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ARTIGO ORIGINAL

Notes on artificial intelligence: concepts, applications and techniques

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Resumo

A Inteligência Artificial (IA) tem estado cada vez mais presente no mundo, com aplicabilidade em diversas áreas do conhecimento. Soluções baseadas em IA, implementadas com diferentes técnicas, estão presentes em diferentes sistemas. O objetivo deste artigo é (1) apresentar um breve histórico e os principais conceitos relacionados à Inteligência Artificial – com foco em técnicas de aprendizado de máquina (AM) –, (2) discutir suas nuances, técnicas e (3) apresentar algumas aplicações em diversas áreas. A intenção é abordar o assunto de forma acessível ao público não especializado, de forma a promover a compreensão de seus principais conceitos, mas sem a necessidade de recorrer a detalhes muito técnicos. Para isso, é realizada uma revisão narrativa da literatura sobre IA abordando brevemente sua história, conceitos, interseções com outras áreas e aplicações. O segmento de aprendizado de máquina recebe atenção especial, com destaque para o aprendizado supervisionado e sua aplicação em problemas de classificação. O artigo também destaca as capacidades apresentadas pelas mais modernas técnicas de aprendizado de máquina que, em alguns casos, apresentam resultados melhores do que os obtidos por humanos. Dados esses resultados promissores, o futuro da IA aponta para a criação de sistemas com capacidades que se assemelharão cada vez mais às do intelecto humano. Porém, a criação de máquinas verdadeiramente pensantes, e não de simuladores pensantes, ainda deve permanecer por muito tempo como um objetivo a ser alcançado.

Abstract

Artificial Intelligence (AI) has been increasingly present in the contemporary world, with applicability in various fields of knowledge. AI — based solutions, implemented with different techniques, are present in different systems. The purpose of this article is to (1) present a brief history and the main concepts related to AI — with a focus on

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machine learning (ML) techniques , (2) discuss its nuances, techniques and (3) present some application examples in several areas. The intention is to approach the subject in an accessible way to the non-specialized public, in order to promote the understanding of its main concepts, but without the need to resort to very technical details. For this, a narrative review of the literature on AI is carried out, briefly addressing its history, concepts, intersections with other areas and applications. The machine learning segment receives special attention, with emphasis on supervised learning and its application in classification problems. The article also highlights the capabilities presented by the most modern ML techniques which, in some cases, present better results than those obtained by humans. Given these promising results, the future of AI points to the creation of systems with capabilities that will increasingly resemble those of the human intellect. However, the creation of truly thinking machines, and not of thinking simulators, should still remain for a long time as an objective to be achieved.

Keywords: Artificial Intelligence; Machine Learning; Supervised Learning; Rating Problems

1. Introduction

Artificial Intelligence (AI) is currently one of the main topics of debate in the world. Important cinematographic works (for example, Her, Eve, Ex machina and Westworld) and various documentaries (Coded Bias, AlphaGo and The dilemma of networks) on streaming platforms have contributed to the discussion on the limits and applications of the subject (34). However, the phenomenon called ChatGPT has gained the global spotlight in recent months, literally causing a transformation in the technological landscape, which has consequently made the subject increasingly "familiar" to the non-specialized public.

In 2020, McKinsey Analytics published The State of AI in 2020, an online survey answered by 2,395 individuals with the aim of analyzing the conditions for

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REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

implementing AI in institutions (41). According to Stanford University's The AI Index 2022 Annual Report, more than 93.5 billion dollars were invested in AI in 2021. This is more than double the total invested in 2020. The results showed that companies are increasingly investing in AI, but it was during the COVID-19 pandemic that there was a significant increase in the adoption of these technologies, especially in the health and pharmaceutical sectors (47).

AI has applicability in various fields of knowledge, whether in astronomy, physics and mathematics, or in medicine, genetics and cell biology, as well as bioethics, law, economics and the arts (7;11;14;26;92). In this sense, Russell & Norvig (70) describe AI as "one of the most interesting and fast-growing fields".

Today, AI-based solutions, implemented with different techniques, are present in the most diverse types of systems. These include systems for translation, logistics organization, investments, image and voice recognition, games, robot control and many other artifacts (13; 29; 50). Also according to Russel & Norvig (70), AI is not “magic or science fiction, but science, engineering and mathematics” and, as a result, its incorporation among so many media requires a further understanding of its potential and limitations.

Based on these considerations, the aim of this article is to (1) present a brief history and the main concepts related to AI with a focus on machine learning (ML) techniques, (2) discuss its nuances and (3) present some examples of application in various areas. The special interest in ML is due to the large number of studies carried out using techniques of this type. It should be noted that the intention of the text is to present the concepts related to the topic as well as reflections on its applicability in a way that is accessible to a non-specialist audience. To this end, this review includes sections on the concept of AI from different points of view; areas of knowledge that have contributed to the development of AI; machine learning, its paradigms and applications; and some final considerations on the subject.

2. Methods

The article presents a narrative literature review which is useful "to describe and discuss the state of the art of a given subject, from a theoretical and contextual point of view, which basically consists of an analysis of the literature published in books, articles in printed and/or electronic journals and the author's personal interpretation and critical analysis" (65) involving a survey of scientific knowledge about AI. To compose the text, publications were selected from books and scientific journals that deal with the subject of "Artificial Intelligence", with a special interest in those that

present the concepts and paradigms of ML, as well as their applicability in the most diverse areas of knowledge.

3. History

Although in its infancy, the idea of AI comes from times past, when concerns were already focused on developing machines or methods that could reproduce human abilities. The philosopher Aristoteles (384-322 BC), for example, set out to find a way of codifying "correct thought" (3). As a result of these efforts, formal logic emerged which, after a series of improvements, evolved into symbolic logic which uses symbols for its concepts/conclusions (8) and from there into mathematical logic which underpins mathematical principles and demonstrations (90) becoming an essential tool in the reasoning processes used, above all, in the exact sciences.

