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Review

Artificial Intelligence and Machine Learning Applications in Smart Production: Progress, Trends and Directions

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Abstract: The history of Artificial Intelligence (AI) development dates to the 40s. The researchers showed strong expectations until the 70s, when they began to encounter serious difficulties and investments were greatly, reduced. With the introduction of the Industry 4.0, one of the techniques adopted for AI implementation is Machine Learning (ML) that focuses on the machines ability to receive data series and learn on their own. Given the considerable importance of the subject, researchers have completed many studies on ML to ensure that machines are able to replace or relieve human tasks. This research aims to analyze, systematically, the literature on several aspects, including publication year, authors, scientific sector, country, institution, keywords. Analyzing existing literature on AI is a necessary stage to recommend policy on the matter. The analysis has been done using Web of Science and SCOPUS database. Furthermore, UCINET and NVivo 12 software have been used to complete them. Literature review on ML and AI empirical studies published in the last century was carried out to highlight the evolution of the topic before and after Industry 4.0 introduction, from 1999 to now. Eighty-two articles were reviewed and classified. A first interesting result is the greater number of works published by USA and the increasing interest after the birth of Industry 4.0.

Keywords: artificial intelligence, machine learning, systematic literature review, applications, Industry 4.0

1. Introduction

The father of Artificial Intelligence, John McCarthy [1], in the 1990s defined Artificial Intelligence as *"Artificial Intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs"*. In other words, Artificial Intelligence (AI) is intelligence shown by machines. In computer science the field of AI defines itself as the study of "intelligent agents". Generally, the term "AI" is used when a machine simulates functions that human's associate with other human minds such as learning and problem solving [2].

AI born in 1956 defined it as *"the science and engineering of making computers behave in ways that, until recently, we thought required human intelligence"* [3], that means a branch of information technology that allows the programming and design of both hardware and software systems capable of providing machines with certain characteristics considered typically human, such as, for example, visual, spatio-temporal and decisional perceptions.

On a very broad account the areas of artificial intelligence are classified into sixteen categories [4,5,6,7,8]. These are: reasoning, programming, artificial life, belief revision, data mining, distributed AI, expert systems, genetic algorithms, systems, knowledge representation, machine learning, natural language understanding, neural net-works, theorem proving, constraint satisfaction, and theory of computation [9,10,11].

In the 21st century AI has become an important area of research in virtually all fields: engineering, science, education, medicine, business, accounting, finance, marketing, economics, stock market and law, among others [12,13,14,15,16,17,18]. The range of AI has grown enormously to the extent that tracking proliferation of studies becomes a difficult task [19].

In the last few years, there has been an arrival of large amount of software that utilizes elements of artificial intelligence. Subfields of AI such as Machine Learning, Natural Language processing, Image Processing and Data mining have become an important topic for today's tech giants.

Among the thirteen most significant technologies we can identify the Machine Learning (ML).

ML, actively being used, is a branch of AI and is defined as the study of computer algorithms that improve automatically through experience. Therefore, ML is one of the ways we expect to achieve AI, reliesing on working with large data-sets, by examining and comparing the data to find common patterns and explore nuances. The development of ML technique is very fast now. Its usage has spread to various fields, such as learning machines currently used in medical science, pharmacology, agriculture, archeology, games, business and so forth. Many researches have been performed to create a more intelligent machines that can replace or relieve human tasks such as analyzing, communicating, learning, or making decisions. In this work a systematic literature review of research from 1999 to 2019 was performed about the use of the machine learning technique. The purpose of this study is to determine the techniques and problems in the use of machine learning that may be used as a reference for conducting research in the future [20].

Currently, very rapid development of ML and its use has been expanded to various fields. In other words, it refers to a series of tools for designing, developing and instructing other machines. The base of everything is the concept of experience, namely direct knowledge, personally acquired through observation, use or practice, of a specific sphere of reality. Just as man learns through life experiences, so, in the case of ML, computers and appropriately programmed robots learn from experience. From an IT point of view, instead of writing the programming code that tells the machine what to do, data sets are provided: through them (the acquired experience) the machine will be able to carry out the functions, the activities, the tasks that were requested.

The subject of AI generates considerable interest in the scientific community, by virtue of the continuous evolution of the technologies available today. For this reason, the research is based not only on the improvement of the latter or on the creation of new ones, but also on the analysis of the available literature. Furthermore, the interest in using bibliometric techniques is further increased thanks to the availability of large databases, making bibliometrics an effective and important tool for determining research trends in various fields of science.

Therefore, it is considered necessary to create a classification system that refers to the articles that jointly treat the two topics, in order to have greater variance and reflection. To do this, a review of the global literature and a survey analysis of the data on the application of AI and ML were conducted. Furthermore, to gain a deeper understanding, the influence of other variables has been explored, such as the thematic areas and the sectors in which the technologies are most influential. The main contribution of this work is to have an overview of the research carried out to date.

This paper began with a realization that we are in a wonderful age of discovery about issues concerning AI. A number of impressive documentations of established research methods and philosophy have been discussed in print for several years. Unfortunately, little comparison and integration across studies exist. In this article, it was decided to create a common understanding of AI research and its variations.

This paper is not attempting to provide an all-encompassing framework on the literature on AI research. Rather, it is attempting to provide a starting point for integrating knowledge across research in this domain and suggest paths for future research. It explored studies in certain novel disciplines: environmental pollution, medicine, maintenance, manufacturing, etc.

Further research is needed to extend the present boundary of knowledge in AI by integrating principles and philosophies of some traditional disciplines into the existing AI frameworks [21].

The target that this document would like to assume is not the trigger of a sudden proliferation of an already consolidated sector, but it is hoped that this research could be an important intellectual tool for both the refocusing of the work and creating new intellectual opportunities. This paper presents valuable ideas and perspectives for undergoing research on AI. As stated earlier, research related to AI has proliferated in recent years and does not pretend to be inclusive to deceive ourselves that any of these ideas represent the thinking of all, or even most scholars.

From relevant literature search, these were the themes emerged and surfaced, not only in computer journals but also across a range of scientific journals. The aim would be to anticipate the transformation of the discipline in future age. This would be a journey that may experience change in its course as new generations of scholars contribute to the dialogue and to the action. As noted earlier, this work presents a review, hence, it lays a foundation for future inquiry. It has not only offered a basis for future comparisons but has prompted a number of new questions for investigations as well. While topics that might be considered as results of this work are numerous, some are of particularly broad interest or impact.

The paper is organized as follows: Section 2 presents a brief review of machine learning techniques and artificial intelligence; Section 3 the proposed bibliometric analysis method is explained; Section 4 results of the bibliometric analysis is developed. Finally, in Section 5 are summarized the main contribution of the research.

2. Brief review of machine learning techniques and artificial intelligence

The term “Artificial Intelligence” does not have a univocal definition, but it has different meanings given over time. To date, it can be described as a technology that includes different branches of computer science jointly by the resolution of problems through the so-called "intelligent behaviors", through the use, for example, of techniques based on logic, statistical techniques, analysis techniques of the natural language, computer vision.

One of the broadest areas currently falling under the AI label is Machine Learning. This term includes many different techniques and approaches, but they share a clear and unambiguous property: the resolution of problems through programs that have the ability to learn from what is entered as input. Knowledge, therefore, is no longer the human one transferred to the machine, but is learned by the machine itself in autonomous manner. The role of man becomes only to define how machine will have to learn, through examples and information to ensure by itself how could develop a “knowledge” that will allow it to automate activities or transfer knowledge.

The first is logical (symbolic) techniques, which includes two techniques: decision tree and learning set of rules. The decision tree is a tree that classifies the instances, ordering them based on the values of the characteristics, but it can be translated into a set of rules by creating a separate rule for each path from the root to the leaf in the tree. However, rules can also be directly driven from training data using a variety of rule-based algorithms [22].

The second group consists of perception-based techniques. The perception is a type of binary classifier that maps its inputs (a real vector) to an output value (a scalar of real type). The best-known technique is the neural network, a mathematical model used to understand biological neural networks but also to try to solve engineering problems that involve other fields (electronics, computer science, simulation, and other disciplines).

The third group is that of statistical techniques, characterized by having an explicit probability model, which provides a probability that an instance belongs to each class, rather than simply a classification. It is a technique based on memory: the machine compares the new instances of problems with the instances seen in training stored in memory.

Support Vector Machines (SVMs) are the newest supervised machine learning technique [23], which uses learning algorithms for regression and classification: given a set of training series, each of which is labeled with the class to which it belongs between the two possible classes, the algorithm constructs a model that assigns the new examples to one of the two classes, thus obtaining a non-probabilistic binary linear classifier.

