UNIVERSIDAD COMPLUTENSE MADRID

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ARTIFICIAL INTELLIGENCE: A REAPPRAISAL

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Working Papers / Documentos de Trabajo. ISSN: 2255-5471
DT CCEE-2201 Marzo 2022
https://eprints.ucm.es/id/eprint/71377/

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Abstract:

This article begins with a brief reference to the history of the Artificial Intelligence (A.I.) highlighting the great figures of George Boole, Kurt Gödel and Alan Turing. The algebra of the first, the undecidability theorem of the second and the advanced machine of the third marked the fundamental milestones of this evolution. The use of the binary system and the introduction of quantum mechanics is explained, which is a great step forward by being able to count on the advantages of quantum computer and algorithms, along with quantum statistics and other new complementary technologies. Regarding the controversy over whether A.I. can outperform Human Intelligence (H.I.) we conclude at the end of the work that enormous effort made on the way to the present allows us to affirm that Artificial Intelligence constitutes, in a certain sense, an asymptote of the Human Intelligence.

Key words: I.A.; Turing; Computers, algorithms; Quantum; H.I.

INTELIGENCIA ARTIFICIAL: UNA REEVALUACIÓN

Resumen:

El artículo comienza con una breve referencia a la historia de la Inteligencia Artificial, (I.A.) en la que destacamos en sus respectivos apartados las eminentes figuras de George Boole, Kurt Gödel y Alan Turing. El álgebra del primero, el teorema de la indecidibilidad del segundo y la avanzada y determinante máquina del tercero marcan los hitos fundamentales de dicha evolución. Se explica el empleo del sistema binario, así como la introducción de la mecánica cuántica, lo que supone un gran paso hacia adelante, al poder contar con las ventajas de las computadoras y los algoritmos cuánticos, junto a la estadística cuántica y otras nuevas tecnologías complementarias. Respecto a la controversia sobre si la I.A. puede superar a la Inteligencia humana, tras un último epígrafe dedicado a este tema, concluimos afirmando que el enorme esfuerzo realizado en el camino recorrido hasta la actualidad permite afirmar que la Inteligencia Artificial constituye una especie de “asíntota” de la Inteligencia Humana.

Palabras clave: I.A., Turing, Computadoras, Algoritmos, Cuánticos, H.I.

Materia: Inteligencia artificial
JEL: 03

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Marzo 2022 (fecha de recepción)

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1º A previous Note

For the reader to be clear about the purpose of this paper, it is worth highlighting three issues that will be the object of analysis. The first refers to the interpretation of Artificial Intelligence as overcoming conventional computing through quantum computing. The second question raises the scope and the impact of the "quantum revolution", considering that Quantum Computing constitutes an interdisciplinary research area situated between Quantum Mechanics and Computer Science. The third point to highlight is that in our work we will only address in a residual way the already old dilemma of whether Artificial Intelligence (or now Quantum Artificial Intelligence) can match and even replace Human Intelligence. This question is not exactly the most complicated, and we will pronounce on it due course.

In this article we will begin with a brief summary of the background of what Computer Science is today, ad how much it can refer to the advances experienced in the field of modern Artificial Intelligence. In this unavoidable task we take as a starting point the Aristotelian logic, within the framework of Greek wisdom, and we move on, in a wide jump in time, to the contribution of a group of famous British mathematicians of the 19th century. We are referring, as we shall later, to George Boole, Augustus De Morgan, Charles Babbage ad Ada Lovelace, well known among them, and all of whom were busy developing and applying first-order logic and designing and building complex calculating machines. The story continues by adding two great figures of the 20th century: the prestigious and outstanding Austrian mathematician Kurt Gödel, on the one hand, and another famous English scientist, also a mathematician, Alan Turing, on the other. Both, together with George Boole, the first of the four already mentioned corresponding to the previous century, deserve special treatment given the extraordinary role they played in laying the foundations of the Computing Science in its broadest sense, as in the conception of Artificial Intelligence. Because of this, we will dedicate separate sections to each of the three main great masters and research just mentioned.

After the summarized exposition about the different protagonists of advances in computer science, we will enter the analysis of Quantum Mechanics, Quantum Computing, and what we can call Quantum Artificial Intelligence, dedicating the corresponding section to each of these important subjects. The introduction of such matters in the topic that we are dealing with constitutes the most relevant part of our work, since this means reconsidering everything that refers to new technologies in the wide field of information within the principles and coordinates of Quantum Physics, in general, or Quantum Mechanics in particular.

At this point of our work will be stop in a section on application of Artificial Intelligence to Economy, a task as important as it is difficult, although we will deal only with the most interesting and essential problems and questions. As expected, we conclude our paper by raising the eternal question of whether the Artificial Intelligence, with the many advances achieved, can confront and overcome the Human Intelligence. In this last section we will try to distinguish the advantages and opportunities that the Quantum Artificial Intelligence undoubtedly offers us, on the one hand, and the limits that inexorably prevent the debate on the eventual superiority of the Quantum Artificial Intelligence with respect to the Human Intelligence and its capacity in the broadest sense.

On this delicate and debated matter, we will try to address some arguments and aspects frequently used with an a priori criterion in favour of the superiority of Artificial Intelligence, some of them so debatable and lacking in evidence and deep reasoning, as habitually is the case of the confrontation of human mind and machine in the chess game.

2º A Brief History of Artificial Intelligence

A reference to the background of the Artificial Intelligence it can be done in many ways, going back in time depending on the criteria and methodology adopted. In our case we are in favour of limiting ourselves to the most clearly outstanding milestones or moments, even knowing that we leave aside flashes of creativity, experiments far removed in time, authors who in some way, consciously or unconsciously, were approaching the bases or foundations of what today, in a broad sense, we can understand by Artificial Intelligence. In this regard, our approach is very concise and selective, leaving behind many names that from different angles and at distant times, have contributed to making Computer Science, in its broadest sense, Quantum Computing, and what it is the very Artificial Intelligence, an unquestionable and invaluable reality. Except a brief mention to Aristotle, for reasons that are easy to understand, our references, taking a good leap, begin with several of the most significant investigations carried out during the 19th century, following with the prominent figures who in the 20th century achieved decisive advances in fundamental matters that contributed to developing what for more than sixty years has been part of what today constitutes the Artificial Intelligence, or to be more precise, the Quantum Artificial Intelligence.

Within the framework of classical Greek wisdom, we highlight ***Aristotle*** (384 b.C-322 b.C) because he founded the classical logic, addressing the fundamental principles of reasoning and proposing as fundamental axioms of propositional logic the following:

1º the principle of non-contradiction. $\neg (A \wedge \neg A)$ it is true, and this because A is mutually exclusive with non-A.

2º the principle of identity: $(A \leftrightarrow A)$, that is to say, A is identical to itself.

3º the principle of the excluded third: $(A \vee \neg A)$, or what is the same, A is or not without graduations of validity.

In his *Metaphysics*, inextricably linked to his work *Organon*, Aristotle is dedicated to what he himself called “first philosophy”, the science of first principles, such as those we have just enunciated, the Stagirite making it clear that the first of them is the more important. Also in other works, such as *Rhetoric*, linked in some aspects to strictly logical issues, the founder of the Liceo raises the need to find the method that allows us to argue about any problem, since this gives rise to dialogue thought that ...*”unlike the monologue finds in the interlocutor both a critical presence and a stimulus”.*[1] This precedent, located in the cradle of knowledge, we consider it essential since, as we know and we see later, logic constitutes the basis on which Computer Science and Artificial Intelligence are sustained.

The general leap to 19th century that we referred to earlier place us at the contribution of four prestigious British mathematicians who clearly anticipated and laid the foundations for what would later become Computer Science, Computational machines and, ultimately, Artificial Intelligence. This group of brilliant researches in this field of science and technology was made up of George Boole, Augustus De Morgan, Charles Babbage and Ada Lovelace. We will make a brief reference to each of them, although we will dedicate a special section to Boole given the great relevance that Boolean algebra had and continues to have.

