment issues. The authors claim that technology assessment (TA) can provide a ground for both ethical reflection and social engagement towards participatory decision-making regarding the application of such technologies. The chapter also debates labour substitution as a dominant narrative in economic analysis, while also stressing the need to contextualize technological change and innovation regarding robots and automation in the concrete work processes or tasks, bringing narratives closer to the ground. This discussion leads to the second main theme of the chapter: the potential role of technology assessment in better exploiting the development and use of robots in the workplace, their unanticipated consequences and the ethical and social tensions arising therein. According to the authors, these approaches do not aim at complete or sound predictions but at building participatory and interdisciplinary processes being the chapter ultimately about how we ought to live and to relate to technology.

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Contents

On Human Condition: The Status of Work

Maria Isabel Aldinhas Ferreira

Who are we if not or when not productive?
Hanna Arendt

Abstract At a time we are experiencing the overspread deployment of artificial intelligent systems in all domains of life, the present paper addresses the topic of human condition questioning both the universal existential circumstances that human beings share with all the other life forms and those circumstances that are human specific, claiming, in this case, that the capacity for work, in all its tangible and non-tangible forms, is a unique essential human attribute, responsible for the evolution of humankind as a species and for the development of their world. Being intrinsically human and not the result of a temporary condition or state, [work], i.e. [productive goal-driven action] has been, throughout times, enhanced and augmented by the creation, at first, of rudimentary and then of progressively more and more sophisticated man-made tools. In the course of this developmental narrative contemporary societies have become hybrid environments, this means environments where the physical is permeated by the digital, where human interaction is mediated by advanced forms of virtual communication, where non-embodied and also embodied forms of artificial intelligence coexist with natural intelligence where ultimately [work] in its intrinsic humaneness is being replaced in many sectors by task performing and decision-making per artificial intelligent systems. This present context and its predictable development in the near future demand the emergence of a deep awareness on the part of different stakeholders: research and development institutions, policy makers and governance, business and on the part of society in general, so that intelligent technology remains a human tool for enhancing and augmenting work, respecting its fundamental twofold dimension as: (1) a generative endowment for the creation of human reality (2) a means for the fulfilment and existential satisfaction of every human being.

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Keywords Human condition · Covid-19 crisis · Work · Intelligent tools-the ontological shift · Human dignity · Existential satisfaction

1 Introduction

The title of this chapter is primarily motivated by the consideration of a unique human dimension, that of productive goal-oriented action—the generative and transformative power of work- and the role tools play in this process, in their twofold symmetrical facets as the output of human work and also as work "coproducers".[1]

But this title is also certainly determined by the Covid-19 pandemics and its disruptive effects on the typical way human existence unfolded until March 2020. In fact, the massive disruption caused by this health emergency has made salient the essential fragility of humankind-a condition shared with all the other life forms, but for the sake of being, usually ignored by the self-conscious subject.[2]

Life requires a minimum of stability to unfold, however sometimes the essential parameters responsible for that stability are disrupted by internal or external circumstances: a health condition, a tsunami, a cyclone, a biological hazard- as in the case of plagues,- a war, an economic and social crisis… And it is at these times that human beings-the ones capable of creating worlds but also of destroying the planet-are brutally reminded of the existential frailty they share with their fellow species.

The pandemics has primarily made salient the fact that in spite of all the technological development achieved so far, in spite of having created a robotic engine capable of navigating a 290-million-mile journey and safely landing on the surface of Mars where it will collect samples to bring back home,[3] human beings are not all that mighty and can succumb by thousands when something gets out of control in their surrounding environment, like ants when something crushes their nest.

However, the pandemics has also made visible the wonder of the capacity, so many times challenged throughout history, of human beings to transcend and overcome critical situations thanks to the individual and collective effort of their intelligent productive goal-oriented action- their work capacity. We have seen this, we have all been and are being part of this common huge effort to overcome a crisis, an effort that initially caused the traditional existential private and work spheres to overlap, where most of the typical patterns of behaviour that defined the routines and lifestyles of our societies were erased or substantially changed, producing a time/space continuum where work status and offwork status merged in a nearly permanent working state, each of us trying to cope with the turbulence and instability caused by the pandemics in the personal- emotional/affective and social spheres of human existence and still

[1] We do not endorse here the distinction [labour]/[work] and their multiple interpretations throughout historical times and different ideological frameworks (c.f. Adam Smith, Marx, Arendt, among others) and refer in all circumstances only to [work].