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3. Bibliometric analysis methods

The interest in using bibliometric techniques has increased because of the availability of large scientific databases. It involves a series of techniques that are used to quantify the process of written communication and identify patterns. The methodological approach used mixes bibliometric, content analysis and social network techniques. In this study state-of-the-art research was initiated through the consultation of electronic databases (SCOPUS and Web of Science) on February 19, 2019 and dividing it into three phases, as shown in Figure 1:

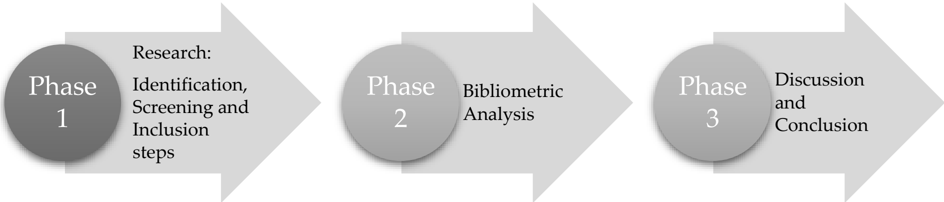

Figure 1: Flow of research phases

In Phase 1, bibliometric data was collected from the two databases mentioned above, using the same keywords for the query in both:

- "Artificial Intelligence";
- "Machine Learning";
- "Application".

The time frame that was considered valid for the study was twenty years from 1999 to 2019, with the intent to understand how the level of attention towards the topic has changed before and after the introduction of Industry 4.0.

First of all, in the Phase 1, it is necessary to identify the overall results obtained from the database search. Subsequently, a screening of the overall result is carried out, to identify which documents can be taken into consideration, in line with the research areas deemed interesting and relevant. At the end of this step, the last step is carried out. This involves the inclusion of the documents that will be the core of bibliometric analysis and are the result of further skimming, compared to the previous step.

In summary, Phase 1 is divided in three steps:

1. Step#1: Identification;
2. Step#2: Screening;
3. Step#3: Inclusion.

Once Phase 1 is completed, the next phase is Phase 2, which is the analysis of the results.

The approach used for the bibliometric analysis was:

- the use of indicators for the parameters studied;
- the SNA (Social Network Analysis) for the keywords.

The indicators chosen to perform the analysis are Total Papers (TP), which is the total number of publications and Total Citation (TC), which is the total number of citations.

The SNA finds application in various social sciences, lately employed in the study of various phenomena such as international trade, information dissemination, the study of institutions and the functioning of organizations. The analysis of the use of the term SNA in the scientific literature has undergone an exponential growth in the use of this mode of computable representation of complex and interdependent phenomena. For the purpose of the study, UCINET, NetDraw software was used, expressly designed for the creation and graphic processing of networks and was used to represent the keywords in the network, and *Excel* for data input.

The software UCINET, NetDraw returns a sociometric network that describes the relationships between the classes, that is, data entered as input.

Another software has been used to analyze keywords of all documents. NVivo 12 is the leading program for computer assisted qualitative analysis (CAQDAS). In the specific case, it was used to

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identify the possible links between the keywords of the various documents examined, developing conceptual schemes from which to make interpretative hypotheses.

At the end of the second phase, a third and final one follows, where the results will be discussed, and conclusions will be drawn.

In Figure 2 are shown the main phases and steps followed for the analysis.

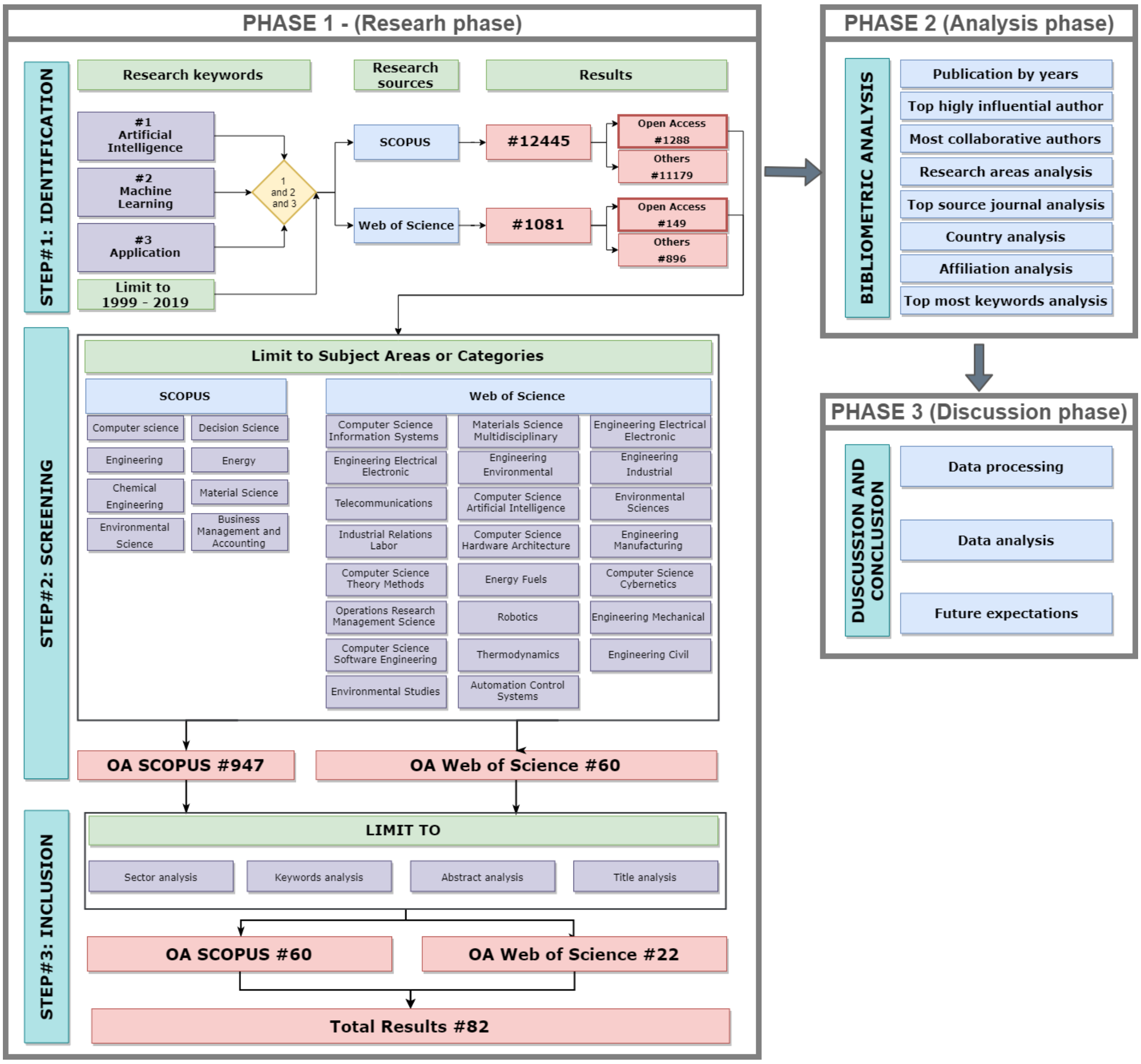

Figure 2: Process flow chart (https://www.draw.io/#G1rTjMubMFSsJFSSsH1STcmkJ6HAHrLeq)

4. Results of the bibliometric analysis

4.1. Phase #1: Research

The first phase consists in the search for documents, which includes the activities of collecting the material belonging to the academic universe. This first phase is divided into three steps.

The first step identifies the documents that can be obtained from the databases used, by entering the keywords and the established time range. A brief analysis of the identified documents follows. In particular, the research growth is analyzed during the chosen time horizon.

The second step concerns screening activities, where the documents considered valid for the bibliometric analysis purpose are chosen based on the research areas. These areas are scientific and exclude the humanities.

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Given the large number, a third inclusion step is required, where further sorting is performed, including the documents in the sample to be analyzed.

Below, the steps will be explained in more detail.

4.1.1. Identification (Step#1)

In this step, Scopus (SCP) and Web of Science (WoS) databases were taken into consideration. In order to maintain the consistency of the results, the same keywords, shown in Table 1, were used in both databases and a time horizon of 20 years was chosen, from 1999 to 2019.

Keywords	Time period
Artificial Intelligence	2009 - 2019
Machine Learning	
Application	

Table 1: Keywords and time period

In total 13,512 documents were extracted according to strategy search.

The results extracted by Scopus are numerically superior to Web of Science: 12,445 for the first and barely 1,081 for the second one (Table 2).

Research carried out on 11 February 2019		
Source of research	Scopus	Web of Science
Results	12,445	1,081

Table 2: Total results of research on Scopus and WoS

The result is not entirely unexpected, and the reason is to be found in the fact that Scopus, being an Elsevier product, collects data from all the other databases, in particular Science Direct and those queried by the Scirus search engine, while WoS collects quite fewer documents.

From the documents extracted in Scopus, it is found that most of them are conference papers (57.28%) and, subsequently, articles (33.85%).

On the contrary, the research on WoS underlines that most of the documents are articles (46.12%) and, subsequently, proceedings paper (42.86%).

All the document types are filled in Table 3.

