

Article - Engineering, Technology and Techniques

Robotic Process Automation and Machine Learning: a Systematic Review

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HIGHLIGHTS

- Mapping of the Robotic Process Automation (RPA).
- Recent advances and new possibilities of RPA.
- RPA platforms available on the market.

Abstract: The need for companies to seek new techniques that generate productivity gains made them carry out the mapping of their processes using Business Process Management (BPM). Well-mapped processes make it possible to identify repetitive tasks, which can be automated using Robotic Process Automation (RPA), where a computer program mimics the actions of an employee. Furthermore, recent advances in Artificial Intelligence have brought new possibilities to RPA. The systematic review developed aims to raise information on Robotic Process Automation (RPA) integrated with Artificial Intelligence (AI) for autonomously automating work processes.

Keywords: robotic process automation; RPA; machine learning; artificial intelligence; business process.

INTRODUCTION

Companies seek advantages that can generate better results in an increasingly competitive market. Thus, Business Process Management (BPM) [1] was created and developed in response to expectations of business constantly emerging and according to the possibilities offered by the available technologies. Companies with well-defined business processes are more focused on their objectives, and to generate the mapping of these processes, use Business Process Model and Notation (BPMN) [2].

Many professionals and researchers propose that companies optimize and automate their processes [3]. For this to be possible, Robotic Process Automation (RPA) has been increasingly applied in several areas [4]. RPA is an industry response to the large volume of manual work individuals must perform to support a high range of business processes [5,6]. RPA can be defined as a technological imitation of a human worker to automate structured tasks quickly and cost-effectively. As advantages present the reduced cost, even costing less than half the value of an employee [4], the constant availability, and the agility in executing the task. RPA can bring more quality to generating complete, correct, and consistent information.

Unlike other systems, RPA does not directly access databases, being, in its basic concept, software capable of imitating a human being who would be performing tasks on his workstation. Not all processes are suitable for use with RPA. Some criteria must be met by the business process for the RPA [6]:

- Tasks that do not need subjective judgment, creativity, or interpretation.
- Tasks that have a high execution volume.
- Tasks need access to multiple systems and applications to get the job done.
- Tasks are highly standardized tasks with few or no exceptions to handle.
- Tasks that are subject to human error due to manual labor.

Machine learning and deep learning, branches of artificial intelligence, can improve the prediction of an RPA [7], which makes the process more autonomous and allows partially automating a wider range of tasks performed by experts in the past. [5]. According to the trained model, analyzing specific situations and acting similarly to a person creates new possibilities for process automation and freeing employees to perform less repetitive tasks.

The objective of the systematic review is to develop and obtain information about the use of RPA along with machine learning or deep learning techniques, observing what has been developed on the subject and pointing out the innovations that deserve to be highlighted. The research questions that guided the study are:

- QP01 - What is the history of RPA and its application?
- QP02 - In what situations can RPA be used?
- QP03 - What are the future possibilities of RPA together with AI?

Based on these issues, it will be possible to go through different stages of this new system that has been increasingly used.

This analysis aims to obtain information and research on the application of RPA, involving machine learning techniques and deep learning, to raise more efficient and appropriate techniques in application in people management to meet complex public sector legislation on its servers.

SEARCH APPLIED METHODOLOGY

The research methodology was composed of the selection of the theme, the definition of the search string, definition of selection and exclusion criteria, selection of the databases to be used, initial selection of articles based on the criteria, and new analysis of the articles that met the inclusion criteria for refinement. Parsifal [8] was essential because it allowed the definition of the systematic review in an orderly manner, besides assisting in the definition of the string according to the database and allowing the selection of articles quickly. The selected databases were Scopus, ISI Web of Science, and IEEE Digital Library. After the search, 228 articles were divided into the following databases: Scopus - 176; Web of Science - 33 and IEEE Digital Library - 19.

The returned articles were analyzed according to the inclusion and exclusion criteria that can be visualized in Table 1 because it is broad research on the subject. The only exclusion criterion was the article did not bring anything about RPA. After this year, we selected 72 articles, as shown in Figure 1. The research was limited by articles published from 2017 to 2021. The list of articles exported from Parsifal can be accessed in Articles, where articles marked with green color were selected after abstract analysis. According to Figure 2, it is possible to note that many publications on the subject are recent. Although not included as a result of the articles, it was used because it contained important information about the RPA and was one of the works that influenced the choice of the theme. A bibliometric network was elaborated using VosViewer [9], where the essential terms for the research are listed in the network. Figure 3 can be observed the occurrence of these words in the works used in the review according to the year of publication. The network's objective is to clarify better the information presented in Figure 2 and how the terms used have been updated.