[2] Those that are permanently or frequently tormented with these thoughts are diagnosed as having a mental condition that requires treatment.

[3] Nasa's Perseverance landed on the 18th of February 2021 on Mars.

trying to fulfill what was/is expected from the specificity of the roles previously assigned and assumed: health professionals giving their best in hospitals in order to save lives, thousands keeping services running, supply chains maintained, long-distance education and research going on… and last but not least scientists tracking the virus evolution in order to control its spreading, in order to understand its nature and behaviour producing vaccines in record time, vaccines capable of ending the threat, capable of restoring the normal patterns of the contemporary human social life.

And in all these situations, intelligent tools have come forward and have shown themselves as precious allies, proving that technological innovation and development, when ethically guided, pay off as their benefits for humanity can be immense.

In this context and bearing the heaviness of a strong philosophical tradition that coined and sustained the concept [human condition][4] and their multiple consecrated artistic expressions,[5] I have humbly accepted the challenge of its interpretation by assuming it as the grounding stone of an argument that tries to highlight the essential existential dimension that work plays in human life, simultaneously discussing the relationship between human beings and their tools, namely the new intelligent ones, within the transformative and generative dynamics triggered out by human productive goal-driven action.

2 The Key Elements of a Universal Existential Framework and the Specificity of Human Cognition

The human species shares with all the other fellow species three essential universal circumstances:

(i) It is endowed with a specific physical architecture that results from a long evolutionary and developmental individual and collective narrative, an architecture that has been shaped by its surrounding physical context and that has, on the other hand, shaped and given meaning to a particular world.[6]
(ii) It is embedded in a dynamic environment to which it is bound by a dialectic relationship of mutual influence and co-determination.
(iii) This physical architecture and its surrounding environment constitute a microcosm, a living unit.

It is thanks to the specificity of their physical bodies that living entities are capable of engaging in a particular way with their environment creating species specific

[4] cf. [1].

[5] cf. [20] and Magritte (1935).

[6] On the role of this physical architecture defining a species specific world cf. [3, 4, 6, 18, 25, 32].

worlds.[7] As Ref. [3] refers reality is not a unique and homogeneous thing, it is immensely diversified, having as many different schemes and patterns as there are different organisms. Every organism is according to that author a kind of monadic being as it has a world of its own, because it has an experience of its own.

However, though all life forms bear distinct physical architectures that determine the construction of specific worlds they are bound to their environments by the same dialectic relationship that characterizes the semiosic process inherent to all forms of cognition and on which the life of each individual entity and life in general depend.

Cognition, i.e., the intelligent capacity of every life form to guarantee their existence by interacting with its surrounding environment, is always an embodied, embedded and situated phenomenon.[8] This means the nature of this cognition depends on the specificity of the corporeal architecture involved and consequently on the type of interactions made available by it. It is embedded because it takes place within the boundaries of a typical environmental bubble which is fitted for that entity and has been extensively shaped by the cognitive architecture that has been evolving in it. This interaction is always situated as it happens along a bounded organic dynamics usually called lifespan, which is translated by a particular spatiotemporal flow according to the view of the human observer.

Though sharing the above mentioned key existential circumstances with all living entities, the human species distinguishes itself from all the others by having a set of specific attributes, namely: a conceptualizing and symbolic capacity that allows for the definition of an external objective reality, the definition of a sense of alterity, of Otherness, and the writing of an internal auto-narrative that permits the experiencer subject to recall past experiences, reflect on the present one and project, predict and eventually anticipate the modes of the future—a consciousness of their place and role in this lived social reality.