Web of Science			**Scopus**		
Document types	**Records**	**Contribute %**	**Document types**	**Records**	**Contribute %**
Article	481	46.12	Conference Paper	7128	57.28
Proceedings paper	447	42.86	Article	4212	33.85
Review	133	12.76	Review	412	3.31
Editorial material	16	1.53	Article in Press	194	1.56
Meeting abstract	2	0.19	Book Chapter	177	1.42
Book chapter	1	0.1	Conference Review	177	1.42
Retracted publication	1	0.1	Book	90	0.72
-	-	-	Editorial	27	0.22
-	-	-	Note	10	0.08
-	-	-	Letter	9	0.07

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-	-	-	Short Survey	9	0.07

Table 3: Distribution of documents types in Scopus and Web of Science

AI began working in the 1940s and the researchers showed strong expectations until the 1970s when they began to encounter serious difficulties and investments were greatly reduced.

Since then a long period began, known as the *"AI winter"* [24]: despite some great successes such as IBM's Deep Blue system, which in the late 1990s defeated the then chess world champion Garri Kasparov, the study of solutions for AI has only come back for a few years. The push for a new technological development has been given by the I4.0, which considered AI as one of the primary Key Enabling Technologies (KET).

From this period onwards, the literature has been enriched with documents as shown in Figure 3. In particular, growth is not so much the moment when researchers started to talk about I4.0 (Hannover Fair, 2011), but two years later, when technologies began to be implemented more frequently.

In fact, this research indicates that over the time period considered (1999 - 2019), the number of published articles remains almost constant until 2013, year from which it undergoes an increase.

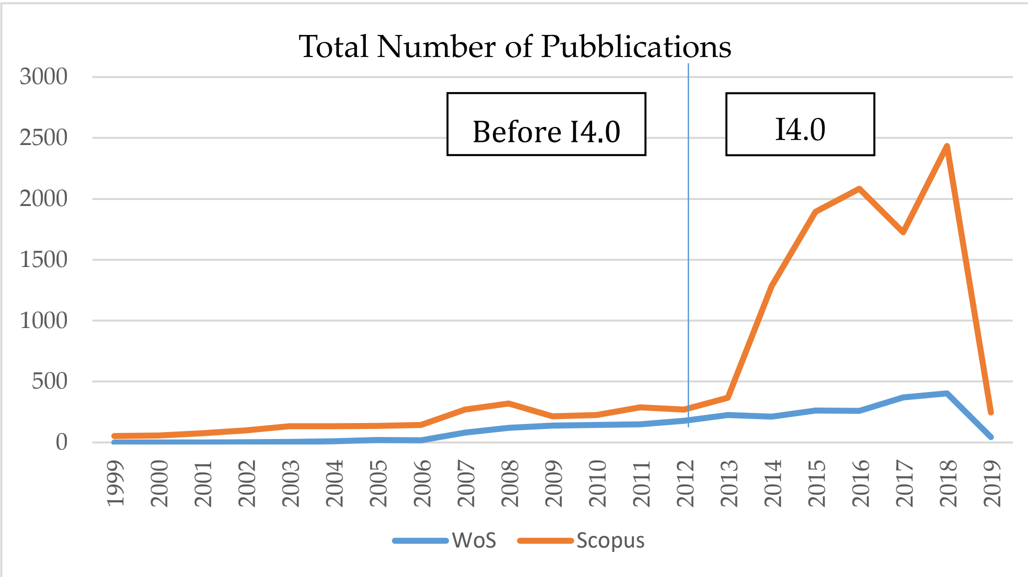

Figure 3: Research growth on Scopus and WoS

Subsequently, the increase in the adoption of these ones has led researchers to keep pace with the growth of I4.0 [25].

4.1.2. Screening (Step#2)

Trying to give an overview of the topics and areas interface, in the screening phase, was chosen to analyze documents characterized by free access, excluding those that have restrictions, and to restrict the field to the thematic areas of scientific interest.

With this in mind, the number of open access items has been drastically reduced (1288 results for Scopus and 149 for Wos) and, also applying the filter related to the thematic areas (Table 4), it determined a further reduction: 947 for Scopus and 60 for WoS.

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Subject area				
Scopus		**Web of Science**		
Computer Science	Chemical Engineering	Computer Science Information Systems	Computer Science Artificial Intelligence	Automation Control Systems
Engineering	Energy	Materials Science Multidisciplinary	Environmental Sciences	Environmental Studies
Materials Science	Decision Science	Engineering Electrical Electronic	Computer Science Hardware Architecture	Operations Research Management Science
Environmental Science	Business Management and accounting	Telecommunications	Industrial Relations Labor	Robotics
		Engineering Environmental	Engineering Manufacturing	Thermodynamics
		Engineering Industrial	Computer Science Theory Methods	Energy Fuels
		Engineering Civil	Engineering Mechanical	Computer Science Cybernetics
		Computer Science Software Engineering	Multidisciplinary Sciences	

Table 4: Subject area filter on Scopus and WoS

Note how the number of filters applied is different. The databases, in fact, offer the same search options but, in the specific case of the thematic areas, the latter are more numerous and structured on WoS compared to Scopus.

4.1.3. Inclusion (Step#3)

At the end of the screening process, the inclusion step was started, that consists in the selection of documents, which was extracted from the last passage, destined to be included in the sample on which to perform bibliometric analysis. In this review step, for the purposes of eligibility, we examined the complete text of each document independently. For each article we examined, in particular, whether there is an interest from the academic world, if it contains case studies or real applications, proposals for new AI and ML algorithms or possible future scenarios.

Therefore, the final sample to be analyzed consists of 60 documents for Scopus and 22 for WoS.

4.2 Phase #2: Analysis

This section presents and discusses the findings of this review.

First, an overview of the selected studies is presented. Second, the review findings according to the research criteria, one by one in the separate subsections, are reported.

4.2.1. Top highly influential analysis

This section lists the most highly cited documents in WoS and Scopus. The list is structured by research source, date, title, authors, source title, top citation (TP) in WoS or Scopus, according to research source. Whole list is available in the appendix. Looking into the appendix it is possible

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underline the document by *Larrañaga et al.* in 2006 has the highest citation count of circa 300. This article reviews machine learning methods for bioinformatics and it presents modelling methods.

Moreover, the document year is 2006, so before I4.0 was introduced. Therefore, having more years than today, it has an advantage in terms of diffusion. This means that it is one of the most influential documents in the academic world, as it proposes some of the most useful techniques for modelling, giving the opportunity to the document to become a pioneer in the "Computer Science" research area.

In general, all documents before I4.0 have a high number of citations, which classifies them at the top of the ranking, along with some of the documents published in the I4.0 period.

The first article that we can identify among the most cited in the I4.0 period dates back to 2016. Again, the document proposes application models to further develop the field of unbalanced learning, to focus on computationally effective, adaptive and real-time methods, and providing a discussion and suggestions on the lines of future research in the application subject of the study.

4.2.2. Publications by years

Consistent with what is defined in paragraph 4.1.1. (Figure 3), the study shows that the number of items included in the analysis is definitely low for the entire period before I4.0 and then suddenly increases starting in 2012. The data shown in Figure 4 also show two holes in the 2001-2008 and 2008-2011 intervals. This means that the technological applications were limited before it became an enabling technology of I4.0 in all respects, only to have a peak of technological implementation, as was foreseeable.

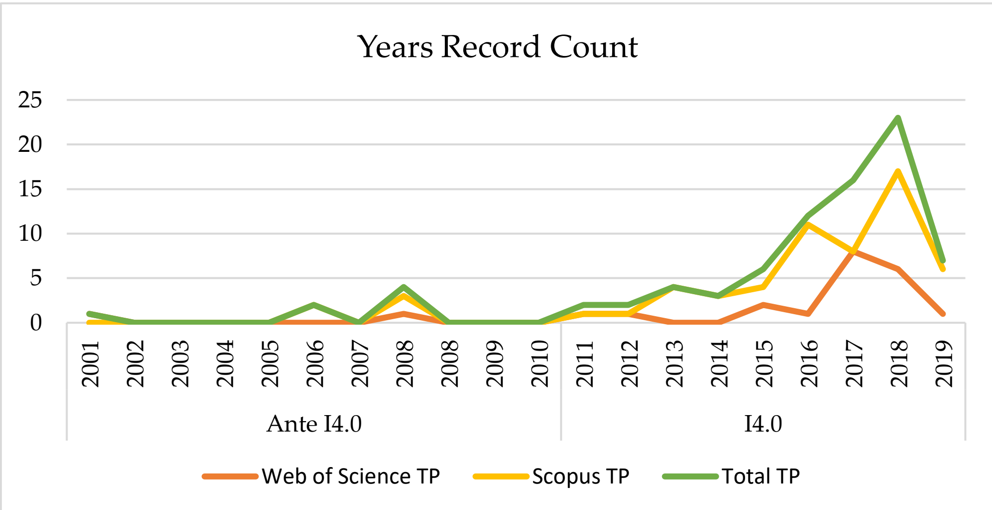

Figure 4: Years Publications

With particular reference to 2019, the figure refers to the first months of the year (the research dates back to February), so it is plausible that during the year there will be a further increase in the

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documents in the literature. Furthermore, an increase is expected in the coming years, in parallel with the growth of I4.0

4.2.3. Most collaborative authors

From the analysis carried out, it can be observed that all the authors are an author or co-author of only one article. However, it is possible to identify the number of authors who collaborated in the creation of each document. As shown in Figure 5, most of the documents were produced by groups ranging from 2 to 5 authors. The documents with more authors are in the order of unity.