More concrete initiatives around AI only emerged during the Second World War (1939-1945), motivated by demands to create technologies that would boost the war industry. During this period, studies began to be carried out (in concentration camps) in order to study the brains of human beings (80). It is worth noting that the studies carried out at this time had inhumane, cruel, highly reprehensible and often deadly methods.

The Hixon Symposium in 1948 in the United States was a major scientific milestone. On that occasion, the researchers present were able to visualize existing and approximate relationships between the human brain and computers. More than a decade before this event, in 1936, the young English mathematician Alan Turing had written the article "On Computable Numbers With an Application to the Entscheidungsproblem", in which he established the principles of computing through a theoretical, abstract artifact that can be reproduced with paper and pencil, commonly referred to as the "Turing Machine" (83).

"(...) Turing's breakthrough consists in the fact that he demonstrated, through the invention of his machine, that any and all tasks that can be represented in the form of an effective procedure can be mechanized, i.e. can be carried out by a computer... and that any and all types of computer can ultimately be reduced to a Turing machine... because they can be imitated by his machine... making it a true universal principle" (83).

The Turing Machine is of great importance to computing because it formalizes the concept of algorithm, the essence of what lies behind computing. However, it wasn't until 1950, with the article "Computing Machinery and Intelligence", that Turing made a definitive contribution to the development of AI, mainly by presenting an operational definition for the term "intelligence". On that occasion, Turing proposed a kind of imitation game that became popular under the name "Turing test" (84).

Figure 1- Illustration of the Turing Test.
Source: Prepared by the authors

As Figure 1 illustrates, there are three participants in this game: two people and a computer. The interrogator (one of the two people) remains in a separate room asking subjective questions to try to find out who of the other two is a person. If, after a certain time, the interrogator is unable to identify this difference, it is proposed that the computer has assumed a behavior considered intelligent (84).

Another important milestone was an academic seminar that addressed questions about intelligence, automata and neural networks, which took place in Dartmouth, USA, in 1956 (54). This event discussed issues related to problem solving, the computer's ability to "think" and the feasibility of a machine capable of playing chess (39;51). It's worth noting that this was the first use of the term AI (70). From then on, various works and programs emerged that boosted the growth and development of the field, such as GPS (General Problem Solver), a problem "solver" created by Newell & Simon (1961); Lisp, the first programming language for AI and the Advice Taker program, both developed by McCarthy (38); as well as the creation of perceptrons by Rosenblatt (64) and the first neural networks (91). In the 1970s, the first knowledge-based systems appeared, most notably DEBDRAL (18) and MYCIN (76). Later, in the 1980s, more flexible neural networks with greater learning capacity emerged (68), which could be applied to solving more complex problems.

Currently, deep learning techniques are the latest in machine learning and are present, for example, in Convolutional Neural Networks (CNN), Deep Belief Networks (DBN), Deep Boltzmann Machines (DBM), as well as Recurrent Neural Networks (RNN) (57). More recently, generative AI, also based on the concept of deep learning, has stood out for being the basis of the intelligence behind ChatGPT (Generative Pre-trained Transformer) (54) and Midjourney (44), the former aimed at generating texts and the latter at generating images.

Scientific Society Journal
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REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

4. What is artificial intelligence?

The characterization of the concept of AI ultimately depends on an understanding of the terms "Intelligence" and "Artificial", since these two words make up the term "Artificial Intelligence". Mora (46) understands Intelligence "as the capacity of certain organisms to learn and to apply learning". In relation to the term Artificial, it can be designated as "everything that is made by human beings, in other words, an artifact" (94). Roughly speaking, combining the definitions of the words separately, it can be said that AI corresponds to the ability of artifacts (computers) to perform tasks that require intelligence to be carried out, i.e. that have historically depended on the human intellect to be performed.

According to Rich (61), AI is a field of study whose goal is to create systems capable of performing tasks that humans are better at. On the other hand, Bigonha (6) states that AI examines and produces systems prepared to perform actions similar to those of people, such as learning and making decisions, only with a great deal of agility. Goldschmidt (24) defines computational intelligence as "a multidisciplinary science that seeks to develop and apply computational techniques that simulate human behavior in specific activities".

Russel & Norvig (70) provide different definitions for AI, organized into four categories "acting like humans", "acting rationally", "thinking like a human" and "thinking rationally" in which they present a different sometimes complementary view of the subject.

4.1 Acting like human beings

Here, the ability of a computer to impersonate a human being, or in other words, to overcome the Turing Test, stands out as a model of intelligence. In this "Imitation Game", the physical need for a human being to issue answers is "discarded" and the

Scientific Society Journal
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REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

computer, in an "intelligent" way, manages to replace him satisfactorily. Two definitions, considering this aspect, are presented below:

a. "The art of creating machines that perform functions that require intelligence when performed by people" (31)

b. "The study of how computers can do tasks that are now better performed by people" (62).

4.2 Acting rationally

From this point of view, the intelligence model is associated with the rational agent, where rationality is the means to guarantee the most appropriate results according to some predefined utility metric. It's important to note that human and rational behavior are not mutually exclusive. This differentiation is just to highlight that humans don't behave in a strictly rational way all the time. In other words, human decisions are not always made with the aim of achieving the maximum measure of satisfaction. The following definitions take this point of view into account:

a. "Computational Intelligence is the study of the design of intelligent agents" (70).

b. "is related to an intelligent performance of artifacts" (52).

4.3 Thinking like a human

In this context, knowledge from cognitive science is used to idealize a model of intelligence that consists of "reproducing" the human mind, i.e. the way human beings reason. The following definitions are in line with this perspective:

1. "The new and interesting effort to make computers think (...) machines with minds, in the full and literal sense" (70)
2. "[Automation of] activities that we associate with human thought, activities such as decision-making, problem-solving, learning..." (70).

