Technological advances in irrigation from the perspective of artificial intelligence

Avanços tecnológicos na irrigação sob a perspectiva da inteligência artificial

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ABSTRACT
The purpose of this study was to conduct an analysis of technological advancements and current irrigation situation in agriculture from the perspective of artificial intelligence. The Scopus platform's database was initially used to find scientific articles published in recent decades that highlight the use of artificial intelligence techniques regarding irrigation in agriculture. From the 807 publications returned by the search process a sample of 19 publications that underwent systematic analysis were chosen statistically. The areas of Artificial Intelligence were classified: Expert Systems (30.70%), Optimization (30.70%), Machine Learning (10.30%), Evolutionary Computing (10.30%), Robotics and Remote Sensing (10.20%), with Automation, IoT and Natural Language Processing with 2.6%, respectively. Considering the conditions under which the study was conducted the analysis reveals that in the last 10 years (2012 to 2022) account for about 70% of categories assigned to research that is conducted inside AI areas and aims to create data that can be utilized to support practical decisions about the use of water.

Keywords: irrigation, artificial intelligence, systems, exploratory, research, technology.

RESUMO
O presente estudo teve como objetivo realizar uma análise sobre os avanços tecnológicos e a situação atual da irrigação na agricultura, a partir de artigos científicos, sob a perspectiva da Inteligência Artificial. Foi utilizado a base de dados da plataforma Scopus para localização de artigos científicos, publicados nas últimas décadas, que evidenciam o emprego de técnicas de Inteligência Artificial em relação à irrigação na agricultura. O processo de busca retornou 807 publicações na forma de artigos científicos, do qual selecionou-se, estatisticamente, uma amostra de 19 publicações que passaram por uma análise. As áreas da Inteligência Artificial classificadas foram: Sistemas Especialistas (30,70%), Otimização (30,70%), Aprendizado de Máquinas (10,30%), Computação
Evolutiva (10,30%), Robótica e Sensoriamento Remoto (10,20%), sendo Automação, IoT e Processamento de Linguagem Natural com 2,6%, respectivamente. Considerando as condições que o estudo foi realizado destaca-se que a última década (2012 a 2022) contempla cerca de 70% das classificações atribuídas as pesquisas abrangidas dentro das áreas da IA e, visam gerar informações que remontam a decisões racionais referente ao uso da água.

**Palavras-chave:** irrigação, inteligência artificial, sistemas, pesquisa exploratória, tecnologia.

1 INTRODUCTION

Since water resources are continuously declining around the world, efficient water use is a major concern for all nations (ÜNAL, 2021). According to Menezes et al. (2015), irrigation has been used to supplement or replace natural rainfall in order to meet its needs to improve crop yields, and address water scarcity. Furthermore, shortage occurs as a result of some farmers continuing to use traditional agricultural techniques, which results in lower crop yields and productivity, as well as inappropriate water use.

However, Muangprathub et al. (2019) and Zaro (2018) explain that hydric deficiency is also related to soil degradation, which can be remedied by introducing an automated irrigation system, in which water is only available if it is required due to soil humidity.

As a result, Sudarshan et al. (2019) mention that the use of intelligent agriculture became necessary since resources are scarce and the production areas frequently need assistance in order to obtain data on how to manage their operations effectively without raising production costs.

According to Sudarshan et al. (2019) and Unal (2021), farmers spend some of their time monitoring and evaluating their production in an effort to make it smarter. They gather and analyze a larger volume of data, which encourages the producer to seek the advice of experts and new technologies to help them interpret the collected data more effectively and aid in decision-making. According to Varghese and Sharma (2018) and Únal (2021), many of these technologies use systems with advanced methodologies to
automate the monitoring of cultures that call for a minimum amount of human intervention.

As stated by Mendes et al. (2019), decisions for managing irrigation should also take into account related economic, physical, and biological variables that are frequently difficult to predict and over which there is little to no control. Additionally, the authors explain that this causes owners to search for automated solutions to make water use more efficient, which leads to the introduction of various agricultural alternatives to carry out water distribution with spatial accuracy. Navarro-Hélîn et al. (2016) emphasize that systems that assist in decision-making for irrigation and water conservation are heavily used to minimize water application and maximize productivity.