But the human being also distinguishes itself from the other species for its creative and transformative capacity to act on the surrounding environment, to model and shape it. It is the generative power of its productive goal-oriented action, of its work, that defines and develops the human world- a physical, economic, social, cultural and linguistic reality. Reflecting on the creative character of human action Marx points out: (1867:198): "A spider conducts operations that resemble those of a weaver, and the bee puts to shame many an architect in the construction of her cells. But what distinguishes the worst architect from the best of bees is that the architect raises his structure in imagination before he erects it in reality. At the end of every labour process, we get a result that already existed in the imagination of the laborer at its commencement". As Marx also points out, whereas animal is driven by natural impulses, man's specific form of activity is conscious life activity.

It is this conceptualizing capacity and its symbolic encoding—language- plus the power of productive-goal- oriented action that made possible the production

[7] cf. [31, 32]. According to Uexkull when we know the anatomical structure of a species we possess the necessary elements to reconstruct its experience. I would say we have the necessary elements to construct a rough approximation of that experience.

[8] cf. [6, 8].

of artifacts, namely of tools, the accumulation of knowledge and its transmission throughout generations allowing for the definition of a historic narrative that reflects the dialectics from which distinct modes of production, distinct economic, social and cultural models have emerged and that determined the scientific and technological development of humanity.

Given these assumptions, the concept of [human condition] stands in this text for [the set of universal objective circumstances-biological and developmental that determine or affect the being in the world of the humankind].[9] It comprehends on one hand the human fragility and the incomprehensiveness of human beings towards the existential phenomenon in all its dimensions. On the other hand it comprehends the generative power of the creative dimension overcoming the challenges of an ever evolving environment, constructing a human-sized world and using the power of love to hold it together. These circumstances define a condition to which every human being is intrinsically bound and from which cannot depart, as Ref. [1] refers: "The most radical change we can imagine in human condition would be an emigration of men from the earth to some other planet … Yet even these hypothetical wanderers from the earth would still be human […]".

As [8] points out, in a significant number of species, the evolutionary and developmental process has proceeded according to three interconnected axes: (1) interaction ability, (2) task performance ability, (3) tool making ability.[10] The abilities represented by these three axes are made possible by a set of innate endowments that, though exhibiting a degree of variability among species in what relates their level of sophistication and complexity, represent a continuum that is horizontal to all of them. This way the capacity for communication, that the interaction ability subsumes, attains its highest degree of sophistication in human conceptualizing and symbolic language capacity, the same happening with the capacities for distributed task performing and the tool making which are endogenous[11] and define a continuum of progressive complexity throughout different species.[12] Being innate as a potential, these abilities are in human beings also the result of a learning process that takes place in society, that goes on throughout the individual's lifetime and that relies substantially on the accumulated experience of precedent generations and on the intrinsic values of the prevalent economic, social and cultural models. One of the substantial differences we can immediately identify when contrasting tool making in humans

[9] To Ref. [1] the distinctive characteristic of human existence, its conditions, can be classified into two groups. The first group of human conditions consists of basic conditions under which life on earth has been given to man, and these are: life itself, worldliness, plurality, natality and mortality, and the earth itself. The second group of human conditions consists of conditions made by the men themselves, and these are man-made things and relations. Whatever enters the human world of its own accord or is drawn into it by human effort becomes part of human condition.

[10] The interaction ability, in fact, subsumes either (2) or (3). We make the distinction for purely analytical purposes.

[11] Greenfield [13].

[12] Although tool use has for long been assumed to be a uniquely human trait, there is now much evidence that other species such as mammals, namely primates, birds, cephalopods also use more or less rudimentary tools. cf. [2, 28].

and in other species is the fact that while human tools have been evolving exponentially—with some tools exhibiting nowadays a considerable degree of potential autonomy that will require little or no human intervention—tool making among other species has remained essentially rudimentary.

The creation of tools is consequently inherently associated to the biological, economic, social and cultural/scientific development of humankind. Throughout the ages, human beings have modified or updated the inventions of precedent generations or those of other communities of tool makers and have also created new ones in order to overcome difficulties, in order to achieve certain goals. From distinct social settings, distinct modes of production scientific and technological innovations have emerged determining specific working settings, specific working tools, specific divisions of labour.