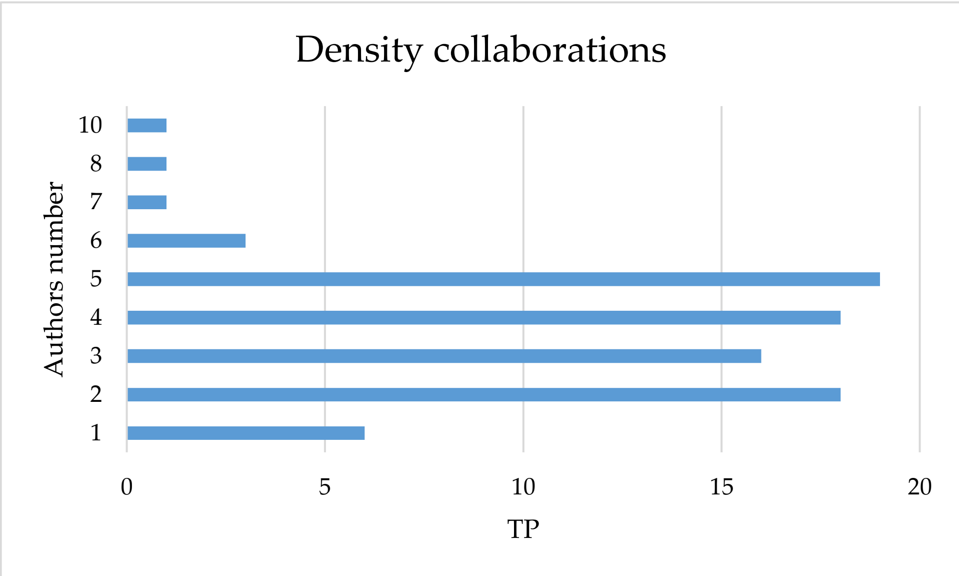

Figure 5 - Collaborative groups

4.2.4. Research areas analysis

Given the small number of documents identified in the period before I4.0, the ranking refers mostly to the current industrial revolution: also in this case, the result is consistent with the introduction of paradigm 4.0 which has intensified research and adoption of technology.

The first thematic areas and disciplines that are at the top of the ranking are Computer Science, Engineering and Biochemistry, Genetics and Molecular Biology, as shown in Figure 6 respectively with 29%, 23% and 6% of publications. Furthermore, the other disciplines identified for which applicative findings are found are to be considered transversal to the first three disciplines and this is a consequence of I4.0.

Shown these numeric data, it is necessary to examine them. The total research area analysis collected from the 82 papers is 164 because each paper can take into account more than one research area analysis. Considering the top 20 research areas, given the frequency of the research areas distribution, Figure 6 shows a higher level of concentration in the disciplines indicated above.

In fact, in terms of percentage contribute, the first five areas cover about 70% of the papers considered. Regardless, counting one time the research areas found, there are 27.

This means two things:

- The large number of fields in which this kind of research is involved;

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- Most papers have a transversal approach, that is, the object of each research crosses more than one field of application involving more research areas.

This confirm the wide interest on these subjects from several fields.

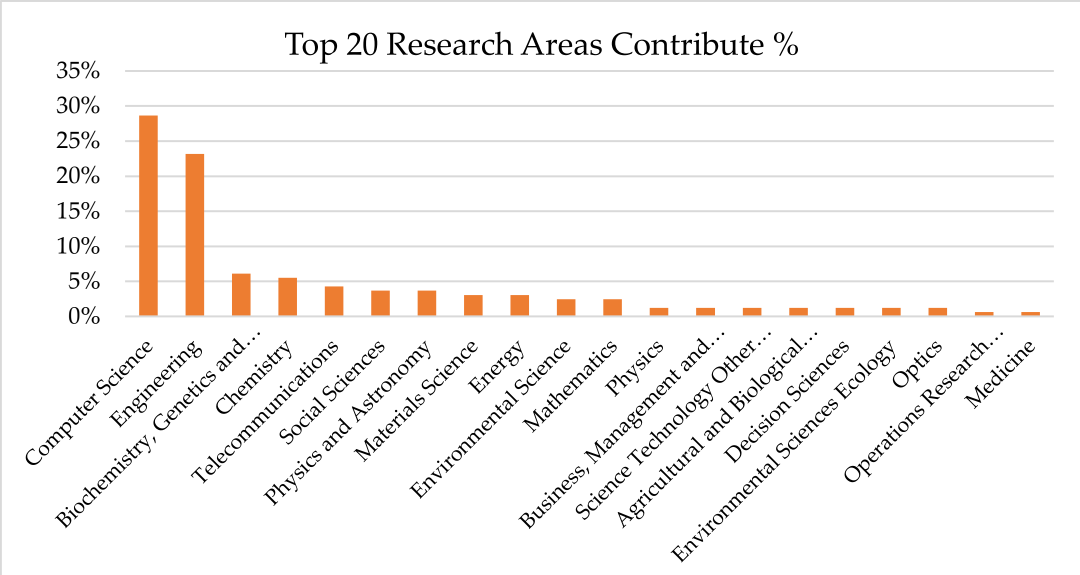

Figure 6: Top 20 Research Areas Contribute

4.2.5. Top source journals analysis

In this section, top 20 sources or journals which were published most frequently are extracted.

A journal is a time bound publication with the objective of promoting and monitoring the progress of the discipline it represents.

In this specific case, the total source journals detected from the document is 74 but, considering the top 20, given the frequency of the source journals distribution only the first 13 sources have more than one paper published with a total percentage contribute of 43% of the total (Figure 6).

Wanting to analyze the sources separately, the results obtained in the two databases are not the same. In WoS the top source journal is IEEE Access with 2 publications, in Scopus the top source journals are Procedia Computer Science, Matec Web Of Conferences and Machine Learning with 4 publications, with contribute of 5% on the total.

Aggregating the data collected from the two databases, the ranking moves to that obtained by Scopus, making sure that IEEE Access is no longer first in the standings, but only 8th, and that the former are precisely those of Scopus: Procedia Computer Science, Matec Web Of Conferences and Machine Learning with the same number of publications. Next, 10 source journals have 3% publication contribute while the rest have a one-to-one relationship (1%) with the corresponding source journal.

The low level of concentration of the sources suggests that there is a great deal of interest on these topics by several scientific journals. As a matter of fact, it is foreseeable that specialized sector sources (*AI Magazine* and *Machine Learning*) are among the first 13, however it is interesting to note that other sources are involved, such as *Sustainability Switzerland* or *BMC Bioinformatics* and *Nuclear Engineering And Design*.

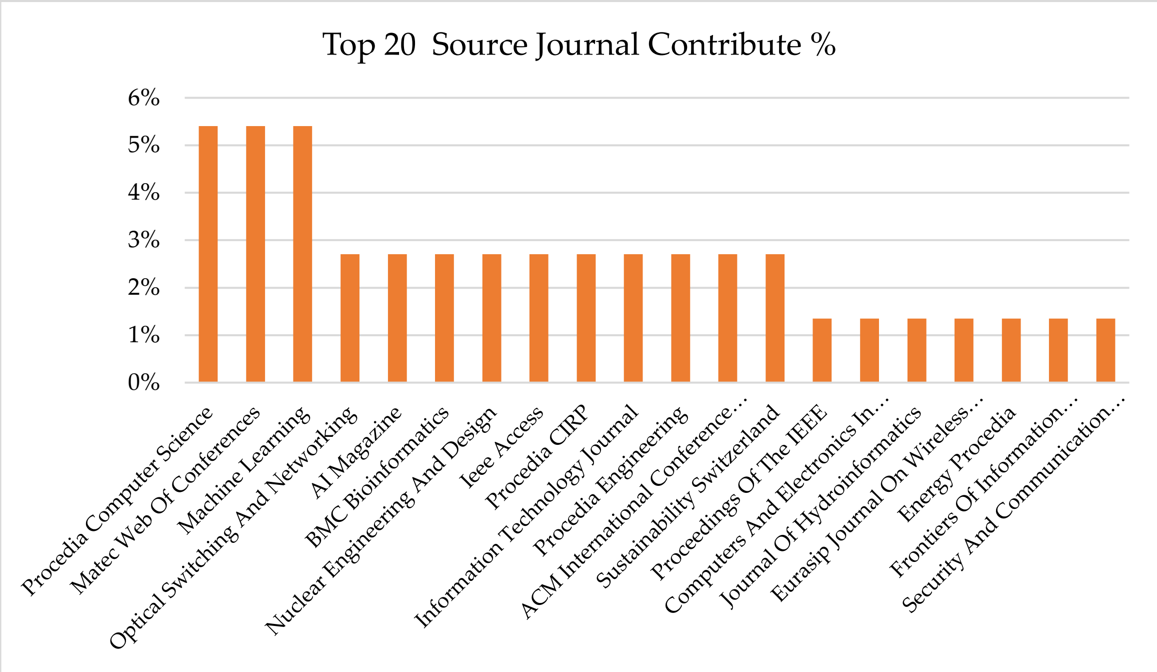

Figure 7: Top 20 Source Journals Contribute

4.2.6. Country analysis

The results emerged through research on the two databases are consistent with each other. In both cases, in fact, the countries that give the greatest contribution to the research are China and the United States.