4.4 Thinking rationally

Finally, we highlight a model of intelligence that is based on the Aristotelian proposal of "codification of thought". This codification presupposes the use of logical resources to build mechanizable and irrefutable reasoning processes, allowing a computational device to conduct "correct thinking". The following definitions take this aspect into account:

I. "The study of mental faculties through the use of computer models".(70)

II. "The study of the computations that make it possible to perceive, reason and act" (70).

4.5 A brief summary

It is possible to state that the tasks of interest to AI are those that, at least in theory, cannot be mechanized, i.e. they cannot be converted into an effective procedure (algorithm) and, consequently, cannot be carried out by a computer. These are tasks in which an extra "ingredient", called intelligence, needs to be used to perform them. Tasks of this type are those that essentially involve decision-making and are associated with a wide variety of areas of knowledge, such as health, law, finance, engineering, business, tourism and marketing, as will be discussed in the next section.

5. Intersections between AI and other areas

AI is an area of knowledge whose foundations have been provided by other more traditional and historically consolidated areas (78; 70). On the other hand, AI has already acquired a sufficient degree of maturity to allow it to be applied to the development of various areas, including those on which it is based. The following are the main areas of knowledge that contribute concepts and techniques to building

Scientific Society Journal
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REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

the foundations of AI, as well as how AI has contributed to the development of these areas.

5.1 Philosophy

The construction of an AI project, according to Porto (58), must take into account the metaphysical foundations of AI, paying attention to the use of the term "intelligent programs", meaning that the "intelligence" of this program is only related to the complexity of the program and not precisely to "intelligence" in general. Indeed, in agreement with Gava (21), the view of AI researchers that computers can and/or could reproduce the functional characteristics of the human mind has had a major impact on disciplines focused on the philosophy of mind:

> "The philosophy of mind has as its main issue the search for arguments that demonstrate what the real nature of the mind is and what relationship exists between the mind and the brain, as well as the advent of artificial intelligence, a new way of studying the mind through computational models has also emerged, which has been called the functionalist theory of mind" (21).

The discussion that permeates AI goes through philosophical issues related to the conceptual aspects of man, intelligence, the world, knowledge and technology, causing great impact and valuable insights into this debate (77). In this context, it is worth noting that Nakabayashi (2009) studied AI in the Philosophy of Mind as a science belonging to the nature of cognition and, in view of the findings a *bot (*robot) capable of playing the role of a tutor in virtual teaching environments he considered *chatbots to be* a very interesting alternative for use in education because their form of communication is based on natural language.

5.2 Engineering

Engineering, especially those branches more closely related to electronics and telecommunications, has made indispensable contributions to the materialization of the concepts produced in the sphere of computing. It is through the data processing, storage, transmission and sharing devices produced by this area that computer systems in general can become a reality (70).

On the other hand, engineering has been influenced by AI through the use of systems to collaborate in production, the stock sector, estimating demand, organizing orders and quality control, making it essential (79). Another point is automation, which tries to improve the performance of industrial machinery and human-like techniques, with research into behavioral conduct and understanding human reasoning at its core (45).

Recent research by Cardozo (12) sought to capture information from a domestic environment using sensors and a fuzzy logic algorithm. It was possible to monitor luminosity, the presence of gases, people or animals in the environment, either locally or remotely, and it was found that the implementation of this system contributed to a reduction in electricity costs.

5.3 Psychology

Debates on the relationship between psychology and artificial intelligence are not new (10). In fact, Tiberius (82) correlated computing (for great revolutionary machines) with cognitive psychology (focused on the brain) through the conceptualization of memory, intelligence and the performance of computer systems. However, with the COVID-19 pandemic, these ties have been tightened, especially in the educational aspect, facilitating learning processes (10). "It's natural to think of AI research, on the reproduction of automated reasoning or intelligent behavior, as something based heavily on the technology that makes it possible to build these artifacts, with no commitment to a more reflective approach on

Scientific Society Journal
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REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

aspects of how the mind works. However, AI can be thought of as an area of research that emerges from the activity of incessant scrutiny of the human mind, which began in Ancient Greece and spans centuries of history, when inserted into the present time with the manifestation of high technology. In this 21st century, humanity is able to artificially reproduce the natural processes of the human mind, externalizing intelligence. Perhaps this is the most peculiar aspect of AI. While philosophy and psychology seek to understand the aspects of the intelligent mind as internal manifestations and enclosed within the limits of being, AI, in turn, externalizes them" (42).

A recent study by Santamaría & Sánchez-Sánchez (71) looked at the use of new technologies for the psychological assessment of professionals and patients. The authors found that the interaction between technology and psychology is still far from being a reality; they also recognized that a closer correlation between the fields must take into account the training of professionals in order to solve problems properly, so that bad practices don't occur:

"Artificial intelligence is a technology that lies halfway between science and art. Its aim is to build machines that, when solving problems, appear to think. A good example is the chess-playing machine" (81).

According to Teixeira (81), robopsychiatry and robopsychology are set to revolutionize the understanding of mental illnesses, since the focus is on understanding robots with various particular and distinct characteristics or psychoses.

5.4 Biology

Nature-inspired computing as part of Natural Computing uses ideas from reality to create artificial systems whose purpose is to solve complex problems, encompassing the fields of physics, chemistry, engineering, biology and computer science. Indeed:

Scientific Society Journal
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Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

"Nature-inspired systems have broken paradigms with regard to conventional technological solutions, which follow a strict set of rules and therefore often fail to produce satisfactory results in solving complex problems. This fact, combined with the infinite possibilities for applications of bioinspired systems, means that these systems are gaining more and more ground, either in solving new problems or in improving or replacing traditional models" (23).

Among the main techniques involved are "Biologically Motivated Computing", "Biological Metaphor Computing" and "Bioinspired Computing" (9). The latter, "Bioinspired Computing", one of the main methods investigated, employs different computational approaches, mainly artificial neural networks. These techniques are aimed at research focused on biology in its practical aspects, such as biological classifications and groupings related to DNA, as well as testing and comparison between species (25).