Marx regarded work produced by means of tools as a feature differentiating human beings from the rest of the animal kingdom and referred to tool use as an extension of the laboring body,[13] viewing technologies as extensions of the human will domination over nature:

> Nature builds no machines, no locomotives, railways, electric telegraphs [...]These are products of human industry; natural material transformed into organs of the human will over nature...they are organs of the human brain created by the human hand (Marx 1993, p. 706).

Tool making and its natural evolution is inherently associated to the huge transformative and generative power resulting from the endogenous human capacity to define particular worlds, as can be observed by the way distinct artifacts have come to define distinct stages of human historical development, distinct civilization frameworks. Tools are in fact a particular subset of artifacts.[14] They share, with the broader category they belong to, the essential feature {function}, i.e. they are suited to a particular purpose, but their semantic specificity is also realized aby another fundamental feature. When looking at the definition of the concept [tool] in a language dictionary[15] we read:

1. A **tool**[16] is any instrument or piece of equipment that you hold in your hands **in order to help you to do a particular kind of work.** e.g., "workers downed tools in what soon became a general strike".
2. A **tool** is also any object, skill, idea etc., **that you use in your work** or that you need for a particular purpose.

By looking at these definitions we realize that the concept of [tool] is primarily associated to a working scenario and to the production/creation of a particular entity.

[13] Ref. [15].

[14] The definition of the concept of [tool] has been subject to different versions by researchers studying animal behavior. Ref. [16] defines [tool] as an object that has been modified to fit a purpose or an inanimate object that one uses or modifies in some way to cause a change in the environment, thereby facilitating one's achievement of a target goal.

[15] Collins Cobuild English Language Dictionary. Collins Publishers. University of Birmingham 1988 (1st edition).

[16] Emphases mine.

This means that inherent to the semantics grounding the concept of [tool] is the trait **{cause an object, an event or a state to come into being, through physical and/or mental activity}** which is the essence of the concept associated to the verb [work], weather the nature of this work is tangible or not.

This fact can be easily foreseen when we think not only of a shoemaker handling their tools to create or repair a pair of shoes, but also of a factory worker interacting with a machine to produce a particular piece, the farmer that drives a tractor to plough the field, the researcher that sits at the computer using a text processor to write a paper, the doctor that relies on machine learning to his medical procedures.

Tools can be seen primarily as extensions of the physical body[17] not only in the sense of being extensions of the "human hand" but essentially by being always somehow extensions of the human mind, providing a means for enhancing or augmenting the capacity for productive action that the bare human corporeal architecture finds difficult or is not able to attain by itself. This quasi prosthetic nature of tools is evident in the way human motor behaviour and its corresponding mental patterns are influenced by their handling. In fact, handling and/or operating any kind of artifact always requires the adoption of specific motor programmes[18] and the definition of new neural pathways that will allow particular patterns of behavior to become typical and routinary, being, this way, instantly triggered out by specific contexts of use without depending on a reflexive attitude.[19]

This prosthetic nature of the tool is also addressed by Ref. [26] that refers how tools are taken into ways into which human beings enroll and project themselves into work practices as they "withdraw" and become "ready-to-hand".

Perhaps because of this nearly physiological extension, this quasi-symbiotic process, between a human being and a specific instrumental artifact, through which a specific effect is produced causing a specific entity to come into being, there is frequently a link of affective attachment uniting workers to their tools and to their produced works. This frequent affective attachment reflects itself in the care often revealed by workers in the maintenance and keeping of their tools,[20] in the way artisans have always carved out or just signed their names on the created object or in the sense of achievement and even pride manifested by those that have contributed to the coming into being of important realizations, of particular endeavours. This feeling was evident, for instance, in a newspaper interview to the workers that participated

[17] It is particularly interesting how some technological tools are sometimes presented as extensions of the physical body. I recall on this purpose the sentence that opened up a small video that performed when I started my laptop computer produced by Texas Instruments in the early 90s—"Texas Extensa, an Extension of yourself".