In this regard, Fawzi and Jalal (2017) argue that an intelligent irrigation system is one that supplies water to plants, when necessary, in the proper quantities at the appropriate times and locations. According to Rodriguez-Ortega et al. (2017), compared to conventional irrigation systems that operate on the principle of irrigation based on a timer, which supplies water to plants randomly without any feedback, intelligent irrigation is required to increase productivity and improve the quality of the plants.

In support of this, Wolfert et al. (2017) note that traditional irrigation systems are often designed based on assumptions made by farmers, and those assumptions are frequently away from the actual and optimum conditions for irrigation. Additionally, the authors mention that the intelligent irrigation relies on reliable readings to determine the appropriate timing and amount of water to be used for the irrigation of de crops.

In order to achieve a higher yield, Allani et al. (2012), Bai et al. (2012), and Liang et al. (2012) reinforce the idea that an automatic irrigation system may be extremely important since it can apply the necessary amount of water according to the method. As a result, using systems to aid in decision-making during irrigation is crucial to assisting producers in finding solutions to partially or completely unstructured problems (ÜNAL, 2021).

In this context, irrigation in agriculture is a topic that is frequently discussed in literature. Systems of irrigation and support for decision-making are currently being developed and improved with the aim of optimizing the use of water and, as a result,
enabling the sustainability of the production system. Therefore, the purpose of the current study is to conduct an analysis of technological advancements and the current state of irrigation in agriculture from the perspective of Artificial Intelligence (AI).

2 METHODOLOGY

According to Piovesan and Temporini (1995), the study is an exploratory research project that focuses on familiarizing the researcher with the topic under study so that they can become more intimately acquainted with its context and gather data to generate hypotheses. This makes the methodology relevant to the study because it is impractical to conduct a study involving thousands of related scientific articles.

As a result, a bibliographic search was conducted using Scopus' database, which included international scientific papers published in specialized journals. Irrigation, agriculture, and artificial intelligence-related search terms were used in the paper's title, abstract, and keywords. Additionally, only English-language "conference paper" and "article" kinds were examined and the searches were conducted between the months of February and March of 2022.

In order to assign meaning to the key words used in the research, the search for AI areas and subareas was based on the proposal made by Russell and Norvig (2013), specifically: Machine learning, neural network, machine learning, deep learning, image processing, automation, wireless sensor network, zig-bee, control system, computer vision, computational vision, machine vision, image processing, image segmentation, object detection, ICT, computers, software, information technology, natural language processing, NLP, speech recognition, text retrieval, expert system, decision support, smart system, knowledge-based system, remote sensing, unmanned aerial systems, unmanned aerial vehicles, drone and artificial intelligence, fuzzy logic, fuzzy set, fuzzy, fuzzy inference system, fussy control, fuzzy expert, internet of things, ubiquitous computing, embedded intelligence, cloud of things, big data, bigdata, evolutionary computation, genetic algorithm, evolutionary optimization, swarm Intelligence and artificial intelligence.
The identified articles composed a database that was the focus of the investigation. The number of papers in the sample was determined using Equation (1) to reflect the population.

\[ n = \frac{Z_{\frac{\alpha}{2}}^2 \cdot p \cdot q}{E^2} \]  

(1)

Where:

- \( n \) is the sample size; \( Z_{\frac{\alpha}{2}}^2 \) is the critical value related to the degree of confidence, \( p \) is the population proportion of individuals belonging to the category being studied, \( q \) is the population proportion of individuals not belonging to the studied category (\( q = 1 - p \)), and \( E \) is the fixed error margin.

In situations like these, when the population level parameters \( p \) and \( q \) are unknown and the correct size of published research in each area is unknown, it is possible to substitute \( p \) and \( q \) with empirical values, that is, values derived from a preliminary sample. To estimate approximate values for \( p \) and \( q \), however, rather than using a preliminary sample, the estimative proposed by Levine et al. (2000) and described in Equation (2) was used.

\[ p \cdot q = 0.25 \]  

(2)

This way, a confidence level of 95% was established, obtaining \( Z_{\frac{\alpha}{2}}^2 = 1.95 \) and defining a 5% error margin while determining the minimum sample size of 19 articles to be examined.

As this is a technological analysis, De Paula's (2019) proposal for the definition of the sample consisted of a random stratification technique where the number of individuals was proportional to the population of each stratum.