Focusing on Europe, Germany published more papers than any other European country. This isn't a random result: I4.0 was born in Germany, so this outcome was expected. However, the following observation can't be ignored from this data: USA and China carry the first two places in the list, while it is not the same for European countries. Europe, despite its talents and resources, has lost ground. Presenting his report on artificial intelligence, the French deputy and mathematician Cédric Villani declared that "Europe must be able to compete with China and the United States while protecting its citizens and pointing the way to go on ethical issues". If we are not careful, the twenty-first century rules will not be defined in Brussels, but in Shanghai. Artificial Intelligence is also a land marked by intense geopolitical rivalry that could redefine global power relations.

Below, Figure 8 and Figure 9 show country contribution distribution.

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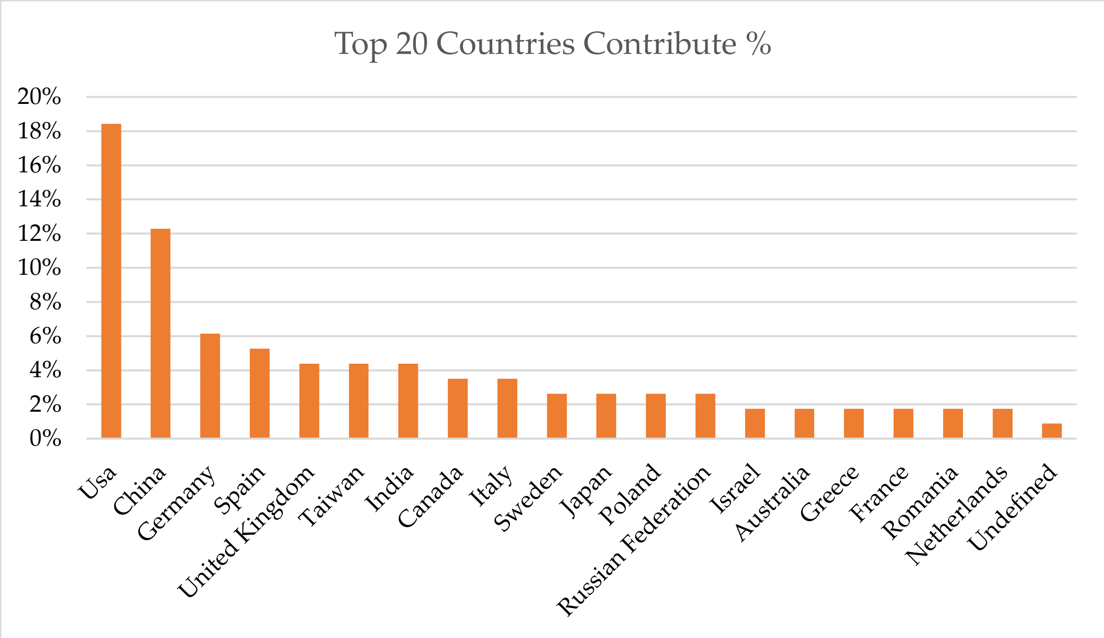

Figure 8: Top 20 Countries Contribute

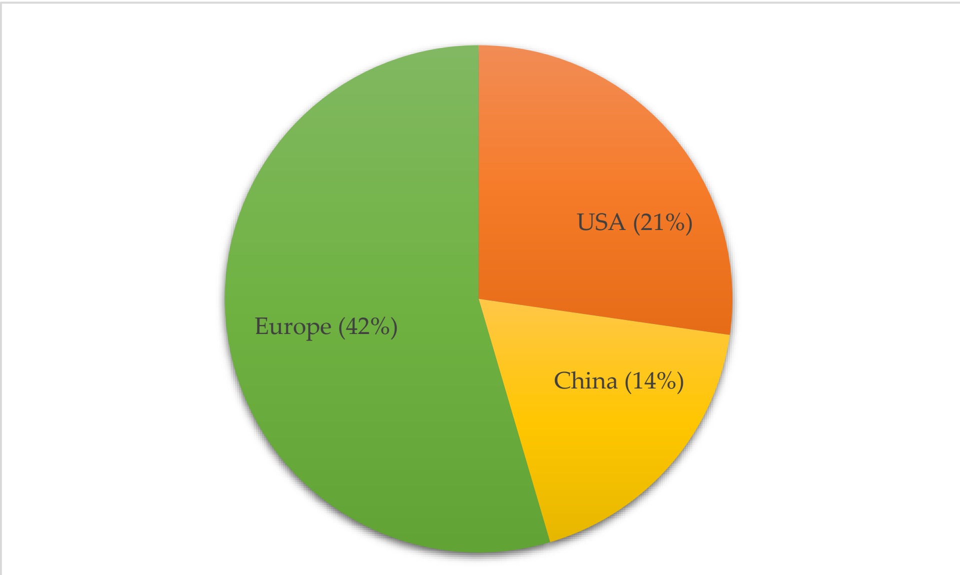

Figure 9: Focus on Europe Contribute

4.2.7. Affiliation analysis

The total affiliation detected from the 82 papers is 153. Also, in this case, considering the top 20, the frequency of the affiliation distribution shows that most papers have a relationship one to one with the corresponding affiliation. Only the first four affiliations have three papers (2% of contribute) and the second four have two papers (1,3% of contribute). This result gives us information about the wide interest on this subject from several Universities and Research Centers all over the world. Then, the affiliation analysis confirms the result of country analysis (Figure 10). In fact, if we try to sum the first eight affiliation by their own country the outcome is:

- 9 papers from China
- 6 papers from Germany;

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- 5 papers from USA.

In September 2018, the most important event on artificial intelligence was held in Shanghai. China is very determined to focus on future technologies. For some months China has become the world's leading power in terms of scientific publications. Late in the twentieth century technologies, China chose to do what the English-speaking people call a "frog jump", and focus on 21st century technologies. China, with its 800 million Internet users and without any privacy protection policy, has access to more personal data than the United States and Europe.

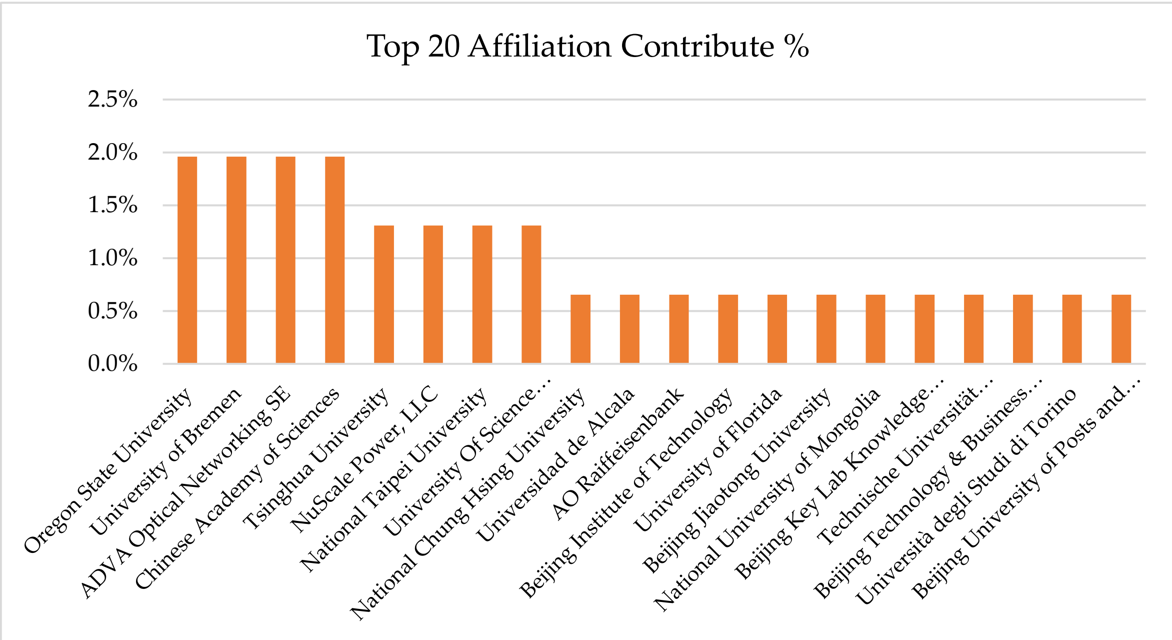

Figure 10: Top 20 Institute Affiliation Contribute

4.2.8. Top most keywords analysis

Almost all keywords are common in WoS and Scopus extracted documents that used one or more keywords. To analyze the most popular keywords, two different software were used: NVivo 12 and Ucinet.