Augustus De Morgan (1806-1871), together with *George Boole* (1815-1864), raised Aristotelian logic to the level of first-order logic through a new and more abstract notation that provided great symbolic power, thus allowing the resolution of complex reasoning problems. Mathematician, logic, and professor of Mathematics at the University College of London, Der Morgan devised a system of rules that make it possible to express, manipulate and simplify logical problems that admit two states, true or false, by mathematical procedures. Of clear Boolean influence, in digital electronics the meaning of true and false is symbolized by 1 and 0 respectively. As Ignasi Belda states in his excellent book on the subject, with all these advances today we have first-order logic that is still the

[1] QUESADA, Julio (2011): p. 76.

cornerstone of modern computing, Artificial Intelligence and automatic reasoning.[2]

Charles Babbage (1791-1871), mathematician and computer scientist, and professor of Mathematics at the University of Cambridge during the period 1828-1839, was an engineer inventor of programmable calculating machines, being noteworthy his attempt to design and develop a mechanistic calculator capable of calculating tables of numerical functions by the method of differences. The machine based on the finite differences´´ method was never built, and in a new attempt, in the year 1837 Babbage bean to design his analytical machine, the same thing happening as with the first due to technical difficulties that arose, and to the opposition of the British Association for the Advancement of Science. In 1991, the London Museum began the construction of the Babbage machine of differences in commemoration of his 200[tth] anniversary of his death, and in October 2010 the British programmer John Graham-Cummings began to organize the construction of the analytical engine of the undoubtedly great computer scientist, waiting that it could be ready in 2021.

Augusta Ada Lovelace (1815-1852), daughter of the great English poet Lord Byron, was a mathematician and writer well known and famous above all for her work on the Babbage´s Analytical Machine, being considered the first computer programmer. Between 1842 and 1843 he translated an article by the Italian military engineer Luigi Menabrea on the machine, which she supplemented with an extensive set of notes of her own, simply called Notes. These Notes are important in the history of computing. In her training in the field of science, and more specifically as a student of mathematics, always under the strict control of her mother, Ada Lovelace had Augustus De Morgan as her last teacher and Master, who, as we say before, was then professor *at University College London (UCL). In 1833 she also met Charles* Babbage, with whom she would be her friend and collaborator ever since.[3]

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[2] BELDA, Ignasi (2019): pp. 24-26.
[3] NAVARRO, Joaquín (2019): pp. 81-84.

And now, without taking away the importance of the precedents briefly commented, we must remember, as we say in the Previous Note, that the solidity of the foundation on which modern Computer Science and the remarkable progress of Quantum Artificial Intelligence are based, is the result of the work of three great Masters, all them exceptional mathematicians: George Boole, Kurt Gödel and Alan Turing. We will dedicate a section to each one of them, highlighting the respective contributions made and to what extent they constitute instruments related to the topic at hand, as well as their capacity and scope relative to the pursued objective.

Boole´s algebra, without hesitation, constitutes the conceptual and analytical basis of everything related to the Computer Science and the Quantum Artificial Intelligence. In his turn, we find a close relationship between the approaches and contributions of Gödel and Schrödinger, both in the mathematical logic used and in the relevant problem of quantum superposition. There is also a strong connection between the principles of Boolean algebra and the conception, design and functioning of the Turing machines, relationship that we can check when we get to the corresponding section.

It should be clarified that although we do not dedicate a special epigraph to Erwin Schrödinger, an well-known Austrian physicist and Nobel Prize winner, nationalized Irish, his thought and work are alive at all times, with a substantial presence when we address the key epigraph on Quantum Mechanics, before penetrating the advances in Computer Science and in the New Quantum Artificial Intelligence. Furthermore, as we will see when exposing Gödel´s theorem, on the one hand, and entering the problem of quantum superposition considered within the framework of quantum mechanics, on the other hand, we will verify the fundamental role that Schrödinger plays in the development of quantum theory.

3º Boole´s Algebra

As is well known George Boole (1815-1864) being a British mathematician who helped establish modern logic and whose algebra of logic, or Boolean algebra, is basic to the design of digital computer circuits. We can find the origins of their work in his book *Mathematical Analysis of Logic (1847)* that together with his later work *Laws of Thought (1854)* marks the foundations of modern computational arithmetic. The main factor of Boolean algebra is the fact that it deals with the study of binary variables whose possible values are 1 (true) or 0 (false). It is important to highlight that Boolean algebra deals with conjunction, disjunction, and negation, unlike elementary algebra that is expressed using mathematical functions, such as addition, subtraction, multiplication and division.

A first approximation to Boolean algebra is the one that poses in a very simple way the internal binary operation of a addition and a product starting from the set (0,1) and the binary variables (a, b).

The respective operations would as follow:

a	b	a + b
0	0	0
0	1	1
1	0	1
1	1	1

a	b	a • b
0	0	0
0	1	0
1	0	0
1	1	1

In the binary operation of the addition it can be seen that 1 + 1 is still 1, thus representing what in Set Theory is called “universal set”, which the philosopher and Roman Emperor Marco Aurelio already spoke about it in his Meditations although, obviously, he wasn´t referring to anything to do with algebra. More generally we can say that ({0, 1}, −, +, •) is a Boolean algebra if it satisfies the following axioms:

1º Associative law of the addition:

$\forall$ a, b, c, $\in$ $\{0, 1\}$: (a + b) + c = a + (b + c)

2º Associative law of the product:

$\forall$ a, b, c, $\in$ $\{0, 1\}$: $(a \cdot b) \cdot c = a \cdot (b \cdot c)$

3º Existence of the neutral element for the addition:

$\forall$ a $\in$ $\{0, 1\}$: a + 0 = 0

4º Existence of the neutral element for the product:

$\forall$ a $\in$ $\{0, 1\}$: $a \cdot 1 = a$

5º Commutative law of the addition:

$\forall$ a, b $\in$ $\{0, 1\}$: a + b = b + a

6º Commutative law of the product:

$\forall$ a, b $\in$ $\{0, 1\}$: $a \cdot b = b \cdot a$

7º Distributive law of the addition with respect to the product:

$\forall$ a, b, c $\in$ $\{0, 1\}$: $a + (b \cdot c) = (a + b) \cdot (a + c)$

8º Distributive law of the product with respect to the addition:

$\forall$ a, b, c $\in$ $\{0, 1\}$: $a \cdot (b + c) = (a \cdot b) + (a \cdot c)$

9º There is a complementary element for the addition:

$\forall$ a, $\in$ $\{0, 1\}$; $\exists \bar{a}$ $\in$ $\{0, 1\}$: $a + \bar{a} = 1$

10º There is a complementary element for the product:

$\forall$ a, $\in$ $\{0, 1\}$; $\exists \bar{a}$ $\in$ $\{0, 1\}$: $a \cdot \bar{a} = 0$

The Boole contribution to the modern computational arithmetic has been recognized by authors such as Ernest Nagel and James R. Newman in their work on *The Gödel Demonstration: "Le renouveau des études logiques à l´époque moderne date de la parution en 1847 de L´Analyse mathématique de la logique de G. Boole. Le but principal de Boole et de ses premiers disciples était de développer une algèbre de la logique susceptible de fournir une notation précise pour traiter de types de déduction plus généraux et plus variés que ceux dont rendaient compte les principes de la logique traditionnelle".*[4] On the other hand, it is necessary to bear in mind that the Boolean program is closely associated with the mathematicians of the nineteenth century as regards the fundamentals of analysis, in the sense of trying to show that pure mathematics can be considered as a simple chapter of formal logic, an interpretation that can be found in Whitehead and Russell´s Principia Mathematica in 1910.

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[4] NAGEL, Ernest; NEWMAN, James R,; GÖDEL, Kurt ; GIRARD, Jean-Yves (1989) : pp. 46-47 We reproduce the paragraph in French because we are using at this specific point the text on Gödel´s Theorem published by the prestigious Editorial Seuil. In any case, Molière´s language is always welcome.