It is also worth highlighting, in the sphere of intersections between biology and AI, the potential of the concept of *artificial life, in the* following terms:

"The concept of artificial life is still recent within studies of the human body, precisely because it is still closely linked to research into robotics and crude computing. There are, however, some researchers who are already talking about the post-human, which means that the exchange of information between the artificial and the biological can be thought of as part of studies into improving the human body. From this perspective, it seems that the human body would be just one of the models to be reproduced by artificial life, and possibly the most challenging and unattainable. However, it is worth looking at it from another angle, one in which artificial life promotes not only the means to reproduce biological life in an artificial environment, but also ends up driving technological advances to promote changes in human bodies too, so that the concept disconnects from raw science and begins to dialog with other areas of knowledge" (35).

Scientific Society Journal
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Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

In this sense, Reis (59) analyzed cases resulting from the junction between computing, mathematics, biology and neuroscience and realized that lives can be germinated and proliferated in a natural environment (by bringing artificial life closer to natural life) and that biocybernetics can involve living beings (neuroscience), environments (biology) and objects (computing).

5.5 Logic

Logic plays an extremely important role in the field of AI, developing reasoning and premises for solving problems (56). Six objectives of AI are therefore described in relation to logic:

"Firstly, AI aims to mechanize logic, an absolutely essential tool for so many rational activities; Secondly, AI intends to make the subconscious logic we use explicit and well-defined, testing it objectively through its automation; Thirdly, AI employs logic as a generic language of communication, knowledge and procedures, between humans and computers, as well as between computers themselves; Fourthly, in AI, even when procedures and artifacts are not implemented using logic directly, logic can take on the role of a precise language for specifying the requirements of those procedures and artifacts, as well as a formalism through which to study their semantic properties; Fifthly, AI has contributed significantly to equating and examining the problem of identifying the limits of proper symbolic reasoning embodied in computers, as well as assessing whether these limits apply to human beings; Finally, and sixthly, AI has helped researchers to explore new questions and new methods of reasoning, as well as to combine disparate modes of reasoning into a uniform and unified framework, in order to deal with incomplete, imprecise, contradictory and changing information" (56).

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

Logic and probability collaborate directly with the theories and measurements used by quantitative science; roughly speaking, it can be said that the evolution of computing and consequently its use by AI, has required a closer relationship between mathematics, logic and probability to solve problems (70; 78).

5.6 Linguistics

Computer science related to linguistics computational linguistics is nothing more than a multidisciplinary branch of study focused on the syntactic, semantic and logical learning of natural language, with the aim of promoting improved technology in aspects involving communication (53).

"Although existing systems are far from reaching human capacity, they have countless possible applications, the aim is to create software products that have some knowledge of human language. These products will change our lives. They are urgently needed to improve human-machine interaction, because the main obstacle in human-computer interaction is simply a communication problem" (85).

Computational linguistics is subdivided into two subfields: (1) *corpus* linguistics, which is concerned with language and its various linguistic forms; and (2) natural language processing, linked to the development of virtual assistance systems (chatbots), translators, voice recognition, among others (55; 19).

An important piece of software used by linguists to work with *corpus* linguistics is WordSmith Tools, which has an arsenal of language patterns in various languages (75). Berber-Sardinha (5) studied how to find the most important keywords in a *corpus* using WordSmith Tools and concluded that in order to have the best chance, the first keywords in the list, ordered by keyness, should be chosen.

Recent research has studied the use of AI through *chatbots* in the customer service process and has found several benefits related to cost, productivity, flexibility, quality and innovation (74). Currently, many companies use *chatbots* (robots) to

Scientific Society Journal
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Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

"triage" situations that can be solved through "robotic" customer service, differentiating them from those that will require an interlocution with a human.

In 2022, Meta, a giant technology company, unveiled a new AI model capable of translating 200 different languages with 44% accuracy (43). Microsoft recently released VALL-E, an AI capable of transforming a three-second audio into another audio with a different voice: I say "good morning" and the platform can generate a "good night" with my voice (89). At the same time as being an innovative tool, it can cause many problems, since creating audios not said by people and faithfully replicating them with their voices can contribute to the creation of *Fake News*.

6. Applications of AI

AI has a huge number of applications and, based on this, Russell & Norvig (70) categorized the area according to the following segments: (i) Natural Language Processing (NLP), (ii) Automated Reasoning, (iii) Knowledge Representation, (iv) Computer Vision, (v) Robotics and (vi) Machine Learning (ML).

- Natural Language Processing (NLP) encompasses computational models capable of performing multiple tasks, such as organizing, translating and creating documents from a database, among others. The ways of carrying out this work can be based on rules (symbolic) or quantitative data (statistical) (2).

- Automated Reasoning uses a logical inference mechanism that acts on facts and rules related to a given domain to derive conclusions or recommendations (70).

- Knowledge representation is characterized by the ability of a computer to express information so that it can be used by an AI system, and this involves various forms and patterns of representation (CÂMARA, 2001).

- Computer Vision, according to Hollerweger (28), "comprises the set of processes (acquisition, processing, analysis and comprehension) applied to digital

Scientific Society Journal
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REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

images, with the aim of automating tasks that require the perception provided by human vision".

- According to Mataric (2014, p. 21), robotics is "the study of robots, which means the study of their ability to sense and act in the physical world autonomously and intentionally".

Machine Learning (ML) is a sub-area of AI that works with factors and algorithms capable of learning to perform some task (66). It is worth noting that, in common, the tasks presented require skills that are considered intelligent in order to be carried out, which involve, for example, perception, reasoning, learning, planning, adaptation, prediction and language.

For the purposes of this article, it was decided to explore AM concepts and techniques in detail, focusing mainly on the supervised learning paradigm. This approach has a more "controlled" learning capacity and generally provides significant results in predictive tasks.

7. Machine learning

ML uses concepts from neuroscience, biology, statistics, mathematics and physics to make computers "learn". Imagine you're playing against a computer, 10 games have passed and you're still winning, but at a certain point, the computer starts to beat you. There are two options: you could be getting worse or the computer has learned to win. This means that if it has learned to win, it will be able to use the same strategies with other participants; this is a simple example of AM (36).