Through NVivo 12, the top 20 keywords were extracted directly, which are those that always appear in association with each document.

Starting from this classification, the graphic representation, a word cloud shape, of the keywords (Figure 11) was extracted. It can be noted that the most used term is precisely "Machine", "Learning" and "Intelligence" that the software represents with greater characters than all the other terms.

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Figure 11: Top 20 Keywords Cloud Contribute by NVivo 12

In essence, the font size describes how much the keyword is indexed. Another mode of representation is the tree words (Figure 12). Also, in this case, the most indexed words are those represented in the larger boxes.

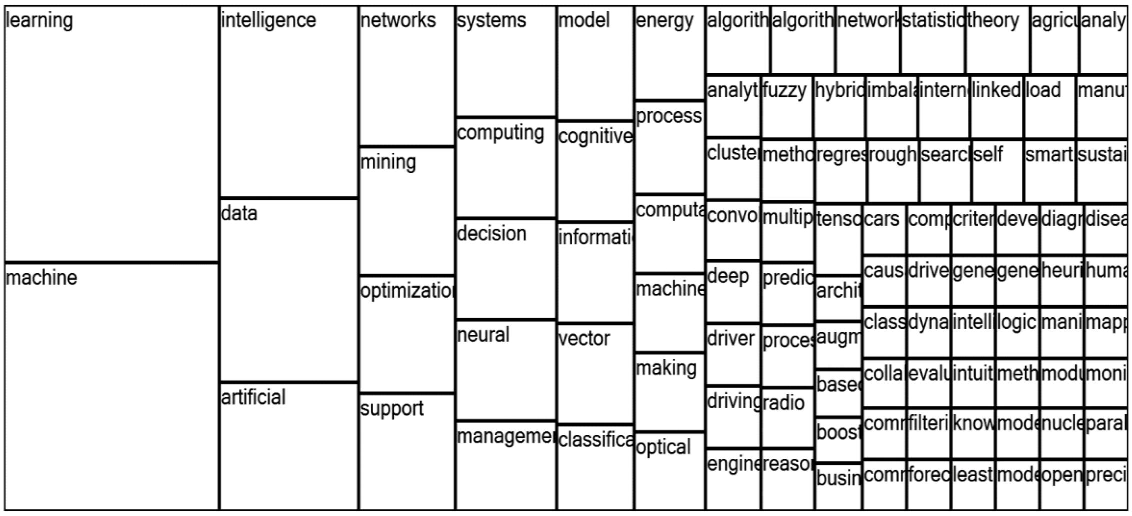

Figure 12: Top 20 Keywords Tree Contribute by Nvivo 12

As expected, the most indexed words are obviously "learning", "machine" and "intelligence" with high numbers. It is logical to have obtained among the first results words that recall the technology itself but it is interesting to note that words referring to other fields of the AI applications are also indexed. The reason is to be found in the fact that AI and ML are technologies that cross all the sectors involved in I4.0 and that, therefore, don't remain circumscribed.

Specifically, words such as "data", "neural", "decision" and "management" are very or average indexed, demonstrating the fact that AI also extends to many other sectors.

Another tool for analysis for keywords is the UCINET software, through which a Social Networks Analysis is carried out.

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Social Network Analysis (SNA), often also called "social network theory", is a modern technology of social relations. The SNA finds application in various social sciences, recently used in the study of various phenomena such as international trade, information dissemination, the study of institutions and the functioning of organizations.

The analysis of the use of the term SNA in scientific literature shows, in the last five years, an exponential growth of the use of this mode of computable representation of complex and interdependent phenomena.

The software returns a graph representing a socio-metric network (Figure 13), which draws the relationships that exist within the class. Each relationship is represented by an oriented arrow.

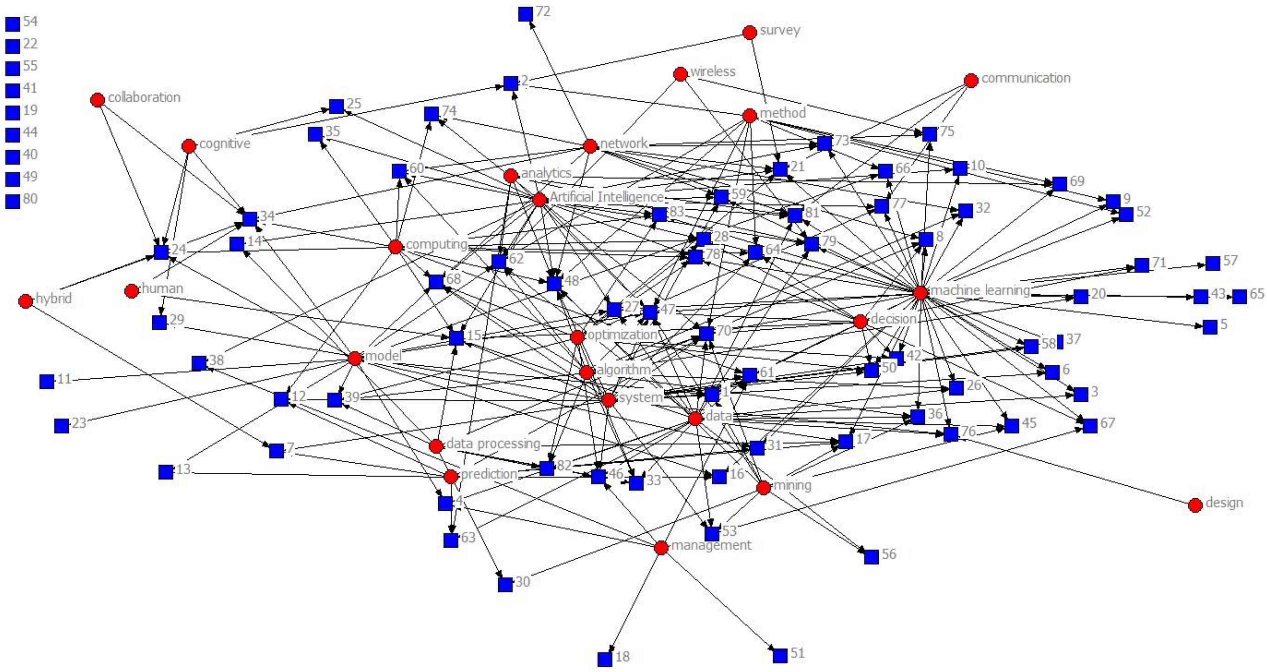

Figure 13: Keywords Network by UCINET

In the graph shown in Figure 13, nodes and leaves can be identified. The nodes are represented by red circles and correspond to the most common keywords, where the words "machine", "learning", "artificial" and "intelligence" have been united to form the key words "machine learning" and "artificial intelligence".

The leaves, on the other hand, are represented by blue squares and correspond to the articles. To facilitate reading, the document titles have not been inserted, but the ID count for each of them is shown in Table 5.

The first thing that can be noticed is the isolation of many leaves that are not connected to the nodes. This means that the corresponding documents are not described by the keywords represented by the nodes. Really, they are characterized by keywords that have a frequency of the order of units.

Another thing that easily jumps to the eye is a density that is larger around the keywords “machine learning”, “decision”, “data”, “algorithm”, “system”, “artificial intelligence”, “method” and “optimization”. This density is reflected in the cloud and the box chart produced by NVivo 12 (Figure 11 and Figure 12). Therefore, we can say that those are the words that most appear in the

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documents analyzed, emphasizing, once again, that they include terms that do not just refer to the technology object of study, but also other fields of application.

5. Discussion

From the analysis of the research carried out, the first information emerged is that the interest in the subject is extended to all scientific sectors, with a particularly wide impact. The direct consequence could be that of having new generations of researchers who will contribute to future comparisons, accompanied by new questions for investigations.

Other information emerged is about the authors and the affiliation. Many of these are in a 1:1 ratio compared to the selected documents and this supports the fact that there is no interest in technological applications in one direction, but that, once again, the interest is very wide in the scientific community. Furthermore, it can be said that the countries most interested in scientific research are USA, China and European countries. It is important to underline that this document was produced using only two databases, i.e. WoS and Scopus, in which only documents with open access were included.