Table 1. Selection criteria used in the literature review.

Inclusion criteria
CI01 - The article talks about machine learning and RPA
CI02 - The article talks about RPA in automation
Exclusion criterium
CE01 - The article does not mention Robotic Process Automation

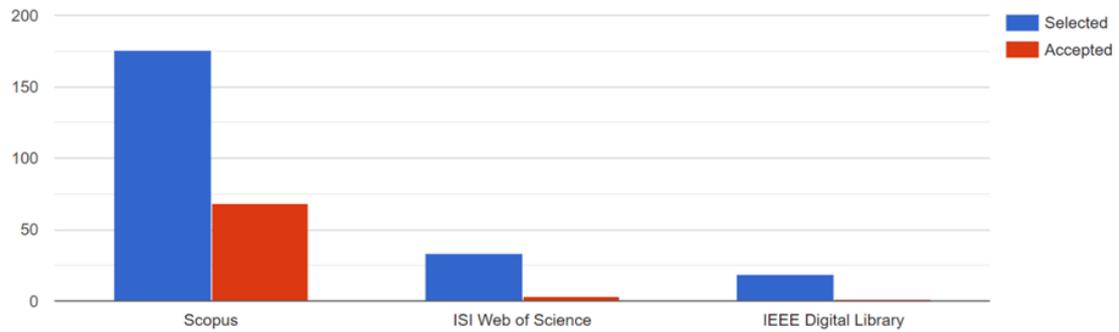


Figure 1. Selected and accepted articles following the selection criteria.

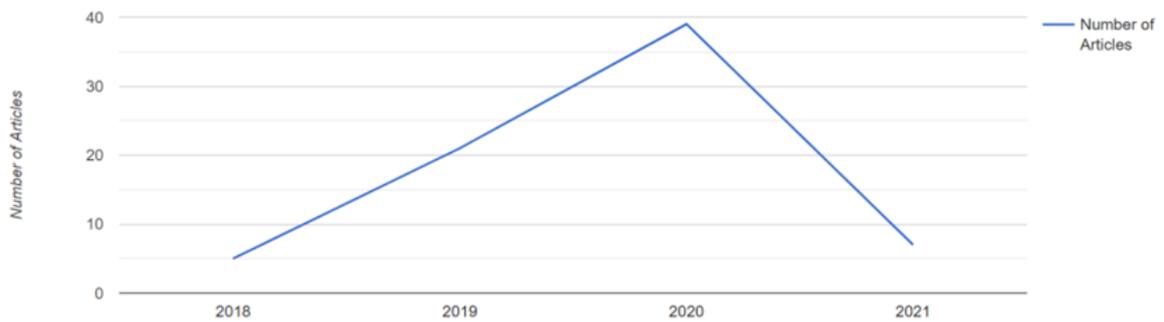


Figure 2. Year of publication of selected articles.