As a result, twelve strategies were established using the following distribution: Articles published in 1999 or earlier are included in Stratum 1; Articles published in Stratum 2 during the years 2000 and 2004; Stratum 3: Articles published between the
years of 2005 and 2009; Stratum 4: Articles published in the years of 2010 and 2011; Stratum 5: Articles published in the years of 2012 and 2013; Stratum 6: Articles published in the years of 2014 and 2015; Stratum 7: Articles published in the years of 2016 and 2017; Stratum 8: Articles published in the years of 2018 and 2019; Stratum 9: Articles published in the years of 2020 and 2021;

The number of scientific articles to be examined in each stratum was determined proportionally, taking into account both the overall number of articles found and the total number of articles in each stratum. After the quantity was established, scientific articles from the stratum that correspond to the same proportion in relation to the minimum calculated size for the sample were chosen randomly. The number of scientific articles that were examined (Table 1) and which had fractional values were rounded to whole number while maintaining the margin of error and confidence interval.

A systematic analysis was conducted on 19 scientific articles that were chosen from 807 that were collected based on a general search, taking into account areas and subareas of artificial intelligence in agriculture related to the topic of irrigation.

<table>
<thead>
<tr>
<th>Period</th>
<th>Total Number of Papers</th>
<th>Proportion (%)</th>
<th>Total Number of Papers Analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>before 1999</td>
<td>21</td>
<td>2.60</td>
<td>1</td>
</tr>
<tr>
<td>2000 to 2004</td>
<td>8</td>
<td>0.99</td>
<td>1</td>
</tr>
<tr>
<td>2005 to 2009</td>
<td>78</td>
<td>9.67</td>
<td>2</td>
</tr>
<tr>
<td>2010 and 2011</td>
<td>62</td>
<td>7.68</td>
<td>1</td>
</tr>
<tr>
<td>2012 and 2013</td>
<td>50</td>
<td>6.20</td>
<td>1</td>
</tr>
<tr>
<td>2014 and 2015</td>
<td>76</td>
<td>9.42</td>
<td>2</td>
</tr>
<tr>
<td>2016 and 2017</td>
<td>86</td>
<td>10.66</td>
<td>2</td>
</tr>
<tr>
<td>2018 and 2019</td>
<td>150</td>
<td>18.58</td>
<td>3</td>
</tr>
<tr>
<td>2020 and 2021</td>
<td>230</td>
<td>28.50</td>
<td>5</td>
</tr>
<tr>
<td>2022</td>
<td>46</td>
<td>5.70</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>807</strong></td>
<td><strong>100</strong></td>
<td><strong>19</strong></td>
</tr>
</tbody>
</table>

The data obtained were analyzed using the "Microsoft Excel" program, in percentages of return within the areas and subareas of the IA, with analysis by descriptive statistical analysis of the results obtained.
3 RESULTS AND DISCUSSIONS

3.1 SCIENTIFIC PAPERS RELATED TO THE IA FIELD

The results of the analysis of the articles selected using the structured analysis method, considering references, year of publication, proposed problem, and AI areas supported by the work, are presented in Table 2. The articles were grouped according to identification into one or more categories, including Machine Learning, Evolutionary Computing, Internet of Things, Optimization, Natural Language Processing, Robotics, Remote Sensing, and Expert Systems.