Among the various possible explanations for ML, some stand out:

- "Machine Learning is about making computers modify or adapt their actions (to make predictions or control robots) to get more accuracy" (36).

- "Machine learning is the science (and art) of programming computers so thatthey can learn from data" (22).

Scientific Society Journal
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Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

- "The ability to improve performance in performing some task through experience" (MITCHELL, 1997, p. 2).

- "Machine learning techniques are mainly used to solve problems involving phenomena for which there are no known analytical models that adequately represent them" (78).

A variety of ML techniques can be applied in everyday situations, whether it's to improve healthcare (diagnosing diseases, making prognoses, monitoring patients, indicating medication, monitoring medical records...), translations, speech recognition, safer transportation, control and detection of possible fraud (e.g. credit card scams), among many other benefits. Despite their extraordinary growth, these ML techniques can also have negative points such as reducing human resources in companies, exacerbating social inequalities, accentuating discrimination and loss of privacy, among others (33).

In the context of ML, learning consists of building models capable of performing different tasks, which are basically divided into predictive and descriptive. Predictive models are directly related to a paradigm called supervised learning, while descriptive tasks are related to the unsupervised learning paradigm. Figure 2 highlights these relationships (17).

Scientific Society Journal
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Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

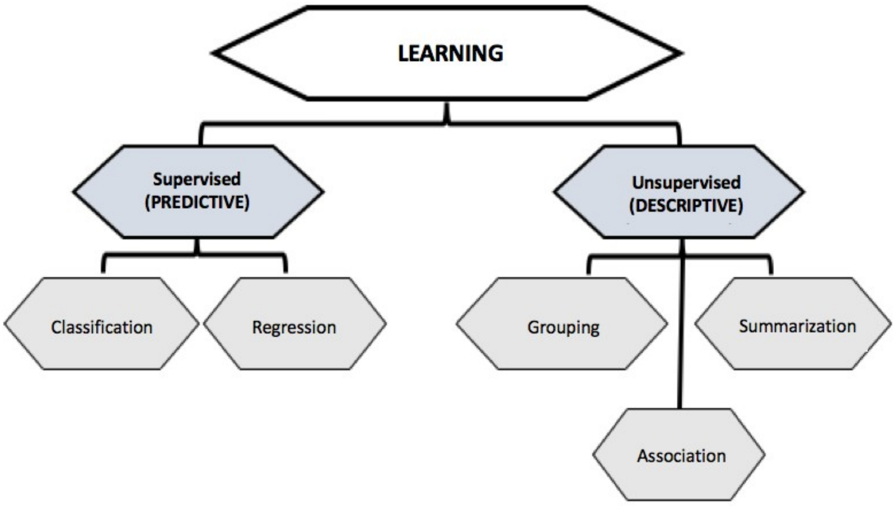

Figure 2 - Learning paradigms and their tasks.
Source: Faceli *et al.* (2010) adapted by the authors.

ML also considers other paradigms such as semi-supervised, active and reinforcement learning. In this article, however, only details related to the supervised paradigm are covered, with emphasis on its application in classification tasks.

7.1 Supervised Learning

Supervised ML is applied to predictive tasks which can be of two types: classification and regression. In both cases, each element that takes part in the learning process is described by a set of descriptor attributes and there is also a target attribute, which establishes the label associated with that element. In cases where this label takes on a categorical value, there is a classification task, while when it takes on a numerical value, there is a regression task (70).

Regardless of the type of task, the aim of supervised learning is to build predictive models with good generalization capacity, i.e. capable of predicting the target value for new elements that did not take part in the learning process, but which have similarities to those (17).

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

7.1.1 Regression

Regression models attempt to discover the behavior of one variable in relation to the changes undergone by others (16). In the meteorological field, it is very common to use regression models to outline temporal analyses. Another example is trying to predict age from an image. Figure 3 illustrates a learning problem involving a regression task. In it there is a data set in which each element is made up of two attributes, a descriptor x (independent variable) and a target y (dependent variable). The regression model learned corresponds to a linear estimator. In general, regression models related to real problems require the construction of much more complex estimators, which are highly non-linear and involve many descriptor attributes.

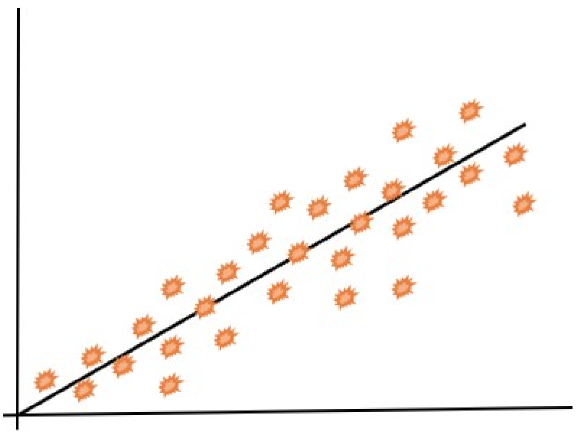

Figure 3 - Linear regression model obtained from a data set.

Source: Prepared by the authors

7.1.2 Classification

Classification models try to separate a set of elements according to previously established categories. Sorting the answers to a survey into domains and categorizing them based on certain criteria corresponds to a classification task. Another example of

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

classification, presented in Santos (73), refers to the granting of credit by a bank. For the bank to grant credit, it needs to have financial data on its customers and, according to their profile, classify them as to the risk of default in order to decide whether or not to grant credit. Figure 4 illustrates a learning problem involving a classification task. In it, the elements of the data set are represented by the descriptor attributes x and y and by the target attribute which establishes whether an element belongs to the class of "clouds" or "stars". The learned classification model is represented by a linear separator that establishes a decision boundary between the classes involved. As in the case of regression models, classification models associated with more complex problems require the construction of non-linear separators, which involve many descriptor attributes and many classes (17).