[18] According to [32] the two fundamental human handgrips, first identified by J. R. Napier, and named 'precision grip' and 'power grip', represent a *throwing grip* and a *clubbing grip*, thereby providing an evolutionary explanation for the two unique grips, and the extensive anatomical remodelling of the hand that made them possible.

[19] cf. Ferreira [7].

[20] We recall on this purpose the particular attachment a hairdresser revealed towards her set of high specialized scissors, which she had acquired when becoming a professional and uses in her daily practice or the attachment and care a professional musician dedicates to his violin.

in the construction of the 25th of April Bridge (former Salazar Bridge) in Portugal, on the occasion of its 50 anniversary.[21] According to António Rosa, one of these workers, the construction of this bridge, the biggest in Europe at that time, was a real challenge to everyone and its construction site became a kind of second home to those deeply committed to their edification. With more than 40 years dedicated first to its building and then to its maintenance, this worker confessed that he still kept some of the tools he used then, namely a brush.

As Ref. [1] points out tools and implements have become an inalienable part of human existence and human beings have adapted to them from the moment they conceived, designed and produced them. Every tool is designed to make human life easier or more pleasant and to enhance human capacity or creativity in order to produce better work. The ontological dimension of tools, i.e., their nature and instrumentality can be understood exclusively in an anthropocentric sense that is historically determined.

3 Work as a Human Endowment

Different ideological perspectives, distinct epistemological frameworks[22] have converged on recognizing the uniqueness of [work] as a human endowment and its essential character in the definition of what it means to be human.

To Ref. [22], [work] is the unique means through which human beings objectify their existence and come into being, i.e., acquire an identity and a social role.[23] This essential objectivation is to him the essence of humanness. On the close connection between the role one plays as a worker and the definition of a psycho-social identity, Arendt writes [1]: "The moment we want to say who somebody is, our very vocabulary leads us astray into saying what he is […]".

Another fundamental perspective on the essential character of this endowment in the definition of humanness is the Encyclica Laborem Exercens (14 September 1981). This encyclical, written by Pope John Paul II, is part of the larger body of Catholic social teaching tracing its origin back to Pope Leo XIII's 1891 encyclical Rerum Novarum. The Encyclica Laborem Exercens highlights the fact that the capacity for work is an essential human feature that cannot be comparable by its intrinsic characteristics to the performing of certain tasks by other species in order to subsist.

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21 https://www.sabado.pt/portugal/detalhe/conhece-o-dono-da-ponte-25-de-abril.

22 cf. on this purpose [17, 22].

23 In "Is identity more than a name?" In On Meaning: Individuation and Identity, [6] refers that the construction of a psycho-social identity reinforces the already granted individual biological uniqueness. According to this author, identity formation starts at early infancy and develops throughout the individual's lifetime in a process identical to the formation of pearls. Beginning in the restricted early family circle it develops successively along other spheres of life- the enlarged circle of family and friends, the school and education circle, the work domain, giving this way substance to an identity that is generally actualized by a first name followed by a family name.

> Work is one of the characteristics that distinguishes man from the rest of creatures, whose activity for sustaining their lives cannot be called work [….] it bears a particular mark of man and of humanity, the mark of a person operating within a community of persons. (ibidem, p. 1).

As the encyclical points out [work] is universal in the sense that it embraces "all human beings, every generation, every phase of economic and cultural development" and it is simultaneously a process that takes place within each human being, a personal narrative acknowledged by the conscious subject. Consequently it develops along two fundamental inseparable and complementary dimensions:

1. An objective dimension
2. A subjective dimension

Its objective dimension relates to its generative and transformative power through which human beings act on the surrounding environment- "dominating nature",[24] "subduing the earth"[25]- and by so doing creating with the effort of their bodies and the intelligence of their intellects the necessary conditions for their "being" throughout the dynamics of an existential historical time.

> [….]there thus emerges the meaning of *work in an objective sense,* which finds expression in the various epochs of culture and civilization (ibidem, 2).

This objective dimension is the tangible or non-tangible existential imprint registered not only by each society but by each of its individual members, from the most notorious to the most anonymous, since individual and collective existence and progress depend on the coordinated action and work of each and all in the different domains of human life.