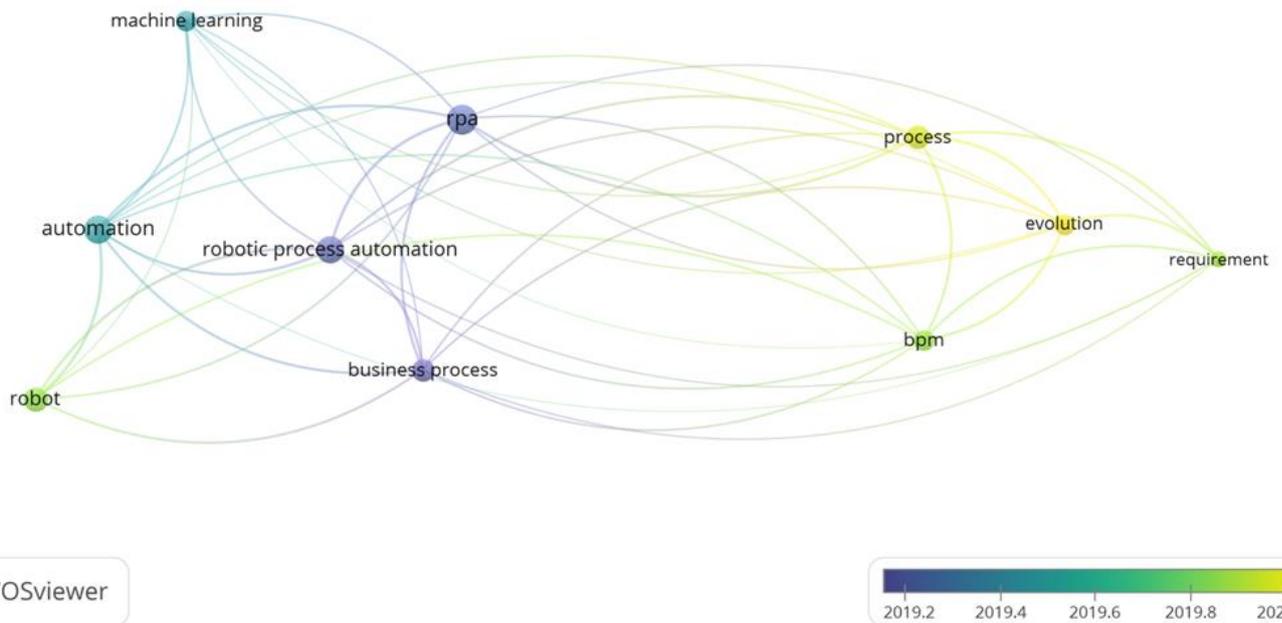


Figure 3. Year of publication of selected articles.

SELECTED ARTICLES AND RESULTS

After the analysis of the selected articles, it was possible to perceive how the RPA integrated with AI has become usual in several areas and, almost unanimous, the dependence on the correct selection of the process to be automated directly impacts the performance of the RPA. Table 2 presents the list of articles selected for systematic literature review, and Figure 4 shows the conceptual map developed based on the articles. The results that contributed to the research theme are presented in the following sections.

Table 2. List of selected articles.

Reference	Title	Publication Year
[6]	Automation of a business process using robotic process automation (RPA): A case study	2017
[5]	How do Machine Learning, Robotic Process Automation, and Blockchains Affect the Human Factor in Business Process Management?	2018
[15]	Identifying Candidate Tasks for Robotic Process Automation in Textual Process Descriptions	2018
[18]	Machine Learning with Certainty: A Requirement for Intelligent Process Automation	2018
[14]	Assessing Suitability Process for AI-based Automation. Research Idea and Design	2019
[12]	The Future Digital Work Force: Robotic Process Automation (RPA)	2019
[25]	Robotic Process Automation in Public Administrations	2019
[22]	A Novel Approach in Designing A Security Workbench with Deep Learning Capabilities and Process Automation	2019
[24]	Contractual Employee Management System Using Machine Learning and Robotic Process Automation	2019
[10]	Cognitive BPM: Business Process Automation and Innovation with Artificial Intelligence	2019
[26]	Robotic Process Automation (RPA) and its future	2019
[3]	Robotic Process Automation: A case study in the Banking Industry	2019
[11]	Hyperautomation to fulfill jobs rather than executing tasks: the BPM robot manager vs. human case	2020
[16]	Cognitive automation: A new era of knowledge work?	2020
[1]	Business Process Management Systems: Evolution and Development Trends	2020
[17]	From Robotic Process Automation to Intelligent Process Automation	2020
[20]	Resource-Based Adaptive Robotic Process Automation: Formal/Technical Paper	2020
[7]	Using machine learning for cognitive Robotic Process Automation (RPA)	2020
[23]	A Supervised Machine Learning Approach for Intelligent Process Automation in Container Logistics	2020
[19]	Intelligent document processing based on RPA and machine learning	2020
[21]	Development of Programming Materials using Gameplay RPA	2020
[13]	A systematic literature review on intelligent automation: aligning concepts from theory, practice, and future perspectives	2021

BPM

The idea of the development is to make possible the contextualization of the RPA in the business environment. Information was raised about BPM, where three specific works deserve to be highlighted. The first elucidates the Business Process Management System (BPMS)[1]. The second presents a study on Cognitive BPM (CBPM) [10], and the third shows a panel with professionals from around the world. It discusses the possibility of a robot BPM manager rather than a "human" manager. [11]

In [1], the author presents a study on BPMS, informing history, developments in recent times, and trends in how these systems should evolve. In [10] and said that the idea of CBPM and automation, mining data from business operations, monitoring execution, obtaining information, and using this data to train a cognitive system to respond to business situations automatically. Wherein each new situation, the system learns and adapts to determine the best action. This work aims to demonstrate the empirical research developed in future proposals.