4º The Gödel´s Theorem

As we mentioned in the section dedicated to presenting a brief history of Artificial Intelligence, the figure of Kurt Gödel (1906-1978), the great Austro-Hungarian mathematician constitutes an important high point to consider in the process that has led to what we currently call Quantum Computing, on the one hand, and Quantum Artificial Intelligence, on the other. In 1931, in his article *"Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme",*[5] the famous Gödel proof came to give a complete answer to Hilbert's second problem and to overcome the difficulties of Russel and Whitehead, sowing great concern in the broad field of science, in general, and mathematics in particular. Indeed, Gödel showed that in a strictly logically formulated system, such as the one developed by the two English thinkers, for the arithmetic of natural numbers there are always "undecidable" propositions from the axioms of the system. He also concluded that it is impossible to prove, using the methods referred to by Hilbert that the axioms of arithmetic will not lead to a contradiction. In this regard, it is necessary to clarify that by "undecidable" propositions we understand those in which it is impossible to ensure their truth or falsity, based solely on the characteristics of the object of study, expressed in the form of axioms and rules of inference.[6]

An in-depth analysis would exceed the limits that we have set for ourselves in this work, especially if we consider its cumbersomeness and difficulty, also given the fact that our main objective is focused on defining the current and future possibilities of Artificial Intelligence in the framework of Quantum Mechanics. We consider it more interesting for our purpose to briefly present, by way of example, an application of Gödel´s Theorem in the field of Law, more specifically in the area of accounting jurisdiction, in order to demonstrate its incompleteness and its consequences.

Let us suppose that the Spanish Court of Accounts has investigated the economic-financial management of a city council, having detected important irregularities incurring serious responsibilities of an accounting

[5] "On formally undecidable theorems of Principia Mathematica and related systems"
[6] FERNÁNDEZ DÍAZ, Andrés (1999): pp. 202-204.

and criminal nature. After the procedural steps carried out by the High Court, the corresponding trial takes place, made up of magistrates who acts as judges, by the Attorney General of the Institution, by the Head of State Legal Services who must guarantee the interest of the public treasure and, finally, by the lawyer of the city council which accounts have been object of public auditing or control. It is necessary to know if the Town Hall lawyer will file a lawsuit against the Mayor or not, that is, if the legal representative of the Town Hall will sue the Mayor, in compliance whit his obligation, or will defend him with his silence. In the language of Quantum Physics, when we open the box we will know if the cat is alive or dead, or what is equivalent, when the lawyer of the audited local corporation speaks, we will know if he comes as a plaintiff or as a defender.

Elaborating in what we have said and given that we cannot know “a priori” if the procedural representative of the local corporation will act as a judge or as a party, we effectively find ourselves with a problem of Quantum Superposition. And as it would said in terms of Schrödinger´s paradox, to which we will refer later, and as we have just stated, we would have to wait for the moment in which the box is opened to know if the cat is alive or dead. Obviously, and here our peculiar version of Gödel´s Theorem relentlessly arises, there can be no unequivocal pronouncement on the proposition…and the procedure ends up being shelved.[7]

To end this section let us remember that when in 1952 Kurt Gödel, who since 1938 belonged to the Institute for Advanced Study of Princeton, obtained the title of *Doctor Honoris Causa* from Harvard University, his nomination mentions the work of 1931 as one of the most important carried out in logic in modern times.

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[7] FERNÁNDEZ DÍAZ, Andrés (1999): pp. 205-210.
A full and rigorous version de our work mentioned in this note and in the former, develops in detail the content of the Gödel´s Theorem. Their application to the accounting jurisdiction constitutes a paper based in a real case in which participated the first author of the present work as a member of the Spanish Court of Accounts.

5º Alan Turing

British mathematician was one of the fathers of the Computer Science and forerunner of the modern computing. Together with his friend the mathematician Gordon Welchman, Turing developed in late 1939 and mid-1940 a machine that was baptized with the name of Bombe, with which they managed to successfully decipher the Enigma transmissions, the unbeatable and complex code used by the Nazis in World War II, thereby avoiding great loss of human life and war material from the allied forces. As payment for the valuable services rendered to his country, he died prematurely because of the shameful and criminal persecution to which he was subjected by the British Administration of Justice for being homosexual, protected by a clearly inadmissible legislation in the thresholds of the second half of the 20th century.

In his book *A Brief History of Artificial Intelligence (2021)*, Michael Wooldridge, Professor and Head of the Department of Computer Science at the University of Oxford, studies with undisguised passion the key role played by Alan Turing in the development of the techniques, procedures, and machines that have led to a marked improvement in computing and to obtain a clearer and more precise idea of what it is the Artificial Intelligence. In a passage of the mentioned book the author affirms that… *"We have many possible choices for the beginning of AI, but for me, the beginning of the AI story coincides with the beginning of the story of computing itself, for which we have a pretty clear starting point: King's College, Cambridge, in 1935, and a brilliant but unconventional young student called Alan Turing. It is hard to imagine now, because he is about as famous as a mathematician could ever hope to be, but until the 1980s, the name of AlanTuring was virtually unknown outside the fields of mathematics and computer science".*[8]

[8] WOOLDRIDGE, Michael (2021): pp. 13-14.

From a certain moment Turing began to think seriously about the possibility of artificial intelligence. He wanted to definitively silence those who argued that “machines cannot think.” To this end, he proposed a test,

which we now call the Turing-Test and whose content was explained in an article that with the title of “Computing Machinery and Intelligence” was published in the prestigious international journal *MIND* in the year 1950. As the Professor Wooldridge says, this article is generally recognized as the first Artificial Intelligence publication.[9]

Although we are highlighting what refers to his invaluable contribution to Computer Science and Artificial Intelligence, we cannot conclude this section without, at least, defining what a Turing machine is. In a general view we can say that a Turing machine is a mathematical model of computation that defines an abstract machine that manipulates symbols on a strip of tape according to a table of rules. Despite the model's simplicity, given any computer algorithm, a Turing machine capable of implementing that algorithm's logic can be constructed. Similarly, it could also be defined as a mathematical model with capacity of performing a sequence of instructions in a mechanical way, such as through a finite state automaton or as a mathematical model of a computing device whose logical structure is simpler than what be imagined, in such a way that according to Turing´s hypothesis, any calculation capable of being effectively carried out by the human mind can be realized by a Turing machine.

A formalized definition can be specified as a quadruple

$$T = (Q, \Sigma, s, \delta)$$

where:

- Q, is a finite set of q
- Σ, is a finite set of symbols
- s is the initial state of $s \in Q$
- δ is a transition function determining the next move:

$$\delta: (Q \times E) \rightarrow (\Sigma \times \{L, R\} \times Q)$$

[9] WOOLDRIDGE, Michael (2021): p.24-25.

indicating with L and R the action of moving one square to the left (L) and another to the right (R), respectively, going in both cases to the state q_j.[10] Although we do not go into more detail here, it is worth specifying that as was proved by Shannon in 1956, current definitions of Turing machines usually have only one type of symbols, just 0 and 1, thus reducing the Turing machines to a binary one. But in his original definition there were two types of symbols, those corresponding to the binary system, and the so-called symbols of the "second kind", differentiated on the Turing machine tape by using a system of alternating squares of figures and symbols belonging to this other set that, as we said, it is known as *second kind*.

To conclude this important section let us say that at present the Turing machine constitutes a reference in research on the basics of Computer Science, and in questions such as what algorithm is, computation, physical computation, efficient computation, and so on. At the same time, it can be considered a giant step forward in laying out the foundations that allow us to address the main issue that relates and compares Artificial Intelligence with the Human Intelligence.