<table>
<thead>
<tr>
<th>Id*/ Ref</th>
<th>Proposed Problem</th>
<th>IA Fields</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2) Su e Wen (2001)</td>
<td>A spatial decision-making system for agricultural planning.</td>
<td>Expert Systems, Remote Sensing</td>
<td>The system can be designed to integrate future models of industrial and municipal water usage for more extensive applications.</td>
</tr>
<tr>
<td>(3) Rajasekaram e Nandalal (2005)</td>
<td>Decision Support System for resolving conflicts in the management of reservoir water in a single, multipurpose reserve.</td>
<td>Expert Systems, Natural Language Processing</td>
<td>The research initiatives that use advanced IA technology and AIML are left for future development.</td>
</tr>
<tr>
<td>(4) Nangia et al. (2008)</td>
<td>The study of the effects of nitrogen application in the WPET system for corn crops in irrigation scenarios was conducted to better understand how to manage future increases in water productivity.</td>
<td>Expert Systems, Optimization</td>
<td>The research demonstrates that there is still significant potential to improve productivity and WPET under dry and irrigated conditions.</td>
</tr>
<tr>
<td>(5) Hendrawa e Murase (2011)</td>
<td>Evaluate the potential of bio-inspired approaches as a pre-treatment Rede Neural Artificial algorithm to determine the water from mosses.</td>
<td>Machine Learning, Evolutionary Computing, Optimization</td>
<td>Some bio-inspired approaches were able to optimize the attribute selection process.</td>
</tr>
<tr>
<td>(6) Domínguez et al. (2012)</td>
<td>Determine the length of growth stage; analyzing the effects of saltwater irrigation on cultures; Sensitivity analysis of the key factors that influence the cost of water for irrigation.</td>
<td>Expert Systems, Optimization</td>
<td>Changes in the management of corn culture that result from deficit irrigation strategies conserve water that may be used by other cultures, resulting in a higher gross margin.</td>
</tr>
<tr>
<td>(7) Bachour et al. (2014)</td>
<td>Apply an algorithm to calculate the actual evapotranspiration for the irrigation area while estimating the development of an RVM model that provides spatial distribution of evapotranspiration due to</td>
<td>Machine Learning, Remote Sensing</td>
<td>Establishes the basis for estimating evapotranspiration on days when satellite images are not present, allowing for more accurate prediction</td>
</tr>
<tr>
<td>Id*/ Ref</td>
<td>Proposed Problem</td>
<td>IA Fields</td>
<td>Results</td>
</tr>
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<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>(8)</td>
<td>Providing real-time fish and water management tools through an environmental decision support system has the potential to improve the balance of water management decisions that have an impact on ecosystems.</td>
<td>Expert Systems, Optimization</td>
<td>Improvements enabled by the system were achieved without causing greater harm to its infrastructure whether it came to water, riverside property, or agricultural production in dry or wet conditions.</td>
</tr>
<tr>
<td>(9)</td>
<td>Analysis of the potential for supplemental irrigation as a strategy to increase the productivity of corn grown in tropical conditions.</td>
<td>Expert Systems, Optimization</td>
<td>Significant differences in the culture's simulated yield in response to water, showing improvements in water utilization with reductions of between 10% and 15% compared to complete irrigation.</td>
</tr>
<tr>
<td>(10)</td>
<td>Method for calculating the hydraulic performance of drippers; evaluation of the model's performance in comparison to the statistics of the hydraulic performance obtained from the model and experimental results; and investigation of the impact of structural parameters of drippers and pipes on the performance of developed models.</td>
<td>Evolutionary Computing, Optimization</td>
<td>The use of GEP models can yield results that are accurate or sufficient to forecast the hydraulic performance of drippers.</td>
</tr>
<tr>
<td>(11)</td>
<td>Study of the elements of the Decision Support System to evaluate the water, energy and food nexus. Case study from the study area and discussion of the key discoveries and potential future research directions.</td>
<td>Expert Systems, Evolutionary Computing, Optimization</td>
<td>Efficacy was demonstrated, aiding in decision-making by identifying nutrient and water management strategies that could increase crop productivity.</td>
</tr>
<tr>
<td>(12)</td>
<td>Identifying the potential of hydrological resources to maintain irrigation on a small scale in Ethiopia throughout the dry season in order to increase the availability of food produced via the cultivation of vegetables and understanding the gaps and limitations in production.</td>
<td>Expert Systems, Optimization</td>
<td>Promoted conservation measures for both water and soil, optimizing the use of irrigation for the growth of plants, reducing evaporation, and increasing the availability of water in the area critical to culture.</td>
</tr>
<tr>
<td>(13)</td>
<td>Provide a blockchain solution for the viability of using photovoltaic irrigation systems as well as determining the benefits and economic outcomes.</td>
<td>Expert Systems</td>
<td>Due to the use of renewable energy, the system may be effective for small farmers who are unable to use an irrigation system during the dry summer months.</td>
</tr>
<tr>
<td>(14)</td>
<td>Using a model that makes use of the System of Support to Decision for Transfer of Agrotechnology, determine the best irrigation timings for the production of cotton under conditions of full and deficit irrigation.</td>
<td>Expert Systems, Optimization</td>
<td>Allows the producers of cotton who use the model to make appropriate irrigation-related decisions that will increase productivity while also ensuring hygienic safety.</td>
</tr>
<tr>
<td>(15)</td>
<td>Following then Venapp project, a model will be implemented in the Vensim, integrating drivers for hydrology,</td>
<td>Expert Systems, Optimization</td>
<td>This type of models may be used to identify and analyze the effects of factors that appear unrelated to each</td>
</tr>
<tr>
<td>Id*/Ref</td>
<td>Proposed Problem</td>
<td>IA Fields</td>
<td>Results</td>
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<td></td>
<td>agriculture, and economics, and allowing users to access a model of the program without entering the Vensim modeling environment.</td>
<td></td>
<td>other, such as the prices of agricultural products, subsidies, or exploration costs, on the development of the use of subterranean waters.</td>
</tr>
<tr>
<td>(16) Unal et al. (2020)</td>
<td>Investigated the benefits of using deep learning in agricultural applications. Review of the potential for using deep learning techniques in agricultural businesses.</td>
<td>Machine Learning</td>
<td>They categorized the key topics to aid new researchers in the field and stressed practices that might help guide future research.</td>
</tr>
<tr>
<td>(17) Han (2021)</td>
<td>Describes the design and construction of a high-performing automated grass cutting and irrigation machine.</td>
<td>Robotics, Evolutionary Computing, Optimization</td>
<td>By regrinding the grains, the robot can reduce labor costs, improve trimming efficiency, and save water. The system may be implemented on a large scale, which will be useful in robotic applications for grass cutting in fields.</td>
</tr>
<tr>
<td>(18) Katiyar e Farhana (2021)</td>
<td>Review of research on agricultural automation with the aid of sensors, robots, drones, and IA-focused technologies aiming to increase productivity, identify limitations, and address future challenges of intelligent agriculture.</td>
<td>Automation, Robotics, IoT</td>
<td>This study is an attempt to think about mechanization in agriculture. A study of agricultural applications using artificial intelligence and the internet of things was presented.</td>
</tr>
<tr>
<td>(19) Shahverdi et al. (2022)</td>
<td>Utilization of an algorithm to manage water in irrigation canals by regulation of water level.</td>
<td>Machine Learning</td>
<td>The results demonstrate a reasonable precision and skill in controlling the level of water within the canal.</td>
</tr>
</tbody>
</table>