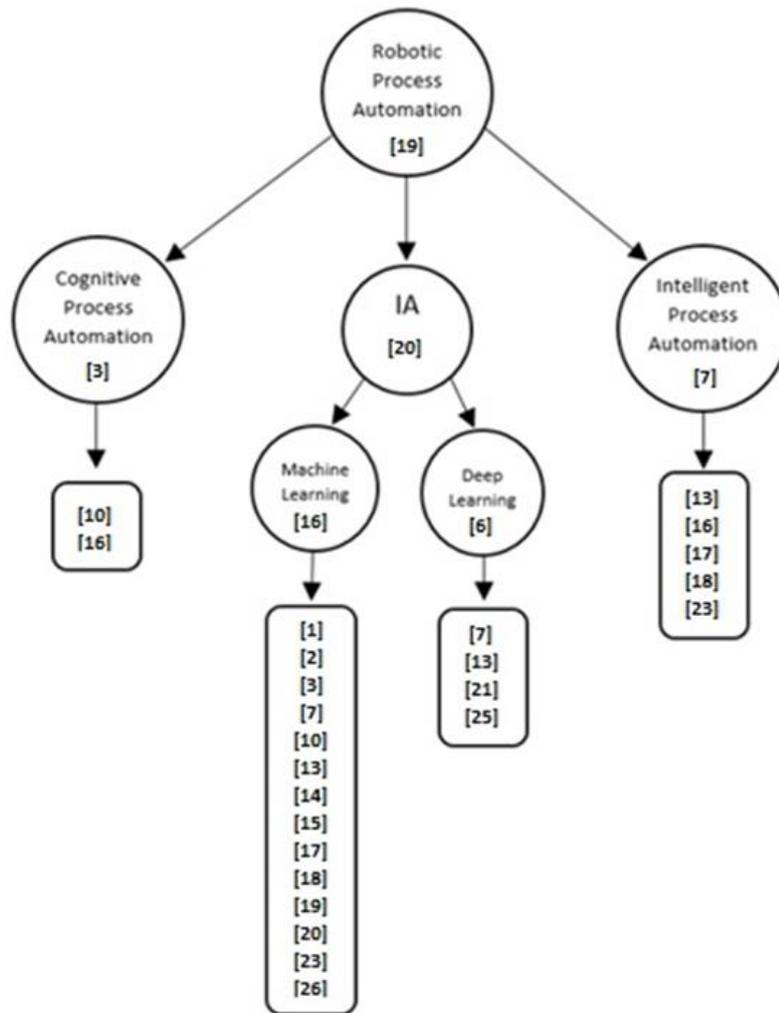


Figure 4. Conceptual map.

The reference [11] reports the panel with several professionals worldwide, presenting the term Hyper-automation which involves knowledge work automation with a broad scope of business and technologies integrated with a responsive workforce, mainly combining RPA with ML and/or other AI functionalities. The panel mentioned in the article featured 33 professionals from various countries and discussed the possibility of a robot performing the activities of a BPM manager. Initially, the characteristics and options of both RPA and manager are discussed. In addition to the hard work in a robot. The conclusion obtained by most professionals was that it was possible to implant an RPA robot to perform the role of a BPM manager.

Although not the focus of the article, BPM is important because implementing this method indicates well-mapped processes with defined rules in the company, facilitating automation by using RPA.

RPA and Machine Learning

In the other results found in the systematic review, those relevant to the proposed theme are presented.

The reference [12] provides an overview of the RPA, showing its importance, history, operations that an RPA can perform, and the professionals developed in designing the tool and informing several automation solutions that are currently existing. The author indicates that the next digital workforce will be the RPA because it has applications in various areas such as health, financial services, telecommunications, energy, etc. These areas usually already have extensive use of AI [13]. In addition, there is a forecast that the global market for RPA products and services is expected to grow to nearly US1.2 billion by 2021.