Following the Wooldridge´s line, and in order to make clear the milestone that represented the gigantic contribution of Alan Turing, let us remember that as De Mol states in his work already mentioned,…*"one could argue that the stored-program concept originates in Turing's notion of the universal Turing machine and, singling this out as the defining feature of the modern computer, some might claim that Turing is the father of the modern computer"*.[11]

[10] For further development see:
DE MOL, Liesbeth (2021): Section 1.3

[11] DE MOL, Liesbeth (2021): Section 5.2

6º Computing and Chaos

In some texts and articles on Chaos Theory and its applications, we have had the audacity to say, following the line of renowned authors, that the three winning discoveries of the 20th century were the theory of relativity, the quantum theory, and chaos theory. Between the two great conquests of science, the theory of relativity and quantum physics on the one hand, and chaos theory on the other, there is a fundamental difference. The first two are respectively great, decisive and consolidated branches or fields of science, whereas what we call chaos theory is actually a set of techniques and mathematics conceived as an instrument, or logical support, for those sciences in which complexity is an irrefutable fact, where non-linearity constitutes a characteristic of a dynamic system, and there is an important dependence on small variations in the initial conditions. ·Does this mean that we should neither use the expression chaos theory nor should it to figure at the same level as the theory of relativity and quantum theory? Within a strict and rigorous criterion, the answer would be yes, since comparisons cannot be made when there is no homogeneity. But this does not in any way diminish the great scope of the applications of mathematics of chaos techniques and the important successes and advances achieved in a relatively short period of time.[12]

It is frequently stated that where there is chaos there can no possibility of predicting what necessitates identifying chaos with randomness, something inconsistent with the very definition of chaotic behaviour than, under the disguise of irregularity, hides a deterministic law that we must discover. That´s why can say that chaos does not always imply low predictability. An orbit can effectively be chaotic and still be predictable in the sense that it is followed or shadowed by a real orbit, thus making its prediction physically valid. As has been widely recognized by relevant authors, chaos theory has made a decisive contribution to solving many problems that in the past we found intractable. Among them and taking into account the applications in different scientific fields we have considered, we can mention, by way of example, complex studies on

[12] FERNÁNDEZ DÍAZ, Andrés (2019): pp. 75-78.

atmospheric phenomena, sequencing of the human genome, cardiological and neurophysiological episodes, capital markets evolution, policy analysis, decision making, or the novel problem of managing and controlling certain chaotic processes depending on their derivable consequences. But of course, there is still a huge research effort ahead.

Thinking about the matter, the famous British mathematician Roger Penrose, to whom we will return later in another section, affirms that…"*despite such profound difficulties for deterministic prediction, all the normal systems that are referred to as chaotic are to be included in what I call computational. Why is this?"*[13] Penrose himself answers that in order to decide that a procedure is computational we must now whether it can be put into an ordinary computer. On this basis we allow ourselves to add that we can include chaotic systems, given that its work with long apparently random series, but with great frequency, and after applying the different tests, they are deterministic series that hide important laws and behaviours.

Having said the foregoing, a fundamental question remains that refers to the need to define oneself with respect to the usefulness of establishing a profitable relationship between computing and chaos. Penrose, to whom we have already referred, gave a detailed analysis of the matter in his enchanting book on the Shadows of the Mind written, as we know, in 1994, concluding that *"chaos does not really get us out of our difficulties with the computational model"*.[14] However, in recent years some books and papers have been published in which we find new approaches about the possibilities of Chaos Computing. For instance, Willian Ditto, at Georgia Institute of Technology, is known for the development of a new type of computer based upon nonlinear dynamics and chaos and, in the same way, there are other authors that affirm that there is also another emerging computing paradigm, one which exploits the richness and complexity inherent in nonlinear dynamics, called chaos computing.

This discrepancy seems normal and acceptable, but there is something that requires clarification. In the first place, it is very likely that we are failing

[13] PENROSE, Roger (1994): p. 23.
[14] PENROSE, Roger (1994): p.179.

to comply with the principle of the Theory of Knowledge according to which *"only what is comparable can be compared",* and the two mentioned authors are not at all comparable. Perhaps our statement may seem untenable from the point of view of intellectual morality, but as Victor Hugo said in *Les Misérables,* man is like an ellipse whose foci are his ideas and his facts. Bearing this thought in mind, we find that professor Ditto, recently named a fellow of the American Physical Society and of the National Academy of Sciences, has formed the Nonlinear Artificial Intelligence Laboratory to explore the intersection of Chaos, Nonlinear Dynamics and Artificial Intelligence.

It is easy to understand that the expression Nonlinear Artificial Intelligence does not make any sense, because when talking about Artificial Intelligence it is supposed that it implies everything that it contains, and we want to express with those two words. Effectively, it implies the nonlinearity that constitutes one of the basic characteristics of the mathematics of chaos, the existence of endogeneity, the use of the most sophisticated tools and techniques of computing, and so on. We prefer the more moderate and cautious words of Professor Penrose to the sparsely considered and thoughtful words of the well-known Dr. Ditto. Nothing of what has been said in this section prevents us from talking together about Computing and Chaos.

7º Quantum Mechanics

Recently, the fact that considering Computer Science and Artificial Intelligence in the context of Quantum Mechanics it would open new advances for both. Before going further, it should be clarified that some authors, perhaps the majority, think regarding the title of this section that the expression Quantum Mechanics rather than Quantum Physics, reflects the emphasis on principles and methods rather than applications. It may be so, but we are interested in one as well as the other. We believe that it is a semantic problem, although it is true that Quantum Physics covers a more genera vision, while Quantum Mechanics supposes a more specific, formalized and rigorous treatment.[15]

Quantum Mechanics is the result of the work of Louis de Broglie, Erwin Schrödinger, Werner Heisenberg, Paul Dirac, Max Born and others, locating the central nucleus of the contributions between the years 1923 and 1927. Fundamentally it supposes a profound revolution in Physics by introducing several new concepts and principles in our methods to describe the behaviour of matter.

In the most current literature on this advanced branch of the Science, Richard D. Taylor (2020), Professor of the Pennsylvania University State, has published an article with the title *"Quantum Artificial Intelligence: A precautionary U.S. approach?* Although the author says that he has not written a technical paper, he points out several questions that are of great importance for our purposes. Among them we first refer mainly to the problem of "undecidibility" that we addressed when dealing with Gödel´s theorem applied to the incompleteness of the account jurisdiction. As professor Taylor recognizes…"*Quantum Superposition* is *the cornerstone of quantum physics".*[16] Its basis is described by the Institute of Physics as follows: "*At the quantum scale, particles can also be thought of as waves.*

[15] For a good knowledge of the matter, we advise the following:
ALONSO, Marcelo; FINN, EDWARD J. (1986): pp. 55-105.
MANDL, Franz (1992).

[16] TAYLOR, Richard D. (2020): pp.1-3.

Particles can exist in different states, for example they can be in different positions, have different energies or be moving at different speeds. But because quantum mechanics is weird, instead of thinking about a particle being in one state or changing between a variety of states, particles are thought of as existing across all the possible states at the same time."

The relevant subject of a quantum superposition arose when we introduced the Schrödinger paradox, giving place to the existential problem known, as we saw before, as the "famous cat" that was alive and dead at the same time, which means, effectively, accepting the existence of a quantum superposition. In other words, the wave function of the system composed of the box, the cat and the device is a quantum superposition, and its evolution in time is determined by the Schrödinger equation, whose formulation we omit to facilitate the task of the non-specialized reader.

A particle of interest can only be described by the probability of being in a certain location. This is the famous Heisenberg *"Uncertainty Principle"*. The particle really doesn't have a definite state but is in a *superposition* of all possible states. However, once a measurement of a particle is made, and its energy or position is known, the superposition is lost and then there is a particle in one known state. The Heisenberg Uncertainty Principle, the other issue to highlight in Quantum Mechanics, came in 1927 to practically mark the end of the Laplacian deterministic dream. According to this principle, the position (x) and the momentum (p) of a particle cannot be determined simultaneously, in the sense that the more exact the determination of its momentum (or product of its mass by the velocity), the more insecure its position will be, and vice versa. Analytically, the principle would be expressed as follows:

$$\Delta x \cdot \Delta p \geq h$$

indicating with Δx the uncertainty in the position, with Δp the uncertainty in the measurement of the momentum and being *h* the Planck constant.