John Paul II points out that [work] has an ethical value of its own, which clearly and directly remains linked to the fact that the one who carries it out is a person, a conscious and free subject.

> Working at any workbench, whether a relatively primitive or an ultramodern one, a man can easily see that through his work he enters into two inheritances: the inheritance of what is given to the whole of humanity in the resources of nature, and the inheritance of what others have already developed on the basis of those resources, primarily by developing technology, that is to say, by producing a whole collection of increasingly perfect instruments for work (ibidem, p. 6).

On the other hand, the subjective dimension relates to the consciousness every worker must acquire of their personal narrative and of the importance of their individual role, their contribution in a collective process to which all individual efforts converge. It is in its inherent humanity that resides the dignity of [work]:

> through work man not only transforms nature, adapting it to his own needs, but he also achieves fulfilment as a human being and indeed, in a sense, becomes "more a human being (ibidem, p. 9).

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[24] Ref. [22].

[25] Laborem Exercens 1981.

4 When Tools Become Autonomous: The Ontological Shift

Technological development is the result of the physical and intellectual effort of millions, throughout multiple generations, the result of their creativity and accumulated experience/knowledge, aiming at producing the necessary conditions to liberate individuals from the toil frequently associated to hard work, promoting individual well-being and the society's development, improving life conditions, eradicating poverty and disease, assuring defence against eventual threats.

Laying aside the evident differences inherent to the distinct stages of development that characterize the momentum of the present and those of the past technological revolutions, perhaps the most important feature brought about by the present one is the ***ontological shift***[26] of the concept of [tool]. Until recently, either hand tools or machine tools have been manipulated or operated by human beings, depending on human skill and on their will. Language reflects this instrumental character assigned to the artifacts we handle or manipulate, to achieve a certain goal, in the syntax and semantics of most action verbs, e.g.,

X paints Y with Z
X: human – Agent. Y: a surface – Object. Z: artifact – Instrument.
Though we can have the Instrument in subject position it is never assigned agency, e.g.,
Z paints well.

This is interpreted as Z having intrinsic properties that allows it to be a good tool and not because Z is particularly skiillful or talented.

However, the present tools are becoming progressively more and more independent from human control. By introducing forms of artificial intelligence in the means of production, in work processes, by endowing machines with a form of intelligence that assigns them the capacity to operate and perform tasks independently, capable of decision making, technology is in fact not only introducing a factor of instability in the nature of the relationship between the human being and their tool but potentially interfering in the very nature of a fundamental human dimension- that of productive goal- oriented action, the generative capacity of work.

Martins [21] refers to this as "a technological mutation, that ceases to be instrumental and conceived as an extension of the human arm but merges with human being, producing the very arm and threatening to produce the whole being".[27]

[26] Refs. [8, 9].

[27] My translation.

More than the anticipated huge impact on employment[28] which is object of ongoing studies and monitoring[29] in order to reduce its negative consequences on the labour market,[30] and that in our opinion can be reverted or at least minimized by implementing the adequate social and political measures,[31] it is the potential expropriation of the generative and transformative power from human "hands/minds" that can become an existential problem.

Hal Varian, chief economist at Google, predicted the future in the following terms: "The future is simply what rich people have today. The rich have chauffeurs. In the future, we will have driverless cars that chauffeur us all around. The rich have private bankers. In the future, we will all have robo-bankers [...] One thing that we imagine that the rich have today are lives of leisure. So will our future be one in which we too have lives of leisure, and the machines are taking the sweat? We will be able to spend our time on more important things than simply feeding and housing ourselves?"[32]

These words come, in a way, nearly in line with the prediction made by John Maynard Keynes in *Economic Possibilities for our Grandchildren* (1930: I):

> My purpose in this essay [....] is not to examine the present or the near future, but to disembarrass myself of short views and take wings into the future. What can we reasonably expect the level of our economic life to be a hundred years hence? What are the economic possibilities for our grandchildren?
>
> [...] We are being afflicted with a new disease of which some readers may not yet have heard the name, but of which they will hear a great deal in the years to come–namely, technological unemployment. This means unemployment due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour. [....]But this is only a temporary phase of maladjustment. All this means in the long run that mankind is solving its economic problem.
>
> I would predict that the standard of life in progressive countries one hundred years hence will be between four and eight times as high as it is to-day [....] Yet there is no country and