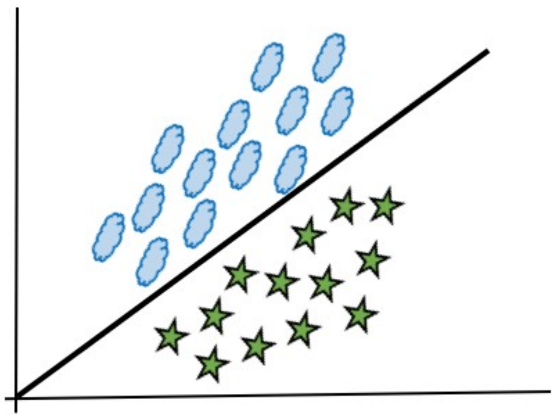

Figure 4 - Classification model obtained from a data set.

Source: Prepared by the authors.

There are various methods that can be used to build predictive classification models. In general, these methods are based on distances, probability, search, optimization, hybrid, among many others (17).

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

7.1.2.1 Distance-based methods

These include techniques that use a proximity criterion to assign a label to an element that has not yet been classified. A well-known distance-based algorithm is k-NN (k-nearest neighbor), which assigns the most frequent label among the k nearest neighbors to a new element (17). Figure 5 shows an example of a data set in which each element represents a message received by email and is described by two attributes.

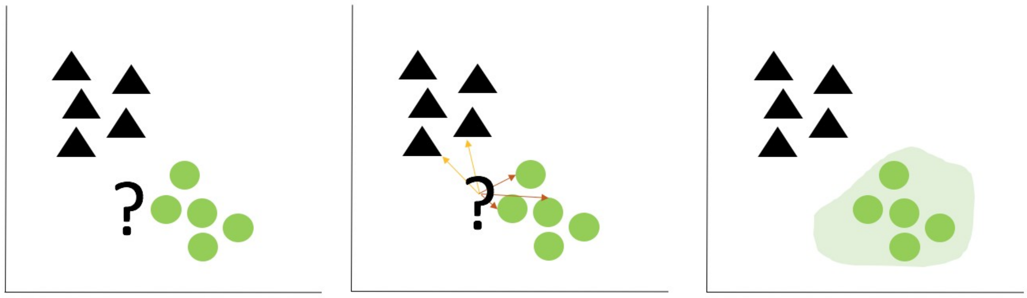

Figure 5 - Classifying a new element with the k-NN algorithm.

Source: Prepared by the authors

Each message is labeled "*spam*" (triangle) or "*not spam*" (circle). When a new element is introduced, whose label is unknown, the 5 nearest neighbors are identified, for example. This new element is then given the label "*not spam*" (circle), since of the 5 nearest neighbors, 3 are from the "*not spam*" class (circle) and 2 are from the "*spam*" class (triangle).

7.1.2.2 Probability-based methods

Better known as Bayesian probabilistic methods, probability-based methods are based on Bayes' Theorem, which makes it possible to calculate the probability of an event as a result of the probability of an event that has already occurred (17). As an example, considering that 10% of a population has the disease COVID-19, the test

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

carried out to detect the disease is not yet completely reliable. That said, when people take the IgG test and the result is positive, 70% of them are confirmed to have the disease and when it is negative, 90% of people do not have the disease. COVID-19 can have two values: absent or present and IgG positive or negative. As you can see, the value of the COVID-19 variable influences the value of the IgG variable, but the opposite is not true. The situation presented can be represented as:

P(*COVID-19* = present) = 0.10 and P(*COVID-19* = absent) = 0.90

P(*IgG* = *positive*|*COVID-19* = present) = 0.70

P(*IgG* = negative| *COVID-19* = absent) = 0.90

There is also the possibility of a tabular representation as shown in Figure 6:

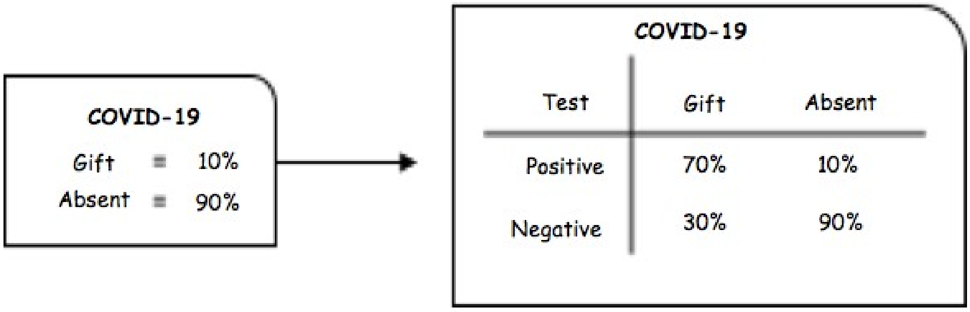

Figure 6 - Tabular representation of the COVID-19 problem.
Source: FACELI *et al*. (17) modified by the authors

7.1.2.3 **Search-based methods**

Search-based models interpret learning as a search problem in a space of possible solutions (17). A well-known technique for building search- based models is decision trees (88). This involves building a hierarchical structure, represented by a tree, in which each internal node corresponds to a test carried out on an attribute, each branch represents a possible result of this test and the leaves represent the predictions. The tree generated by the learning process can be interpreted as a set of rules that

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

explains the knowledge extracted from the data, which is a very attractive feature in various applications.

A simple example of applying a decision tree would be to make a decision about whether or not to turn on a light bulb. The question "Should I turn on the light?" corresponds to the root node of the tree. The questions "Do you have a switch?" and "Is it bright outside?" correspond to the split nodes and the answers "Should I turn on the light?" and "Should I not turn on the light?" are considered leaf nodes, as shown in Figure 7.