Although it is a good product, RPA depends, as already mentioned, on the correct choice of process to be automated, and some articles suggest ways to choose these processes. The reference [14] conducted research that aimed to assess the adequacy of a process for automation using AI, where he suggested the creation of an artifact. This metric will be a parameter of the process, which indicates the adequacy of AI-based automation. The reference [15] suggests an approach where textual descriptions of processes undergo linguistic preprocessing techniques and are classified using machine learning according to the type

of automation. The result obtained in the study reached an F-measure of 0.81, generating a satisfactory result in identifying tasks for RPA.

As a result of the research, other RPA-related terms were returned, such as Cognitive Process Automation (CPA) and Intelligent Process Automation (IPA). These terms are evolutions of traditional RPA, where there is a use of AI so that it is possible to perform this type of automation. The reference [16] mentions that the differences between RPA and CPA are, in essence, the differences between classical AI and built AI because RPA requires pre-existing knowledge transformed into rules. These rules are not updated based on new data and generate standardized results based on rules. The CPA uses algorithms to discover knowledge and calculate probabilities, enabling predictions by the system, which produces variable results. Figure 5 shows the comparison between RPA and CPA. Also, according to [16], the most advanced form of IPA and the use of AI to discover data knowledge, creating insights of unstructured data in image and audio format, which would typically require a person to understand and then generate judgments. Although it presents advantages, The reference [17] cites the high cost of developing and maintaining an IPA because of the preparation of data and the extraction of the correct characteristics for the construction and validation of AI skills. In addition, AI models should be retrained if changes occur in the business process or changes in the data that will be analyzed. In addition, there is the issue of low adoption because the data used to train an IPA can be manipulated or contain some ideological, racial, or gender bias. These terms interfere with the result generated by the model, and once the IPA makes the error, this can bring monetary risks and loss of reputation for companies.

The reference [18] explores unique requirements for an intelligent automation system, presenting the "SureTree," a meta-learning algorithm for training decision trees with the high risk of false positives. The author used the task of processing documents of an insurer, where the action depends on the type of document. In a similar sense, the reference [19] presents a study where he used RPA in combination with Optical Character Recognition (OCR) and deep learning to perform the registration and classification of official documents, where a document administrator was responsible for preparing and recording documents received in a registration system. As a result of combining the technologies, the RPA error rate was less than five percent of the total documents evaluated in the search.

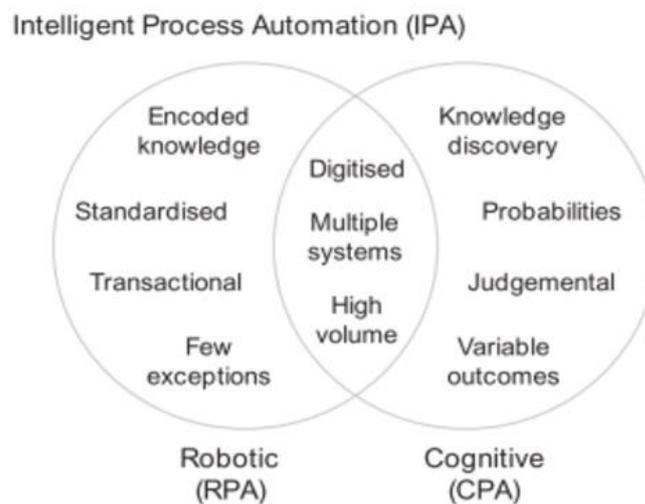


Figure 5. Comparison between robotic process automation (RPA) and cognitive process automation (CPA).

Even with well-trained models, RPA can fail, in which case it needs to inform an employee to perform the task if there is a failure. In this sense, the research presented in [20] conducts a study where the need for interaction between human participants and robots and the definition of tasks that can be automated are considered. The reference [17] even mentions that using AI to automate processes does not mean there will be no intervention with a person, as AI still needs people for proper updates, parameter improvement, or retraining.

Among the studies analyzed, there are many case studies of RPA applications, which are addressed from now on.

The reference [3] conducted a case study in a bank in Portugal, where he suggested using RPA with AI to automate a generic requisition process, to create a new BPM approach. It allows a trained model to define who will perform the task, which task will be performed and when it will be performed, helping the BPM

manager to use a fact-based approach. The author also highlights some risks in using RPA, such as a wholly untrained model and historical data having its risks. Because the process modeling project is still in the implementation phase, the results of the research questions were partial and incomplete.