6. Conclusions

This research focused on the study of the state of the art of AI and ML applications, selecting literature on what has now become a particularly hot topic in scientific research. The literature available on any subject is now wide and a complete coverage of all the documents published with respect to a particular topic can be challenging or even impossible. Therefore, a systematic selection of the most relevant literature was implemented. This document provides a systematic review of applications in various scientific fields using ML techniques. For the selection of documents, objective and clear methods of investigation were used, independent of the experience of the researchers. Among the objectives of the document is not only the desire to provide a comprehensive framework on the literature on the research of AI and ML but also a starting point for integrating knowledge through research in this area and suggest future research paths. There are, therefore, many other documents with restricted access and other indexing databases, such as Google Scholar, that could be integrated into research in the near future.

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Appendix

ID count	Research Source	ID doc	Year	Title	Authors	Source Title	TC
1	SCP	2	2006	Machine learning in bioinformatics	Larrañaga, P.; Calvo, B.; Santana, R.; Bielza, C.; Galdiano, J.; Inza, I.; Lozano, J.A.; Armañanzas, R.; Santafé, G.; Pérez, A.; Robles, V.	Briefings in Bioinformatics	298
2	WoS	62	2008	Data-driven modelling: some past experiences and new approaches	Solomatine, Dimitri P.; Ostfeld, Avi	Journal Of Hydroinformatics	160
3	SCP	26	2016	Learning from imbalanced data: open challenges and future directions	Krawczyk, B.	Progress in Artificial Intelligence	119
4	WoS	63	2001	Computer go: An AI oriented survey	Bouzy, B; Cazenave, T	Artificial Intelligence	114
5	SCP	6	2008	Structured machine learning: the next ten years	Dietterich, T.G., Domingos, P., Getoor, L., Muggleton, S., Tadepalli, P.	Machine Learning	75
6	SCP	28	2016	Machine learning in manufacturing: Advantages, challenges, and applications	Wuest, T., Weimer, D., Irgens, C., Thoben, K.-D.	Production and Manufacturing Research	52
7	WoS	64	2017	MACHINE LEARNING PARADIGMS FOR NEXT-GENERATION WIRELESS NETWORKS	Jiang, Chunxiao; Zhang, Haijun; Ren, Yong; Han, Zhu; Chen, Kwang-Cheng; Hanzo, Lajos	Ieee Wireless Communications	50
8	SCP	3	2006	Machine learning techniques in disease forecasting: A case study on rice blast prediction	Kaundal, R.; Kapoor, A.A.; Raghava, G.P.S.	BMC Bioinformatics	48
9	SCP	4	2008	A comparison of machine learning algorithms for chemical toxicity classification using a simulated multi-scale data model	Judson, R., Elloumi, F., Woodrow, R.W., Li, Z., Shah, I.	BMC Bioinformatics	45
10	SCP	19	2015	A review of intelligent driving style analysis systems and related artificial intelligence algorithms	Meiring, G.A.M., Myburgh, H.C.	Sensors (Switzerland)	33
11	SCP	21	2016	A machine learning framework for gait classification using inertial sensors: Application to elderly, post-stroke and huntington's disease patients	Mannini, A., Trojaniello, D., Cereatti, A., Sabatini, A.M.	Sensors (Switzerland)	31
12	SCP	1	2006	Application of machine learning in SNP discovery	Matukumalli, L.K.; Grefenstette, J.J.; Hyten, D.L.; Choi, I.-Y.; Cregan, P.B.; Van Tassell, C.P.		30
13	SCP	10	2013	Beam search algorithms for multilabel learning	Kumar, A., Vembu, S., Menon, A.K., Elkan, C.	Machine Learning	29
14	WoS	65	2011	Recommender Systems: An Overview	Burke, Robin; Felfernig, Alexander; Goeker, Mehmet H.	Ai Magazine	29
15	SCP	11	2013	Biomedical informatics for computer-aided decision support systems: A survey	Belle, A., Kon, M.A., Najarian, K.	The Scientific World Journal	27
16	SCP	23	2016	Application of machine learning to construction injury prediction	Tixier, A.J.-P., Hallowell, M.R., Rajagopalan, B., Bowman, D.	Automation in Construction	21
17	SCP	12	2013	Quality prediction in interlinked manufacturing processes based on supervised & unsupervised machine learning	Lieber, D., Stolpe, M., Konrad, B., Deuse, J., Morik, K.	Procedia CIRP	18
18	SCP	29	2016	Semantic framework of internet of things for smart cities: Case studies	Zhang, N., Chen, H., Chen, X., Chen, J.	Sensors (Switzerland)	17
19	SCP	20	2015	Support vector machines in structural engineering: A review	Çevik, A., KURTOĞLU, A.E., Bilgehan, M., Gülşan, M.E., Albegmprli, H.M.	Journal of Civil Engineering and Management	15
20	SCP	25	2016	A review of classification problems and algorithms in renewable energy applications	Pérez-Ortiz, M., Jiménez-Fernández, S., Gutiérrez, P.A., (...), Hervás-Martínez, C., Salcedo-Sanz, S.	Energies	15
21	SCP	43	2018	Artificial intelligence (AI) methods in optical networks: A comprehensive survey	Mata, J., de Miguel, I., Durán, R.J., (...), Jukan, A., Chamania, M.	Optical Switching and Networking	15
22	SCP	14	2014	Fault diagnosis of automobile gearbox based on machine learning techniques	Praveenkumar, T., Saimurugan, M., Krishnakumar, P., Ramachandran, K.I.	Procedia Engineering	14

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23	SCP	16	2014	Improving active Mealy machine learning for protocol conformance testing	Aarts, F., Kuppens, H., Tretmans, J., Vaandrager, F., Verwer, S.	Machine Learning	11
24	WoS	66	2016	Strategies and Principles of Distributed Machine Learning on Big Data	Xing, Eric P.; Ho, Qirong; Xie, Pengtao; Wei, Dai	Engineering	11
25	WoS	67	2015	Recent advances on artificial intelligence and learning techniques in cognitive radio networks	Abbas, Nadine; Nasser, Youssef; El Ahmad, Karim	Eurasip Journal On Wireless Communications And Networking	11
26	WoS	68	2018	Artificial intelligence (AI) methods in optical networks: A comprehensive survey	Mata, Javier; de Miguel, Ignacio; Duran, Ramon J.; Merayo, Noemi; Singh, Sandeep Kumar; Jukan, Admela; Chamania, Mohit	Optical Switching And Networking	9
27	SCP	40	2018	Advances in multiple criteria decision making for sustainability: Modeling and applications	Shen, K.-Y., Tzeng, G.-H.	Sustainability (Switzerland)	8
28	WoS	69	2017	Research and Application of a Novel Hybrid Model Based on Data Selection and Artificial Intelligence Algorithm for Short Term Load Forecasting	Yang, Wendong; Wang, Jianzhou; Wang, Rui	Entropy	8
29	SCP	33	2017	Context Aware Process Mining in Logistics	Becker, T., Intoyoad, W.	Procedia CIRP	7
30	SCP	24	2016	Applications of machine learning methods to identifying and predicting building retrofit opportunities	Marasco, D.E., Kontokosta, C.E.	Energy and Buildings	6
31	SCP	37	2017	Operational Demand Forecasting in District Heating Systems Using Ensembles of Online Machine Learning Algorithms	Johansson, C., Bergkvist, M., Geysen, D., (...), Lavesson, N., Vanhoudt, D.	Energy Procedia	6
32	WoS	70	2018	Advances in Multiple Criteria Decision Making for Sustainability: Modeling and Applications	Shen, Kao-Yi; Tzeng, Gwo-Hshiung	Sustainability	6
33	WoS	71	2017	Hybrid-augmented intelligence: collaboration and cognition	Zheng, Nan-ning; Liu, Zi-yi; Ren, Peng-ju; Ma, Yong-qiang; Chen, Shi-tao; Yu, Si-yu; Xue, Jian-ru; Chen, Ba-dong; Wang, Fei-yue	Frontiers Of Information Technology & Electronic Engineering	6
34	SCP	5	2008	Performance evaluation of the NVIDIA GeForce 8800 GTX GPU for machine learning	El Zein, A., McCreath, E., Rendell, A., Smola, A.	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 5101 LNCS(PART 1), pp. 466-475	5
35	SCP	7	2011	A review of artificial intelligence algorith ms in document classification	Bilski, A.	International Journal of Electronics and Telecommunications	5
36	SCP	18	2015	An architecture for agile machine learning in real-time applications	Schleier-Smith, J.	Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining	4
37	SCP	52	2018	Machine learning in agriculture: A review	Liakos, K.G., Busato, P., Moshou, D., Pearson, S., Bochtis, D.	Sensors (Switzerland)	4
38	SCP	22	2016	Application of Information Processes Applicative Modelling to Virtual Machines Auto Configuration	Zykov, S., Shumsky, L.	Procedia Computer Science	3
39	SCP	34	2017	Geometry-aware principal component analysis for symmetric positive definite matrices	Horev, I., Yger, F., Sugiyama, M.	Machine Learning	3
40	SCP	17	2015	A Fuzzy Least Squares Support Tensor Machines in Machine Learning	Zhang, R., Zhou, Z.	International Journal of Emerging Technologies in Learning	2
41	SCP	36	2017	Nuclear energy system's behavior and decision making using machine learning	Gomez Fernandez, M., Tokuhiro, A., Welter, K., Wu, Q.	Nuclear Engineering and Design	2
42	SCP	9	2013	Application study of machine learning in li ghtning forecasting	Qiu, T., Zhang, S., Zhou, H., Bai, X., Liu, P.	Information Technology Journal	1