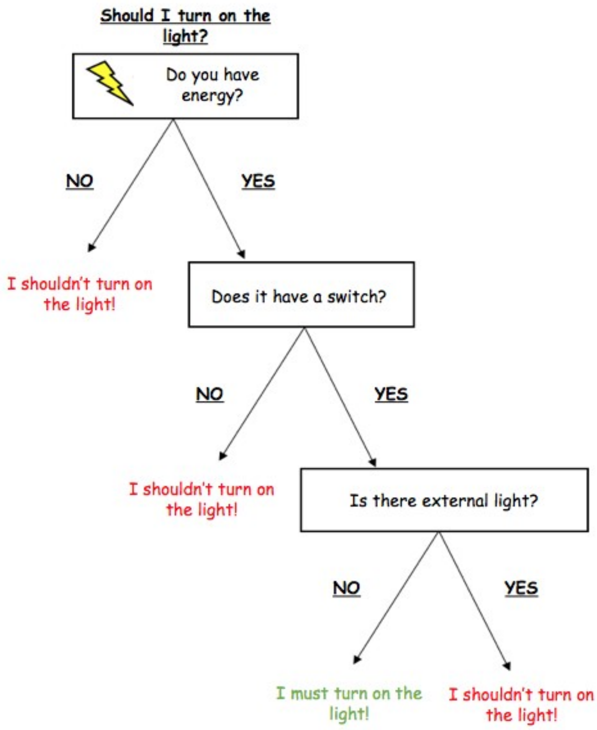

Figure 7 - Decision tree for the lamp lighting problem.

Source: Prepared by the authors.

The generalization capacity sought during the learning process depends essentially on the criteria used to choose the sequence of attributes that partition the data set from the root of the tree to the leaves.

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

7.1.2.4 Optimization-based methods

As the name implies, these are methods or models that develop solutions by optimizing a function. Two techniques that use this method are Artificial Neural Networks (ANNs) and Support Vector Machines (SVM) (17).

Artificial Neural Networks

In order to understand how ANNs work, it is necessary to understand a little about the human nervous system, since these computer systems are inspired by the workings of the human brain (and its neurons) in order to use this knowledge to design computer learning systems.

The biological neuron is made up of dendrites, a cell body and an axon. The dendrites receive nerve stimuli from other neurons, so the impulses are transmitted to the cell body, which processes the information and sends a new stimulus to the axon, which conducts the electrical impulses to other neurons (87). Figure 8 shows a biological neuron.

Neural synapses which allow neuronal communication are established in the relationship between the axon of one neuron and the dendrite(s) of another neuron, which allow neurotransmitters to act in the propagation of signals between cells. Due to the thousands of neurons that make up the human brain, multiple synapses occur all the time, producing countless biological neural networks that process information (87).

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

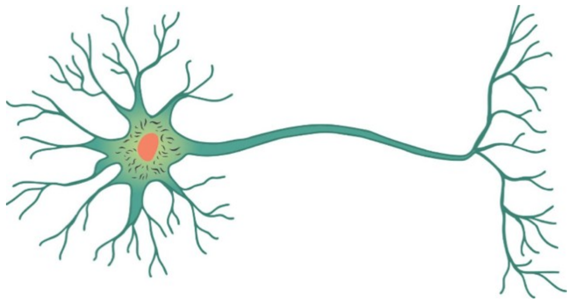

Figure 8 - Biological neuron. Source: Siqueira-Batista & Silva (2019).
Note: Illustration created by Rodrigo Siqueira-Batista and vectorized by Ademir Nunes Ribeiro Júnior

ANN are computer systems interconnected by several artificial neurons. In the artificial neuron, as shown in Figure 9, the values x_1 , x_2 , ..., x_n are the input signals, each of which represents a dendrite (compared to the biological neuron). The values w , w_{12} , ..., w_n correspond to the weights, i.e. the weightings of the signals x , x_{12} , ..., x_n . The Σ function (or cell body, in the biological neuron) acquires the weighted input signals, processes them and returns a value ***u*** called the activation potential. The ***g*** function maps the ***u*** value into a ***y*** value that corresponds to an output (an axon) carrying an excitatory or inhibitory signal (15).

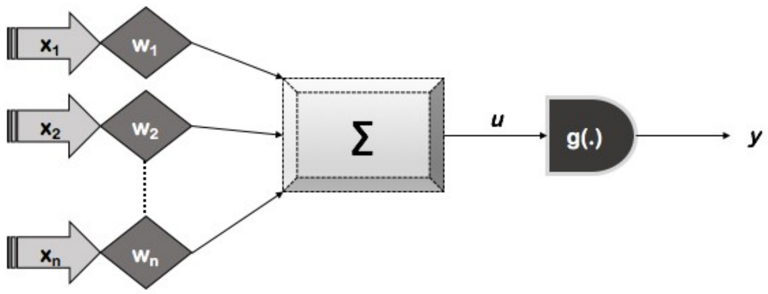

Figure 9 - Artificial neuron.
Source: Prepared by the authors

The architecture of a traditional ANN consists of a set of inputs, one or more layers of hidden neurons and a layer of output neurons. In this type of organization, the

Scientific Society Journal
ISSN: 2595-8402
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neurons in a previous layer are connected to all the neurons in the next layer. The number of inputs is determined by the number of descriptor attributes of the elements to be recognized and the output layer has a number of neurons equal to the number of classes established for the problem. The number of hidden layers, as well as the number of neurons in each one, are determining characteristics for obtaining models capable of adequately performing a classification task. An example that illustrates the application of an ANN is that of classifying a set of flowers of the iris genus, represented by four descriptor attributes, which must be associated with one of three possible classes: "setosa", "versicolor" and "virginica". A possible network architecture for this problem is illustrated in Figure 10.