More simplistically, the reference [21] suggests RPA can be used to run games and thus teach programming to students. The article presents the use of the Python language and tries, through the automation of playing rather than the resolution of mathematical problems, to motivate the learning of the language and technology of RPA.

In information security, the reference [22] pointed out that the conventional approach to detecting malicious activity will not be practical soon. This work suggested an intelligent framework where the model analyzes data in real-time, copies this data, finds considerations, and provides knowledge to decision-makers. In addition, it creates predictive models that have an improved threat detection capability with the ability to detect, generate, predict patterns, recommend solutions, and perform security fixes through DevOps methodologies.

The reference [23] proposes a fully automated process control solution in the logistics area. It used supervised machine learning for automated container targeting, where containers that need to be tied are routed to the station itself. Those that do not need to be are already routed to the forklift station.

The reference [24] proposes an RPA with machine learning fully automated for interaction with the employee contract management system. RPA feeds the system with employee records such as attendances, overtime details, shifts, and shift relay management and uses machine learning to predict employee satisfaction and behavior.

The articles that led to the selection of the theme are [3, 7, 25], the latter making use of CPA to perform the process flow of scanning a public document, recognizing objects, extracting data, and including it in a legacy system. The author points out that the RPA has considerable potential for public administration and administrative modernization. Still, some risks should be considered when deciding on the use of RPA in public administration. The reference [7] proposes an RPA application that uses a trained convolutional neural network with various interfaces and menus to classify interfaces in real-time. The researcher focused on images of the interface of an application, which was the Eclipse IDE, and the trained network presented a result above 90 percent in most cases. The objective was to show the potential of object identification and RPA applications.

In addition to applications, the reference [24] divides the benefits of using RPA into primary and secondary. The primary benefits are:

- 1) Improved efficiency - the most mentioned and understood benefit because efficiency comes from the highest workload capacity and speed in performing tasks.
- 2) Improvement of hits - the automated process does not suffer from fatigue and distraction, such as humans, which allows it to run 24 hours for 7 days and 365 days a year and use computational memory and programmable rules to ensure consistency and accuracy.
- 3) Reduction of full-time equivalent (FTE) - the reduction of employees and one of the most complex benefits to discuss and often misinterpreted. Redistributing the workload and reducing future hiring needs are more realistic options, where companies that adopt automation can cope with increased capacity without having to increase the number of employees.

And the secondary benefits are:

- 1) Asset redistribution - Workload redistribution allows the organization to move its employees from one area to another to address organizational needs.
- 2) Improved customer experience - with increased employee capacity, more time can be allocated to customer-related functions, such as customer service, increased sales effort, etc.
- 3) Fast Scalability - as automation represents a pre-trained digital workforce, scalability can be done quickly. The distribution of new RPAs is faster than hiring new employees, which usually takes time.
- 4) Improved job satisfaction surveys indicate that the most engaged employees feel they are doing significant work that the company's success metrics can map.

The information presented here shows the versatility of the RPA and the possibilities of application and evolution. Still, an important point, as highlighted by [13, 16], where the use of RPA does not eliminate the participation of people in the process, including [20] presents a study that points out the interaction between robot participants in this case, RPAs, and human participants.

A systematic review was carried out on the IPA theme [13], and the researchers identified, in a preliminary analysis, that the first article with the string "robotic process automation" in the title was published

in 2016, besides indicating issues such as the integration of legacy systems and RPA. As the focus of the work was the RPA, the simplest version of the IPA, the work of [13] is a reference for future improvements.

DISCUSSIONS

This section discusses the answers to the research questions used in the systematic review:

QP01 - What is the history of RPA and its application? Although it is a recent term, found only in 2016, as pointed out [13], companies focused on selling solutions to automate business processes. In contrast, other companies seem to be interested in operating in this area, such as Microsoft, which acquired soft motive, a Greek company specializing in RPA, in May 2020 [11]. This fact indicates that the use of software for the automation of business processes presents a potential and focus of work and the development of an RPA for state agencies, enabling the automation of processes without software acquisition.

QP02 - In what situations can RPA be used? RPA should be used in well-defined rules and well-mapped processes that include repetitive activities. Although it has already been mentioned, the choice of the process to be automated and a critical point, as it can impair the performance of the software and cause the impression that this new type of application does not bring benefits to the business. In addition, RPA enables the integration of systems that do not usually have such integration [17] precisely because it mimics a person's actions operating various systems.