* Id: (Number) refers to the identification of the article in the text.

Source: Authors, 2023.

The study of the 19 articles produced 39 classes within the AI domain (Figure 1). It is significant to remember that a given article might present multiple techniques.

The areas with the greatest concentration of papers are optimization and specialized systems, accounting for more than 60% of the assigned classifications, followed by the areas of machine learning and evolutionary computation, which account for about 20% of all papers.
Inferring from the distribution of IA fields through time (Figure 2) that the elements that will be most prominent in the years between 2019 and 2022 will be robotics, optimization, and specialist systems.
Furthermore, it can be deduced that throughout the past decade (2012 to 2022), roughly 70% of classifications have been assigned to work that falls under the scope of the AI.

3.2 EXPERT SYSTEMS

According to Honório (2010), the Expert Systems are computer tools that were developed with standards that replicate an expert's knowledge in order to solve problems in particular domains.

In this context, the majority of the projects categorized as Expert Systems were developed with the intention of becoming DSS. According to Rinaldi and He (2014), a Decision Support System is a computerized system created to assist decision makers in compiling useful information using a combination of raw data, documents, and personal knowledge. The authors claim that the main benefits of using a DSS include the ability to evaluate several alternatives, a better understanding of the processes, the identification of unforeseen situations, direct communication, a better cost-benefit ratio, and greater utilization of data and resources.

In agreement, Rajasekaram and Nandalal (2005) state that the introduction of visual interfaces and many other usability resources into these systems was made possible by the DSS, along with the advancement of artificial intelligence in various applications and advancements in programming, leading to the development of software and simulation technology in a variety of different fields.

It is proven that even in more specific contexts, like irrigation, the use of specialized systems can take many different forms. As examples, the use of Expert Systems based on the analysis of papers (1) Hershauer et al. (1989) and (12) Worqlul et al. (2019), which have as their goals determining viability and managing hydrological resources for irrigation. In contrast, in paper (2) Su e Wen (2001), the agricultural planning process was carried out using an expert system and spatial data. Additionally, the use of this kind of equipment was still mentioned in paper 3 by Rajasekaram and Nandalal (2005), which focused on managing reserve water for various uses.
3.3 OPTIMIZATION

According to Neco (2021), the idea of optimization is related to improving something already present with the aim of achieving non-customary departures with cost restraints. Additionally, from a computational perspective, optimization may be understood as the process of finding the best solutions (possible solutions) to problems that can be modelled using a variety of techniques. In support of this, Torga (2007) mentions that using algorithms to search for a solution can help one obtain an excellent solution. According to implementation, Bastos (2004) describes methods that emphasize combinatorial optimization, and linear and non-linear programming.