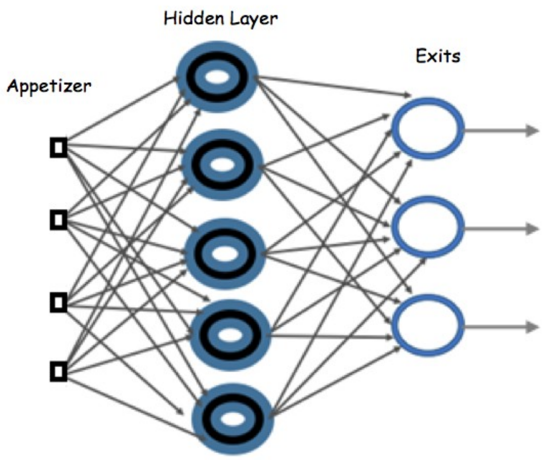

Figure 10 - Artificial Neural Network with 4 inputs, a hidden layer with 5 neurons and 3 neurons in the output layer. Source: Prepared by the authors.

The learning process consists of finding, for the various synapses of the neurons that make up the network, a configuration of weights that allows a model with good generalization capacity to be obtained.

Support Vector Machines

Scientific Society Journal
ISSN: 2595-8402
Journal DOI: 10.61411/rsc31879

REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

Support vector machines (SVM) are a type of supervised learning technique whose aim is to build separating hyperplanes with maximum margin, providing "high-powered and flexible modeling" (63). Thus, considering, for example, a binary classification problem, of all the possible separators for these classes, the SVM finds the one that supposedly has the greatest generalization capacity.

"Support vectors are examples represented as points in feature space. In fact, to define the position of a point in a space, you have to express its coordinates in each dimension as a series of numbers, which is a vector. What's more, you can see them as support vectors, because the hyperplane with the largest margin depends on them - and changing either one changes the margin and the hyperplane that defines it. Support vectors decide the best possible margin, both in the case of linearly separable and non-separable classes" (48).

In other words, the optimal hyperplane can be understood as the one that separates the classes with the greatest possible "thickness". Although an SVM only builds non-linear separators, this technique is also applicable to classification problems that require non-linear separators. In this case, the *kernel* trick is used, which consists of applying a non-linear transformation in space, mapping the data set to a higher-dimensional space in which it is possible to obtain a separating hyperplane for the classes.

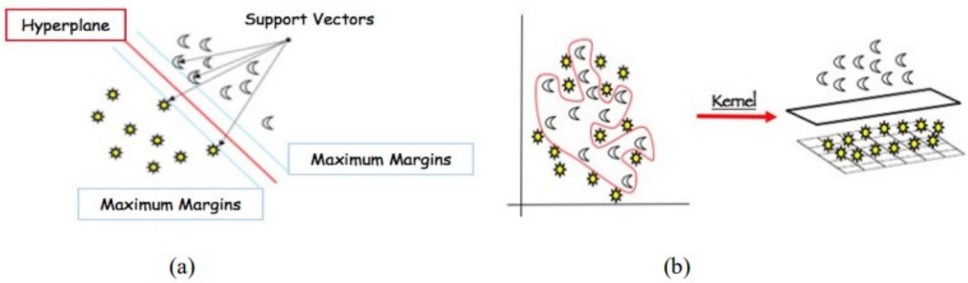

Figure 11- shows two examples of classification problems, one in which the classes are linearly separable (a) and the other in which they are not (b).
Source: Prepared by the authors.

Scientific Society Journal
ISSN: 2595-8402
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REVISTA SOCIEDADE CIENTÍFICA, VOLUME 7, NÚMERO 1, ANO 2024

Multiple Predictors - Hybrid Systems

These are models that combine two or more different techniques within the computational arsenal, but at least one of which must be AI, in order to solve a given problem (60). The functions of Hybrid Systems (HS) are to solve complex problems and bring together the positive points of each technique used, overcoming their limitations (32). With this, "the proposal of HS is to build more robust systems, capable of working with various types of knowledge representation, supporting various types of inference, solving more complex problems, among other advantages" (32). In this regard, Kohavi (30) presented a hybrid system that creates an invariant decision tree using *Naïve Bayes* classifiers in the leaves of the trees, thereby extracting the benefits of the decision tree (segmentation) and *Naïve Bayes* classifiers (accumulation of evidence from various attributes) (17). Another application was proposed by Martinho (37), in which five AI models based on AM were developed, associated with four bio-inspired algorithms, to predict the flow of the Zambezi River (Mozambique). As a result, the author found that combining AI techniques with bioinspired algorithms led to successful results in predicting the river's flow. Still as an example of HS, Santana *et al*. (72) analyzed the performance of predictive models for determining the standard behavior of rainfall series and found that simulation and optimization models are imminently useful for work covering water engineering.

8. Final considerations

Since its emergence the official milestone of which was a conference at Dartmouth College in 1956 (78) AI has evolved in surprising ways, experiencing remarkable development, especially in the last two decades. It is a multi-professional field of activity that has been influenced by various areas of knowledge and has collaborated enormously with global technological developments. Today, it has techniques capable of finding solutions to complex problems which, in some cases, perform better even than human beings. A remarkable result was obtained by a model based on deep learning, called ResNet (27), which in the 2012 edition of the ILSVRC challenge (69) achieved a result far superior to that of a human being in a task involving computer vision.

In the different areas of knowledge, there are countless possibilities for the application of AI. In general, these applications are grouped into: natural language processing, automated reasoning, knowledge representation, computer vision, robotics and machine learning. Applications involving machine learning, in particular, have stood out not only for their versatility, but also for their increasingly promising results. In view of this, this manuscript has focused on the concepts and techniques surrounding machine learning, with an emphasis on supervised learning applied to predictive classification tasks. An overview of some of the main classification techniques was presented, with a view to sharing the idea of how each one works, without the need to resort to technical details that could make it difficult for a non-computer science audience to understand.

The field of AI, particularly machine learning, continues to be a very promising and exciting topic of study. Solutions with capabilities ever closer to those of a human being have emerged and ChatGPT and Midjouney stand out in this context. Science is still a long way from realizing the dream of building truly thinking machines that could even replace Homo sapiens in some tasks. However, the latest advances have made it possible to build systems that can support human professionals in making better decisions in increasingly complex situations. Thus, as a support mechanism, and only a support mechanism, for decision-making, AI has been able to fulfill its role quite competently.

9. Declaration of rights

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Scientific Society Journal
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