Also, we can consider that the time-energy uncertainty relation states that

$$\Delta E \cdot \Delta t \geq h$$

where ΔE means the error in the energy measurement and Δt the inaccuracy in the determination of its time momentum, being able to affirm that the more precise the measured value of the energy, the less defined is the measurement of its time.[17]

After what has been said so far, it should be remembered that in Physics texts quantum and statistical foundations are usually presented together, including thermodynamics in the part that is habitually called Statistical Physics. In the later, in addition to considering classical statistical mechanics, in which the Maxwell-Boltzmann distribution law stands out, Quantum Statistics is studied, with the contributions of Fermi-Dirac distribution law, on the one hand, and the Bose-Einstein distribution law, on the other. On this basis, Quantum Statistics could be defined as a statistical description of a system of particles that obeys the rules of quantum mechanics rather than classical mechanics, being considered that energy states are quantized. Quantum Statistics constitutes a logical and operative support for Quantum Mechanics, which, in turn, enhances the Quantum Computing, technological synthesis on which the Artificial Intelligent rests directly.

[17] FERNÁNDEZ DÍAZ, Andrés (2000): pp.15-20.
MANDL, Franz (1992): pp.82-86.

8º Quantum Artificial Intelligence

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In the Introduction to the book “The Economics of Artificial Intelligence”, the Editors Ajay Agrawal, Joshua Gans, and Avi Goldfarb, remind us that The Oxford English Dictionary defines artificial intelligence as “the theory and development of computer systems able to perform tasks normally requiring human intelligence”, definition that they consider is both broad and fluid. There is something in this definition involves implicitly admitting that Artificial Intelligence (A.I.) could realize everything that human intelligence does, and this constitutes an essential issue that we will address in the last section of this work.

We could go on looking for definitions taken from known texts or papers of reference to offers other definitions more illustrative and complete ones, but we prefer to continue thinking on our own. In this sense, if we consider the background seen in the section reserved to provide an idea of the History of A.I. we would find the fundamental basis of Boolean algebra and its binary system, with the shocking discovery of the Turing machine, with the role played by Gödel´s well-known theorem on “undecidability”, with Heisenberg´s uncertainty principle and the Schrödinger “quantum superposition” problem, all them essential components of the content of we are calling A.I. or, in a broader and more advanced conception, Q.A.I. To this must be added the greater speed of computers in processing massive data (Big Data), on the one hand, and the help or support provided by quantum statistics, to which we referred in the previous section, on the other. With all these ingredient, more than one sufficiently significant can be outlined.

Our objective is found, for the moment, on clarifying what A.I. consists of, considering that today we speak more precisely of “Quantum Artificial Intelligence” (Q.A.I.), with what this implies and entails. The task is not easy, given that very often the terms “Intelligence” and “Intelligence human behaviour” are not well-defined and understood. As Andreas Wichert, professor at the Technical University of Lisbon, says in his book on Principles of Quantum Artificial Intelligence… ”*The definition of Artificial*

Intelligence leads to the paradox of a discipline whose principal purpose is its own definition".[18] This curious but successful word game is nothing more than the mixture, once again, of the whole and the parts, which prevents us from having a clear idea of what we mean. The Q.A.I., as we said above in our attempt to offer a more illustrative definition, is the result of adding and combining, as links, each one of the modern techniques and procedures, or in more specific terms, of faster quantum computers and algorithms. This result, in our aim to assimilate it to Human Intelligence, we call Q.A.I., its components being what we must to know and apply with foundation and rigor.

The journal of *Artificial Intelligence (AIJ)* published by Elsevier, as its editors tell us, contents rigorous papers on broad aspects of A.I. that constitute advances in the overall field including, but not limited to, cognition and A.I., automated reasoning and inference, case-based reasoning, commonsense reasoning, computer vision, constraint processing, ethical A.I., heuristic search, human interfaces, intelligent robotics, knowledge representation, machine learning, multi-agent systems, natural language processing, planning and action, and reasoning under uncertainty. The journal reports results achieved in addition to proposals for new ways of looking at A.I. problems, both of which must include demonstrations of value and effectiveness, thereby providing a wide field for research and development of the different problems and approaches of A.I.[19]

It may seem strange that the title of the Journal that we have just mentioned on does not include the word "Quantum", but it is necessary to keep in mind that its publication began in the year 1970, when the introduction of Quantum Mechanics had not yet clearly penetrated in the broader and more ambitious framework of A.I. In any case, when in the section number 7 we summarized the fundamentals of Quantum Mechanics, it is clear what it entails and contributes to a richer and more complete conception of A.I., although it is quite true that such added value is concentrated in the field of Physics, and more specifically of particle physics.

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[18] WICHERT, Andreas (2013): pp. 1-3.
[19] ARTIFICIAL INTELLIGENCE, Editorial Board, (2022).

As we said at the end of the previous section, within the technological advances in computing capabilities, quantum computing occupies a paradigmatic place, in which calculations are no longer based on bits as a unit of measurement but on “qubits”, a term coined by Benjamin Schumacher, a professor of physics at Kenyon College (Ohio). With this new procedure that is currently being developed, a great calculation power is achieved that allows solving problems that until now were considered incalculable, all of which constitutes a very valuable contribution to what we at present call Quantum Artificial Intelligence.

From another point of view, speaking of computing (or quantum computing in the modern approach) as an essential part leading to Artificial Intelligence, Professor Penrose considers the basic concepts listed below: awareness, understanding, consciousness, intelligence. Taking them as basis, the prestigious mathematician established the following sequence: intelligence requires understanding, understanding requires awareness, the later constituting a *passive aspect* of the phenomenon of consciousness although there is an *active aspect* also, namely the feeling of free will.[20] Although we will come back to this so important issue in the last section of our work, we need to say in this context something about the concepts or terms proposed by the always suggestive and fine professor Penrose. But following the advice of the prestigious mathematician of the University of Oxford we renounce to give a precise definition of the different terms and/or concepts that we have just mentioned and entering the analysis of their relationship with computational activity. We are going to limit ourselves only, at least for the moment, to point out that both terms, awareness and consciousness, deal with understanding phenomena, showing that are cognitive processes that happen in human minds. Besides, when we think of differences, we can identify that awareness does not require fully understanding of a certain thing whereas consciousness requires the in-depth awareness of a particular thing. That is, awareness can be considered as a necessary condition of consciousness. All this constitutes a matter of vital importance when we talk about what A.I. really is, while we will take it into account when we consider in the final part of our work the possibility of comparing Quantum Artificial Intelligence and Human Intelligence.

[20] PENROSE, Roger (1994): pp. 37-40.

9º Applications to Economy

The new technological revolution of recent times that has led to the-challenge of the present and future of Artificial Intelligence clearly and directly affects the economic activity of all modern society. For this reason, and although the current name of Quantum Artificial Intelligence constitutes a term that induces to relate its content to Physics, Chemistry or Mathematics, the truth is that the technological advances that these areas of science promote, end up determining the functioning of basic and strategic sectors of economy, which is why we have considered the title of the section that we are now starting to be appropriate. It is easy to understand, that the impact of the Artificial Intelligence on the economy has a heads and tails that requires reflection no matter how short. As for the heads, it is indisputable that the rapid progress of technologies means greater ease for growth and a significant improvement in productivity, among other undoubted advantages, but at the same time it implies serious problems regarding employment and income distribution. On this we will stop in an abbreviated but illustrative analysis for the purpose of assessing the balance resulting from considering the advantages and drawbacks of using the set of new advances techniques in the field of Computer Science, the core of the Artificial Intelligence.

It seems clear, as it tells us Betsey Stevenson that… *“economists believe that artificial intelligence represents an standards opportunity for substantial economic gains. Indeed, productivity gains have been at the heart of improvements in living from the beginning of time. And so, it is difficult to imagine a world in which productivity gains do not generate benefits sufficiently large that we could compensate the losers”.*[21] We certainly agree with this statement, but the problem is whether the losses are sufficiently compensated, on the one hand, and how the net gains are distributed, on the other.