Generally speaking, the approach used in the area of optimization has to do with developing theories, machines, and systems that could choose how to carry out irrigation for a certain culture. In this instance, artificial intelligence areas are described in order to optimize a certain procedure. Highlighted is the use of sensors to measure plant evapotranspiration and determine the amount of water required for irrigation. Mention is made of the combination of processes for the development of new machines that do more than one activity in addition to irrigation, optimizing procedures aimed at cost reduction.

In this sense, the papers that have been evaluated and classified under the category of Optimization are geared toward seeking an improvement of a particular process, whether through simulations (5, 6, 8, 9, 10, 12, 14 and 17). Corresponds to the authors Hendrawan and Murase (2011); Domnguez et al. (2012); Hyatt et al. (2015); Da Silva et al. (2016); Mattar and Alamoud (2017); Worqlul et al. (2019); Enescu et al. (2018); Martínez-Valderrama et al. (2020) and Han (2021); or mathematical models by (11) Udias et al. (2018).

In the paper (12), by Worqlul et al. (2019), it is highlighted how optimization was used to estimate the hydrological potential and define an irrigation level for vegetables with the aid of a DSS.

According to Arhonditsis et al. (2019), this system consists of a semi-distributed hydrography model that can function over a range of timescales (daily to annual). In addition to this, its structure can accommodate climate variations, variations in the topography of the ground, hydrological processes, and agricultural practices, allowing for
better subsidies for producers, and a device called SWAT for assessing the water and soil quality.

In this context, Optimization can be carried out by a specialized system using simulations or by a combinatorial optimization method, such as those found in the field of evolutionary computing.

3.4 EVOLUTIONARY COMPUTING

The term "Evolutionary Computing" refers to a variety of techniques and algorithms that use the idea of genetic evolution to model and solve issues. The concept of Genetic Algorithm, which includes an algorithm that simulates the process of genetic evolution and natural selection, was first introduced in the field by Holland (1984). Later, this method was modified to be applied in order to find optimal (or nearly optimal) solutions to complicated problems.

As an example, Han's (2021) paper (17), describes a robot prototype developed to cut and water grass with the least amount of human intervention possible by using genetic algorithms. Additionally, while being a prototype, the author's solution may in the future reduce operating costs and improve water efficiency thanks to the use of this device.

In addition, the article (11) Udias et al. (2018) presents a system that aids local managers in evaluating the interaction between water, energy, products, and the environment with the goal of providing management solutions that will improve the production of cultures at the level of the hydrographic basin. This system is offered without charge, and it is currently used by small managers. In addition, it stands out how the intensification of agricultural practices is fostering the development of regional agriculture's productivity by encouraging the use of more inputs (such as fertilizers and water irrigation), as well as the efficient distribution of agricultural land.

3.5 MACHINE LEARNING

Russel and Norvig (2013) define Machine Learning as a subfield of Artificial Intelligence that provides an effective method for building multivariate, nonlinear
regression and classification models without explicit programming. They emphasize that machine learning models learn from training data, or previous experience.

In this context, Shahverdi et al. (2022) describe the use of a reinforcement learning methodology based on Q-Learning for the opening of a canal’s behaviors, making the necessary water available for irrigation.

In the context of neural networks, the application was noted in the papers (16) Unal et al. (2020) and (18) Katiyar e Farhana (2021), whose publications took place in the 2020 and 2021 respectively. The paper 16 by Unal et al. (2020) is also noteworthy because it presents a review of numerous applications related to deep learning (also known as advanced learning). The authors present applications of deep learning in the agricultural sector including disease detection, plant classification, identifying the cover of the ground, precision culling, object recognition, intelligent irrigation, phenotyping, and detection of invasive species. Additionally, this study considers other areas of artificial intelligence related to irrigation, such as, for instance, the Internet of Things, Machine Learning, Linear Regression, and Remote Sensing.