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[28] Andy Haldane, chief economist at the Bank of England. Predicted, in 2015, that 15 million jobs in the UK, roughly half of all jobs, were under threat from automation. He pointed out that the first industrial revolution had occurred in the middle of the eighteenth century and the second in the latter half of the nineteenth century. The third industrial evolution—the era of information technology—appeared to have resulted in an intensification of trends seen in the first two: "a hollowing-out of employment, a widening distribution of wages and a fall in labour's income share".

https://www.theguardian.com/business/2015/nov/12/robots-threaten-low-paid-jobs-says-bank-of-england-chief-economist.

[29] cf. for instance the work going on at OEDE.AI observatory, GPAI working group on the Future of work. The Work of the Future. Report November 2020. Available at https://workofthefuture.mit.edu/.

[30] https://www.theguardian.com/business/2015/nov/12/robots-threaten-low-paid-jobs-says-bank-of-england-chief-economist.

[31] e.g., (i) involving all the stakeholders in this process of change, identifying the distinct needs determined by their respective functional contexts and tailoring technological solutions according to those specificities. (ii) Legally framing the hybrid working settings legislating in order to preserve not only the physical security, but also the mental health, the emotional stability of those working there; Last but probably first of all (iii) providing massive digital literacy and an ethical background that allows for a critical perspective on the new state of affairs and provides guidelines for human behaviour when acting/interaction with intelligent systems.

[32] https://www.ft.com/content/4329a987-9256-3059-b36f-1aba9338b800.

> no people, I think, who can look forward to the age of leisure and of abundance without a dread. For we have been trained too long to strive and not to enjoy. […] For many ages to come the old Adam will be so strong in us that everybody will need to do some work if he is to be contented […]Three-hour shifts or a fifteen-hour week may put off the problem for a great while. For three hours a day is quite enough to satisfy the old Adam in most of us!

Reflecting on the complex equilibrium demanded by the relationship between human beings and machines, Refs. [11, 12] refer to this relationship as a form of human empowerment. In his opinion machines do not limit human faculties as they are modelled on them but take them to a higher level. The fact that they can exalt human capacity to take physical action on our environment, even to the point of enabling new and unnatural functions (such as human flight), goes to show that machines are capable of forming part of a man–machine assembly for the purpose of going beyond boundaries previously believed impossible to overcome.

5 The Future of Work/The Work of the Future: The Way Forward

When one analyses the economic and social predictions and the expected growth estimates made before March 2020,[33] considering how ICTs and artificial intelligent systems would impact economy and society in the years to come, we realize that this type of predictions are exactly what they are—just hypotheses of further economic and social development to be verified if and only if the values of the variables involved don't change. But the reality is that the human environment in all its components—and economy is one of these components- is a complex dynamic system, an ever-evolving entity, whose evolution, that as it happens in the strict physical environment, can be disturbed by multiple factors. The Covid-19 pandemics is certainly one of the strongest causes of huge global economic and social turbulence in decades, causing a disruption whose consequences on the modes of production, on economy and on the social tissue cannot yet be fully anticipated. During the first lockdown and following the trend to introduce automation in management and delivery processes, a trend already initiated much before the pandemics, many companies deployed automation and AI in warehouses, grocery stores, call centers, and manufacturing plants to reduce workplace density and to cope with surges in demand.

According to the February 2021 McKinsey report,[34] Covid 19 has accelerated the already existing trends in remote work, e-commerce, and automation, with up to 25% more workers than previously estimated potentially needing to switch occupations (in the case of advanced economies). According to the evidence collected across the eight countries that were monitored, more than 100 million workers, or 1 in 16, will need to find a different occupation by 2030.

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[33] cf. https://www.mckinsey.com/featured-insights/future-of-work/skill-shift-automation-and-the-future-of-the-workforce.

[34] https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-after-covid-19.