It should be clarified that when we speak of profits and losses, we are not referring exclusively to the part in terms of income that corresponds to the

[21] STEVENSON, Betsey (2019): p 190.

different sectors affected by the incorporation of the most advanced technologies, but fundamentally we are implicitly considering such important problems as the so-called “displacement effect” of employment as a consequence of the application of these technologies. In this regard, it is necessary to remember that technical progress and its effects were studies in the seventies of the last century by neoclassical economists, distinguishing between models of exogenous growth (Solow and Swan) and those of endogenous growth (Romer), incorporating in both cases the technology in the production function. Even earlier, in the post-keynesian current, and within the Cambridge models, we find the contribution of the great figure of Joan Robinson who delves into the theory of growth by enunciating the eight stages through which, in her opinion, an economy that aims to achieve long-term growth must pass.

Within the neoclassical School, and to end this brief reference, we must mention the “vintages models”, also named “with technic progress incorporated”, that can be classified in three types, according to the possibilities of substitution between capital-technology and labour. Such the types are the following: “putty-putty”, “putty-clay”, and “clay-clay”, highlighting for our purposes the putty-clay one, that has a long history in the economic growth theory (Johansen 1959, Solow 1962, Phelps 1963, Cass and Stiglitz 1969). In modern applications of this type of vintage models, Simon Gilchrist and John C. Williams, for example, develop a dynamic stochastic general equilibrium model with putty-clay technology that includes a nonlinear short-run aggregate production function, irreversible investment, variable capacity utilization, and endogenous machine replacement, and that investigates the implications of putty-clay technology for macroeconomic dynamics at business cycle and medium-run frequencies. Low short-low capital-labour substitutability induces the putty-clay effect of a tight link between changes in capacity and movements in employment and output.[22]

When all this has been left behind in the face of the impressive development of modern information technology, which has ended up prevailing for mainly commercial reasons, as is the case with digitization in the field of telecommunications, we are faced with the challenge of

[22] GILCHRIST, Simon and WILLIAMS, John C. (2000): pp. 1-3.

thinking that the machine could reach to overcome and replace human mind, with what this entails for the proper functioning of a society and its economy. After these necessary considerations about the matter, we enter now in the very content and objective of this section, that is, in the impact of the Artificial Intelligence and their main technological weapons on the economic growth, the employment and the income distribution.

In a recent work on Artificial Intelligence and economic growth, Philippe Aghion, Professor at the Collège de France and at the London School of Economics, highlights that Joseph Zeira, in the article published in 1998 on Artificial Intelligence and economic growth, stated in its predictions that growth rates and capital share should rise as a result of automation in the sense given to this term within the A.I., something that goes against the famous Kaldor (1961) stylized facts that growth rates and capital shares are relatively stable over time. This stability is a good characterization of the US economy for the bulk of the twentieth century. The Zeira framework, then, needs to be improved so that it is convincing with historical evidence. One approach to solving this problem may be found in the Acemoglu and Restrepo work (2016)[23]. Their rich environment allows for a constant elasticity of substitution production function and endogenizes the number of tasks as well as automation, taking the research two different directions: discovering how to automate an existing task, on one hand, or discovering new tasks that can be used in production, on the other, reflecting so the fraction of tasks that have been automate. This leads them to emphasize one possible resolution to the empirical shortcoming of Zeira, given that if we are inventing new tasks just as quickly as we are automating old tasks, the fraction or percentage of tasks that are automated could be constant, leading to a stable capital share and a stable growth rate.[24]

We believe it is necessary highlight the fact that the latest generation technology in the framework of Artificial Intelligence results in a significant increase in productivity which, in turn, translates into greater economic growth, that properly managed and distributed, leads to higher levels of welfare in the medium and long term. This point, then, seems to be very

[23.] ACEMOGLU, Daron and RESTREPO, Pascual (2016).
[24] ZEIRA, Joseph (1998): pp. 1091-1117.
AGHION, Philippe, JONES, Benjamin and JONES, Charles (2019): pp.239-242.

clear, and there is unanimity on the matter. Another very different and less important thing are the calculations, not always well-grounded, made by some multinational companies regarding the increase in GDP in the period from this year to 2030.

The second point that we must deal with, as we anticipated, refers to the impact of Artificial Intelligence on employment. This specific issue stems from the delicate and difficult problem of the substitutability of labour for technology, via capital, which we were dealing with when we recalled growth models, especially those belonging to the neoclassical school. Since Keynes´s times until our days, the loss of employment as a result of technological revolutions has constituted a serious problem under constant study. In our capacity of university professor, we have published books and numerous articles on the subject, and really, we believe that almost everything has been said, although at present the problem become more pronounced with the consolidation of Artificial Intelligence. In the recent years, effectively, we find works that offers a very encouraging horizon along with others who clearly express their skepticism. In these circumstances we prefer to remember the Pascal´s thought: *"man is like a reed, the weakest in nature, but a thinking reed"*. Accordingly, let us think about matter.

We want to begin considering that classical division of economic activity between Agriculture, Industry, Construction, and Services, including in the last mainly commerce, finance, and tourism. In a more detailed way, and for the purposes of the problem of replacing man by machine, the following branches or subsectors could be mentioned within the scope of Industry: iron and steel, chemical, textile, naval, military, food, electronics, automotive, and pharmaceutical, mainly. In most of these subsectors of the industry there is a high propensity to substitute the labour factor for the powerful instruments that make up and integrate the Artificial Intelligence, thus provoking a significant loss of jobs. At a second level, we could consider the technicians and professionals who conceive, manufacture and put into operation the "machinery" that carries the application of A.I. This implies the need for a notable increase in the demand for mathematicians, physicists, chemists and computer scientists, among others, which comes to compensate for the loss of employment due to the impact of the new and advanced technology, as we said initially.

Continuing with our analysis based on the consideration of the different sector of an economy in order to know to what extent they may be affected in the sense of displacing employment by being replaced by the lates technology, we can now enter the services sector, without a doubt, the one with greatest weight in the economic structure. (In Spain this sector account for 75,77% of the total employed active population). Within this broad sector we can highlight the importance of the commerce, finance and tourism subsectors for the purpose of considering the possible replacement of a certain percentage of the work factor by the technology provided. The quantification of the respective percentages is not at all easy to carry out, nor is it our objective in this work, which aims to offer an updated overall vision. However, we can illustrate our exposition with a reference to a study, by the way of example, away from both the excessively optimistic and the clearly skeptical. We are specifically talking about the work by Carl Frey and Michael Osborne, from the University of Oxford, published in 2013 under the title of "The future of employment".

The authors ask themselves what are the jobs that are most exposed to being replaced by machines or technological procedures, or what is the same, what percentage of the different types of labour activity would be in danger of disappearing due to the recent advances in Machine Learning and Mobile Robotics. Using the corresponding statistical methodology, Frey and Osborne estimate the probability of computerization for 702 detailed occupations and examine the expected impacts on United States labour market, arriving to the conclusion that after twenty years, in 2033, the 47% of employment would be in risk of being substituted by the application of what would then constitute the full reality of Quantum Artificial Intelligence.[25]

And now the time seems to have come to address the issue of Artificial Intelligence and its implications for income distribution and inequality. Throughout the evolution of moral philosophy, the philosophy of law, political philosophy and economic thought, we can find numerous ideas and contributions regarding the concepts and definitions related to distributive justice and its meaning and scope in the different fields of

[25] FREY, Carl B. and OSBORNE, Michael A. (2013): pp. 1-3; 47-48.

knowledge, going through figures such as Leibniz, Hobbes, Rousseau, Kant, Stuart Mill, Rawls or Dworkin, among others. In the study of such a relevant chapter of Economic Policy we cannot enter here given that our objective is more specific, as we have showed at the beginning of this paragraph, but we can remember that in his development we review the principles of efficiency and equity, the Lorenz´s curve, and the Gini, Theil and Atkinson indices, among other instruments to measure the income distribution.[26] But, as we said, what really interests us in this section is knowing to what extent the progressive application of Artificial Intelligence will affect and is even already affecting such an important matter as income distribution, as well as the delicate and outstanding problem of inequality.