The idea of deep learning is directly related to neural networks, which make use of intricate internal networks with many cameras. According to Russel and Norvig (2013), the neural networks are a type of mathematical organization that encompasses the human nervous system. These networks have four fundamental components: synapses, or points of connection, which are distinguished by their weight, as well as adders for adding entry and exit gates, activation functions for hidden and exit gates, and an external visual cue.

3.6 ROBOTICS AND REMOTE SENSING

Robotics is an interdisciplinary field that includes the design, construction, use, and maintenance of robots. The operation of these robots can be carried out autonomously (or semi-autonomously) using ideas from artificial intelligence, allowing the operator to focus on managerial issues and decision-making.

In this way, in addition to the previously mentioned paper (17) by Han et al. (2021), the paper (18) by Katiyar and Farhana (2021) presents a review of automation
with the aid of sensors, robots, drones, and AI based technologies with the aim of enhancing productivity, identifying limitations, and outlining future challenges for intelligent agriculture. In this section, the authors analyze agricultural applications using artificial intelligence and the Internet of Things.

Referring to Remote Sensing, this is a collection of techniques that make it possible to obtain data about targets on the surface of the earth using remote sensors. Among the reviewed papers, Bachour et al. (2014) (7) provide a spatial distribution of evapotranspiration using satellite images by using linear regression techniques to estimate real evapotranspiration in irrigation areas. In the case of paper (2) Su e Wen (2001), remote sensing techniques are used, but with a focus on planning the agricultural need.

3.7 OTHER AI FIELDS BEING CONSIDERED

Other areas were also identified in the analysis, despite their less representativeness. Even this, they include areas that are important for agricultural structures overall, not just irrigation systems.

In terms of the Internet of Things, Liu and Tao (2016) explain that the main concept lies in developing systems that make use of innovative potential to achieve more effective operations, improve human-machine interaction, and increase robustness in data analysis. According to Marcu et al. (2019), IoT in agriculture competes with intelligent farming systems, or precision agriculture, by combining sensors, information systems, and information management systems with the aim of maximizing production. According to Jiménez et al. (2022) and Ünal (2021), the Internet of Things is heavily used in irrigation, promoting greater accuracy and efficiency in data collection as well as use in the development of irrigation systems that balance water management decisions. Therefore, the IoT space permeates concepts of continuous connectivity, enabling autonomy in decision-making through the integration of devices and other AI-related areas, enabling monitoring and performing point-of-use interventions, and characterizing a range of actions related to precision agriculture.

Automation seeks to improve processes through the development of prototypes and sensors, a field that is, in general, of extreme significance to the agricultural sector.
However, the concept of automation along with IA techniques is only considered in the paper by Katiyar and Farhana (2021), (18). In this paper, the authors analyze agricultural applications in the context of automation using artificial intelligence and the internet of things.

Finally, the field of Natural Language Processing also emerges with the proposal of systems capable of speaking and writing with the user in natural language. In the case of the paper by Rajasekaram and Nandalal (2005) (3), the authors describes a DSS that has a Chatbot (a system that can communicate using natural language) to resolve disputes in the management of multipurpose reservoir water. It is worth noting that recent advancements in AI, exemplified by tools like ChatGPT, offer even more sophisticated natural language processing capabilities that can find applications in various domains, including agriculture.

Additionally, isolated and complementary applications of Deep Learning, Fuzzy Logic, and Linear Regression. In connection with the preceding, Zadeh (1975) explains that the term "Fuzzy Logic" is used to describe a less precise logic system in which the truth values are fuzzy sub conjunctions of the unitary range with linguistic terms. Lecun et al. (2015) describe the linear regression as a meticulous model for making predictions, allowing one to deduce the parameters to determine the number of messages to be processed and check the appropriateness of the parametrization.

4 CONCLUSIONS

In our analysis, we observed applications of Deep Learning, Fuzzy Logic, and Linear Regression, with a lower prevalence. Additionally, the field of NLP introduces systems enabling spoken and written interactions in natural language, such as Chatbots. Notably, recent AI advancements like ChatGPT offer advanced NLP capabilities with broad applicability, including within the agriculture domain.

The areas of Optimization, Expert Systems, Machine Learning, and Evolutionary Computing were the ones that received the most attention in the studies conducted. In general, the last decade (2012 to 2022) takes into account about 70% of classifications attributed to studies conducted within the AI and intended to produce information that
can be used to support local decisions regarding the use of water while taking into account the analyses and conditions under which the study was conducted.

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