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43	SCP	30	2016	WOWMON: A machine learning-based profiler for self-adaptive instrumentation of scientific workflows	Zhang, X., Abbasi, H., Huck, K., Malony, A.D.	Procedia Computer Science	1
44	SCP	31	2017	An event search platform using machine learning	Rodrigues, M.A., Silva, R.R., Bernardino, J.	Proceedings of the International Conference on Software Engineering and Knowledge Engineering, SEKE	1
45	SCP	32	2017	Automated business process management- in times of digital transformation using machine learning or artificial intelligence	Paschek, D., Luminosu, C.T., Draghici, A.	MATEC Web of Conferences	1
46	SCP	42	2018	Application of machine learning methods in big data analytics at management of contracts in the construction industry	Valpeters, M., Kireev, I., Ivanov, N.	MATEC Web of Conferences	1
47	SCP	48	2018	Data mining and machine learning in textile industry	Yildirim, P., Birant, D., Alpyildiz, T.	Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery	1
48	WoS	72	2018	Big Data Analytics, Machine Learning, and Artificial Intelligence in Next-Generation Wireless Networks	Kibria, Mirza Golam; Kien Nguyen; Villardi, Gabriel Porto; Zhao, Ou; Ishizu, Kentaro; Kojima, Fumihide	Ieee Access	1
49	WoS	73	2017	Quantum neuromorphic hardware for quantum artificial intelligence	Prati, Enrico	8Th International Workshop Dice2016: Spacetime - Matter - Quantum Mechanics	1
50	WoS	74	2015	Exploiting Computational intelligence Paradigms in e- Technologies and Activities	Said, Hanaa M.; Salem, Abdel-Badeeh M.	International Conference On Communications, Management, And Information Technology (Iccmit'2015)	1
51	WoS	75	2012	Sentiment Analysis of Products Using Web	Unnamalai, K.	International Conference On Modelling Optimization And Computing	1
52	SCP	8	2012	Taxonomy development and its impact on a self-learning e-recruitment system	Faliagka, E., Karydis, I., Rigou, M., (...), Tsakalidis, A., Tzimas, G.	IFIP Advances in Information and Communication Technology	0
53	SCP	13	2013	Research on adaptive multi-filtering model of network sensitive information	Cao, X.-F., Kang, W., Shi, Q., Shi, F.-F.	Information Technology Journal	0
54	SCP	15	2014	Grade: Machine-learning support for graduate admissions	Waters, A., Miikkulainen, R.	AI Magazine	0
55	SCP	27	2016	Leveraging linked open data information extraction for data mining applications	Mahule, R., Vyas, O.P.	Turkish Journal of Electrical Engineering and Computer Sciences	0
56	SCP	38	2017	Rapid prototyping IoT solutions based on Machine Learning	Rizzo, A., Montefoschi, F., Caporali, M., (...), Burresi, G., Giorgi, R.	ACM International Conference Proceeding Series	0
57	SCP	39	2017	Towards automatic learning of heuristics for mechanical transformations of procedural code	Vigueras, G., Carro, M., Tamarit, S., Mariño, J.	Electronic Proceedings in Theoretical Computer Science, EPTCS	0
58	SCP	41	2018	Application of artificial intelligence principles in mechanical engineering	Zajačko, I., Gál, T., Ságová, Z., Mateichyk, V., Wiecek, D.	MATEC Web of Conferences	0
59	SCP	44	2018	Artificial Intelligence in Medical Applications	Chan, Y.-K., Chen, Y.-F., Pham, T., Chang, W., Hsieh, M.-Y.	Journal of Healthcare Engineering	0
60	SCP	45	2018	A semantic internet of things framework using machine learning approach based on cloud computing	Ding, P.-W., Hsu, I.-C.	ACM International Conference Proceeding Series	0
61	SCP	46	2018	A Survey on Machine Learning-Based Mobile Big Data Analysis: Challenges and Applications	Xie, J., Song, Z., Li, Y., (...), Zhang, J., Guo, J.	Wireless Communications and Mobile Computing	0

62	SCP	47	2018	Big Data and Machine Learning Based Secure Healthcare Framework	Kaur, P., Sharma, M., Mittal, M.	Procedia Computer Science	0
63	SCP	49	2018	Discovering discontinuity in big financial transaction data	Tuarob, S., Strong, R., Chandra, A., Tucker, C.S.	ACM Transactions on Management Information Systems	0
64	SCP	50	2018	Introducing children to machine learning concepts through hands-on experience	Hitron, T., Erel, H., Wald, I., Zuckerman, O.	IDC 2018 - Proceedings of the 2018 ACM Conference on Interaction Design and Children	0
65	SCP	51	2018	Machine learning for software engineering: Models, methods, and applications	Meinke, K., Bennaceur, A.	Proceedings - International Conference on Software Engineering	0
66	SCP	53	2018	Machine Learning in IT Service Management	Zuev, D., Kalistratov, A., Zuev, A.	Procedia Computer Science	0
67	SCP	54	2018	Research and application of computer control system based on complex neural network	Yang, R.	MATEC Web of Conferences	0
68	SCP	55	2018	Text classification techniques: A literature review	Thangaraj, M., Sivakami, M.	Interdisciplinary Journal of Information, Knowledge, and Management	0
69	SCP	56	2019	A Machine Learning Method for Predicting Driving Range of Battery Electric Vehicles	Sun, S., Zhang, J., Bi, J., Wang, Y., Moghaddam, M.H.Y.	Journal of Advanced Transportation	0
70	SCP	57	2019	An empirical comparison of machine-learning methods on bank client credit assessments	Munkhdalai, L., Munkhdalai, T., Namsrai, O.-E., Lee, J.Y., Ryu, K.H.	Sustainability (Switzerland)	0
71	SCP	58	2019	Comparison of multiple linear regression, artificial neural network, extreme learning machine, and support vector machine in deriving operation rule of hydropower reservoir	Niu, W.-J., Feng, Z.-K., Feng, B.-F., (...), Cheng, C.-T., Zhou, J.-Z.	Water (Switzerland)	0
72	SCP	59	2019	Development and evaluation of a low-cost and smart technology for precision weed management utilizing artificial intelligence	Partel, V., Charan Kakarla, S., Ampatzidis, Y.	Computers and Electronics in Agriculture	0
73	SCP	60	2019	Identifying known and unknown mobile application traffic using a multilevel classifier	Zhao, S., Chen, S., Sun, Y., (...), Su, J., Su, C.	Security and Communication Networks	0
74	SCP	61	2019	Optimized Clustering Algorithms for Large Wireless Sensor Networks: A Review	Wohwe Sambo, D., Yenke, B.O., Förster, A., Dayang, P.	Sensors (Basel, Switzerland)	0
75	WoS	76	2019	FPGA-Based Accelerators of Deep Learning Networks for Learning and Classification: A Review	Shawahna, Ahmad; Sait, Sadiq M.; El-Maleh, Aiman	Ieee Access	0
76	WoS	77	2018	A quantum machine learning algorithm based on generative models	Gao, X.; Zhang, Z. -Y.; Duan, L. -M.	Science Advances	0
77	WoS	78	2018	Machine Learning for Network Automation: Overview, Architecture, and Applications	Rafique, Danish; Velasco, Luis	Journal Of Optical Communications And Networking	0
78	WoS	79	2018	A wireless sensor data-based coal mine gas monitoring algorithm with least squares support vector machines optimized by swarm intelligence techniques	Chen, Peng; Xie, Yonghong; Jin, Pei; Zhang, Dezheng	International Journal Of Distributed Sensor Networks	0
79	WoS	80	2017	Nuclear energy system's behavior and decision making using machine learning	Fernandez, Mario Gomez; Tokuhiro, Akira; Welter, Kent; Wu, Qiao	Nuclear Engineering And Design	0
80	WoS	81	2017	Automated business process management - in times of digital transformation using machine learning or artificial intelligence	Paschek, Daniel; Luminosu, Caius Tudor; Draghici, Anca	8Th International Conference On Manufacturing Science And Education (Mse 2017) - Trends In New Industrial Revolution	0
81	WoS	82	2017	The Evaluation of Resonance Frequency for Piezoelectric Transducers by Machine Learning Methods	Chang, F. Michael	27Th International Conference On Flexible Automation And Intelligent Manufacturing, Faim2017	0

82	WoS	83	2017	From Extraction to Generation of Design Information Paradigm Shift in Data Mining via Evolutionary Learning Classifier System	Chiba, Kazuhisa; Nakata, Masaya	International Conference On Computational Science (Iccs 2017)	0