About the matter we would like to begin with a reference to the work realized in 2019 by Anton Korinek and Joseph Eugene Stiglitz with the title "Artificial Intelligence and Its Implications for Income Distribution and Unemployment". The first, a well-known economist who current research focuses on the implications of rapid progress in A.I. for inequality and for the future of work, is Professor at the University of Virginia. The second author, that needs no introduction, is one of the most prominent economists, he received the Nobel Prize in Economics in 2001, and he works as a Professor at the University of Columbia.

In the work mentioned above, the authors begin by affirming convincingly that…."*we believe that the primary economic challenge posed by the proliferation of A.I. will be one of income distribution"*, considering that the long-run implication of A.I. has the potential to disrupt labour markets in a major way, *"even in the short and medium run"*, affecting workers across on many professions and skill levels.[27] When Korinek and Stiglitz considering how technological progress affect the welfare of different groups in society, distinguish between a first-best scenario and a second-best one. In the first case approach it is assumed that all markets are perfect, what includes risk markets that allow individual to insure against the advent of innovations before they know whether they will be workers

[26] A full and rigorous study of this subject may be found in the following reference: FERNÁNDEZ DÍAZ, Andrés; PAREJO GÁMIR, José Alberto; RODRÍGUEZ SÁIZ, Luis (2011): pp. 263-312.

[27] KORINEK, Anton and STIGLITZ, Joseph E. (2019): pp. 350-351.

or innovators, being the main objective to demonstrate that from an ex-ante perspective, compensating workers for the losses derivate of the technological progress constitutes *"a question of economic efficiency not redistribution"*. In addition, the second-best scenario is characterized by the fact that ex post all markets are functioning well and there can be costless redistributions. But the authors take into account a third possibility consisting in considering a first-best ex-post, but with problems in the redistribution, which would give place to an inequality-averse social welfare function, whereupon the workers who lose out would rationally oppose the innovation.[28] This situation, so rigorously explained by the two great economists is based on assumptions that do not correspond to reality, since the markets are imperfect, with the frequent existence of oligopolies, which leads us to think that the opposition of the workers forces a reconsideration by innovators to prudently "manage" the effective application of complex A.I. technologies.

Note: In this regard, and as a curious but significative case, the acceleration of new technologies by the large banks in Spain has provoked the protest of the elderly population, which represents 20% of the inhabitants, something that, in our opinion, constitutes a type of discrimination that, in fact, translates into an added inequality.

Returning to our subject, and by way of conclusion, we could affirm that in predominant literature on the matter and taking into consideration not only the academic articles and books, but also the studies carried out by large companies, it can be affirmed that a great part of the papers defends that A.I. revolution will create a wealthy class of innovation and a separated class of displace works who don´t have the education required. Something similar we said before, although not so sharply, when we were referring to the fact that the incorporation of new technologies of A.I. gave rise to an increase in the demand for the most suitable and necessary professionals to face the present and future challenge.

We finish this section dedicated to the application of A.I. to the economy with a brief reference to the situation in our country relative to the issue at hand. First, let us highlight that in Spain there is a public and private

28. KORINEK, Anton and STIGLITZ, Joseph E. (2019): pp.353-359.

collaboration project between five strategics industries called the CUCO mission. Such a project, subsidized by the CDTI and supported by the Ministry of Science and Innovation under the Recovery, Transformation and Resilience Plan, emerges as the first major quantum computing project at a national and business level in order to progress in scientific and technological knowledge of quantum computing algorithms that allows to accelerate the implementation of these technologies for their use in the medium term, applying them, in principle, to the strategics industries of the Spanish economy: space, defence, finance and logistics.

On the other hand, currently The National Strategy of Artificial Intelligence (ENIA) for the period 2021-2023, with 600 million for that period, sets out an action plan with six strategic areas or objectives: innovation in Artificial Intelligence, infrastructure development, the momentum of national talent, the integration of the IA in the value chain, their use in the administration and the promotion of an ethical framework.

It should also point- out that within the European precariousness in terms of analysis and applications of A.I. Spain occupies a relatively acceptable place, since the use of A.I. in Spanish companies, excluding the financial sector, it is 7%, above the 6% of the European average and of countries such as France and Germany, although very far from the 20% of the always surprising Ireland. Regarding Big Data through machine learning, the situation is repeated, given that our country, with 4% is also above the EU-27 and, among others, France and Germany, but again very far from 20% corresponding to Ireland.[29] For above these figures we find a group of countries, led by the United States and China, that are making a great effort to promote Artificial Intelligence. In addition to the two mentioned, it is necessary to add other important countries such as United Kingdom, Canada, Korea, Japan and Israel.

About Spanish position, we must highlight the fact that it occupies a prominent place in the field of research of the subject, a situation that is part of the highly positive fact that 32% of research on A.I. is carried out in Europe. It could be said in relation to this fact that Europe investigates and China and the United States, especially the latter, focus more on their immediate applications. This consideration should not be interpreted in the sense that

[29] Secretaría de Estado de Digitaliizacion e Inteligencia Artificial (2021): pp. 13-15.

scientific research is above the technologies derived from it, nor vice versa. The duality that is usually made in this regard, almost always to the detriment of the first part, that is, of science, plain and simple constitutes a frivolity in which we must not fall, since it is an indivisible whole, whose components are of the same relevance. It should be clarified that when we speak of duality, we are referring to two large groups, that of the research scientists, on the one hand, and that of large companies that directly promote, produce and apply new advanced technologies, such as IBM Watson, Apple, Amazon, Google, Nvidia, Microsoft and Oracle, on the other.

Starting from his belief that foolish investigations precede unforeseen discoveries, that the role of the non-existent exists, that the function of the imaginary is real, and that pure logic teaches us that the false implies the true, the great poet and French thinker in his posthumous work "*Études philosophiques*", published by Éditions Gallimard in 1957, said that…*"Thus it seems that the history of intelligence could be summed up in these terms: it is absurd for what It seeks, it is great for what it finds".*[30] If in Valéry´s sentence when he says Intelligence we add the word "Artificial", we could take it as a correct, synthetic and original way of explaining the scope and meaning of the matter that occupies our attention.

To conclude this section, and interpreting correctly the Paul Valéry words, to seek an answer to the result of comparing the A.I. with the H.I supposes a time lost, although the enormous efforts realized by the way leaves an important background of quantum computing, quantum algorithms, quantum statistics, and the others advanced technologies that in a certain sense become the Artificial Intelligence in an asymptote of the Human Intelligence.

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30 VALÉRY, Paul (1957): p. 107.

10º Quantum Artificial Intelligence versus Human Intelligence

The crucial moment of our work has arrived, even though in the previous note we said that it constitutes a point of relative importance, at least from a reality and operational point of view. Much has been written about the possibility, even if it was remote, that Artificial Intelligence exceeds the Human Intelligence, using very frequently the famous chess game between the machine and the man, drawing consequences that do not proceed. Indeed, when on May 11, 1997, Garry Kasparov, then world champion, was definitively defeated after several draws, they were quick to say that the machine is superior to the human mind. It would be more correct to say that the world champion had lost, which although it may-seem, is not the same thing. We explain ourselves, beginning with a question: so, what? Nothing is derived from that defeat, absolutely nothing.

In a first approximation we could say that the discussion about the superiority of artificial intelligence over human one lacks a solid basis, especially since in the comparative process there is inevitably a “petition pf principle” given any machine whose intelligence exceeds that of man must to have been built by the human, which prevents affirming for logical reasons that such an artificial machine possesses an intelligence superior to that of the man. Very often, as we have seen, is taking as an illustrative example the chess game, where sometimes computers can play extraordinarily well, getting a level like to those of the best human grandmasters.

The outcome of the confrontation between the machine and the well-known chess champions depends on a set of factors that sometimes favours the man and sometimes the machine. Thus, when the game demands or requires speed, this favours the computer, while if there is enough time for the moves the player has a clear advantage. Likewise, when the game takes only two or three moves, the result us resolved almost instantly, winning the machine, the opposite happening that is, in favour if the man, when it is necessary to make between 50 or 100 movements, as long as this does not give rise to forced calculations. What conclusion could be drawn from these considerations?

Roger Penrose, the British mathematical physicist, Professor Emeritus at the University of Oxford and Nobel Prize of Physics 2020, that already we well know, provided us as early as 1994 a thoughtful answer in which he said: *"Even if it is accepted that the present concept of a computer will not achieve any actual intelligence or awareness, we are still presented with the extraordinary power that modern computers possess and with the potential prospect for an absolutely enormous increase in this power in the future. Although these machines will not understand the things they are doing, they will do them almost incredibly fast and accurately".*[31]

Speaking in general terms, the conflict between the force of the machine and the power of the human mind is usually interpreted as if it were a trader-off between memory and calculational powers, on the one hand, and the importance and value of genuine understanding, on the other; something similar to the introduction of this expression in Economics when in the seventies of the 20th century we suffered the difficult and complex problem of the so-called "stagflation". But the very sense of our reflexion is deeper and intends to go further.

Continuing with the central part of our reflections, we think that the main issues to make clear the comparison between the two approaches regarding Intelligence, is that there is an unquestionable distance between Artificial Intelligence (A.I.) and Human Intelligence (H.I.), due to the lack of awareness of the first, and the existence of a feedback process or circularity in the joint consideration of both types of Intelligence. At the origin of everything is indefectively the human mind. In this regard, let us recall the sequence established by Professor Penrose, to which we alluded earlier, according to which Intelligence requires Understanding, *Understanding requires Awareness, constituting the later a passive aspect of Consciousness. (See note nº 20 at the end of 8ª section).*

We wonder if the reader has noticed the fact that throughout our work that concludes with this last section, at no time have we referred to Digitization, a term closely linked to those of A.I. to the point that in Spain we have a Ministry of Digitization and Artificial Intelligence. Really, we don´t agree

[31] PENROSE, Roger (1994): p. 396.

with such a denomination because, as we have said in other moment, is not correct to mix the whole with the parts, and certainly the digitization constitutes a part or segment of A.I., although an outstanding one. What is the matter with the digitization? Why has stood out so much as a link in the chain that marks the path to A.I.? Before answering let us say something about the origin of digitization.

Among the antecedents of digitization, we find Leibniz (1703), who in addition to discovering integral and differential calculus, anticipated the use of binary system and created the calculating machine. To this distinguished and famous thinker, we must add the great figures of Boole (1854) and Shannon (1938), already studied or mentioned, as well as Stibitz, who in the 1940$_s$ was one of the pioneers of the digital computer. One the race had begun, the new digital technology was imposing itself on analogic one until the time came, when it ended up practically displacing it almost completely.

The strong momentum of digital technology was based in its progressive applications towards the most commercially profitable sectors, clearly concentrating on the field of telecommunications, as evidenced by the enormous importance given to annual call for Mobile World Congress at Barcelona. In these congresses increasingly expensive and complicated novelties are presented creating unnecessary needs in the consumer, also given rise to the well-known case of economist that the highest-cost products are preferably consumed by the lower-income social strata, since it is a type of good of abnormal demand, on the one hand, and the so-called “imitation effect”, on the other. The importance of digitalization is not discussed, nor is the fact that digital technology has spread widely, but rather the needs to establish limits on its application, considering ethical issues and principles. It must be clear, therefore, the role and scope of digital technology, first, and the more complete and ambitious general vision that Artificial Intelligence means, secondly.

A.I. constitutes an interdisciplinary field in which several sciences and professions converge, including computer science, mathematics, physics, economics, psychology, linguistics, philosophy and neuroscience, as well as other specialized fields such as artificial psychology. Human Intelligence is all about learning from various incidents and past experiences. It is about learning from mistakes made via trial-and-error approach throughout one's life. Intelligent thought and intelligent behaviour lie at the core of Human Intelligence. However, Artificial Intelligence falls behind in this respect, because machines cannot think. They can learn from data and through continuous training, but they can never achieve the thought process unique to humans. While AI-powered systems can perform specific tasks quite well, it can take years for them to learn a completely different set of functions for a new application area.

After these considerations related to the comparison of the machine with the human mind, let us pause briefly on Quantum Computing, beginning with its definition and following with their applications and the role it plays in the framework of A.I. The theory of quantum computation constitutes a different computing paradigm which is based on the idea of using quantum mechanics to perform computations, instead of classics physics. It means that while an ordinary computer can be used to simulate a quantum computer, it appears to be impossible to perform the simulation in an efficient fashion. Thus, quantum computers offer an essential and very significant speed advantage over classical computers.

Quantum computing could be defined as the study of how to use phenomena in quantum physics to create new ways of computing. Quantum computing is made up of qubits. Unlike a normal computer bit, which can be 0 or 1, a qubit can be either of those, or a superposition of both 0 and 1. Also it is necessary to highlight that Quantum computers perform calculations based on the probability of an object's state before it is measured - instead of just 1s or 0s - which means they have the potential to process exponentially more data compared to classical computers. As said Nielsen and Chuang, analogous to the way a classical computer is built from an electrical circuit containing wires and logic gates, a quantum computer is built from a quantum circuit containing wires and elementary quantum gates to carry around and manipulate the quantum information.[32]

Given a definition, we can classify the applications in areas as cybersecurity, financial modelling, traffic optimization, weather forecasting

[32] NIELSEN, Michael A & CHUANG, Isaac L. (2000): pp. 5-17.

and climate change, solar capture, electronic material discovering…and Artificial Intelligence, among others. Recent works accepted this type of classification, but we think that quantum computing and artificial intelligence are not at the same level. At most we can admit that Quantum Computing and Artificial Intelligence may prove to be mutual backscratchers, but the reality is that quantum computing and its corresponding algorithms are powerful new tools that allow us to extend the expression A.I. to a more comprehensive and advanced one called "Quantum Artificial Intelligence".

Arrived at this moment of our exposition, we must summarize the essence of what we have seen, while making some observations before concluding. In the first place we consider how may quantum computing affect Artificial Intelligence, highlighting by way of response that the powerful calculation speed when using a quantum algorithm translates into lower power consumption, higher efficiency and more accurate results, something that constitutes the core of the Q.A.I. To this we must add as relevant complements the various technologies and procedures that have been incorporated over the last two decades, including robotics as well as the advances experienced in quantum statistics.

Regarding the controversy on the possibility that Artificial Intelligence in the future can overcome the Human Intelligence, we have nothing to add to what has been exposed on different occasions. However, we want to point out that with some frequency, especially in works or reports realized by external consultants on the subject, statements such as the following are made: "Machines are digital, whereas the human brain is analogue". The brain is neither analogue nor digital. Unlike a digital computer, brain does not use binary logic or binary addressable memory, and it does not perform binary arithmetic.[33] As can be deduced from the footnote, the word "analogue" is equivalent to the word "analog" which encourages a comparative underestimation of the capacity of the brain, since in common language the digital is placed superior to the analogic. In short, the mentioned sentence is unfortunate and misleading. Something similar

[33] Note: The word analog in 1946, entered computer language as an adjective to describe a type of signal that is continuous in amplitude. Habitually is most used the term "analogic".

happens when speaking, for example, about the recent discoveries of the new space age, it is stated that this is due to the application of Artificial Intelligence together with the information derived from “Data Science”. It could be argued that this expression belongs to and is admitted in the framework of Computer Science, but being rigorous, any parcel of knowledge that is already located in specific branches of the scientific field cannot be considered a Science in the strict sense. The study and treatment of data constitutes an essential part of Statistics, Economics, Mathematics, and other fields of formal and empirical sciences.

These observations with which we close our work could be considered extemporaneous, but in our support it should be noted that the set of concepts and instruments that we have handled throughout these pages, such A.I., Quantum Computing, Algorithms, Turing Machines, Boole´s algebra, etc., in short, they are nothing but a “language”, something as great and essential as is clearly reflected in Ludwig Wittgenstein´s phrase, according to which *“thought is the silent use of language”*.

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