QP03 - What are the future possibilities of RPA together with AI? With increasingly advanced AI, the opportunity arises to create the IPA, where traditional RPA and executed with the help of intelligent agents, software programs are trained in data function and make decisions based on the training performed. Figure 6 exemplifies the use of IPA, where it is possible to see the coordination of the human participant with robots during the life cycle of the process, including the identification of which processes can be automated and the retraining of robots, according to performance.

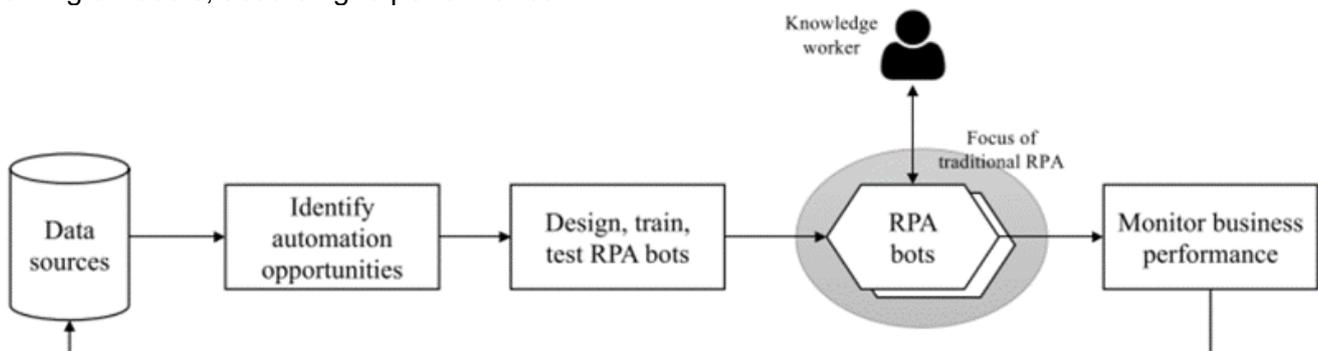


Figure 6. IPA Scope.

RPA PLATFORMS AVAILABLE ON THE MARKET

When process robotization is discussed, information should inevitably be added about the trading platforms found on the market. To this end, the Gartner group annually updates its magic quadrant of existing process robotization platforms on the market by observing the quadrants "Leaders, Challengers, Visionaries, and Niche Competitors" [27]. Figure 7 illustrates the Gartner group report magic quadrant for robotization tools.

It is also essential to keep the definition of RPA up to date. RPA is a market-licensed software platform used to build scripts to integrate applications through a user interface and a control panel or coordinator. RPA platforms automate repetitive, rule-based, and predictable tasks.

Minimally an RPA platform should: allow developers to build robotization scripts, enable integration with the enterprise environment primarily via a user interface, and contain coordination and administration capabilities (including configuration, monitoring, and security). Additionally, it is important to say that almost all platforms have native interfaces with external programming languages, facilitating the integration of Artificial Intelligence and Machine Learning applications. Especially in Python Language, which has many libraries for this purpose.

It is observed in Figure 7 that 18 RPA platforms already exist in the market for acquisition and use by any company. In the quadrant "Leaders," the following four leading platforms can be observed: UiPath, Automation Anywhere, Microsoft (acquired in 2021, the Softomotive), and BluePrism.



Figure 7. Magic quadrant on RPA platforms [27].

Blue Prism pioneered robotic process automation and was founded in 2001 in the UK, developing robotic process automation software to eliminate repetitive manual work. Its RPA product, the Intelligent Automation Platform, includes the following main components: Blue Prism Cloud, Automation Lifecycle Management (ALM), Capture, Interact, Decipher IDP, and Digital Exchange (DX). It also includes governance tools and security features. Blue Prism guarantees its customers a platform capable of quickly creating and implementing robots to perform digital tasks, providing appropriate and flexible tools with the security of processes and systems. Blue Prism has a solid vertical market strategy, with experts, campaigns, partners, and accelerator tools focused on the industry. It offers 42 industry-specific solutions and has a large customer base spanning most of the productive sector.

UiPath is the leader of this Magic Quadrant. The Romanian company, UiPath, initially named DeskOver, was founded in 2005 to build automation scripts. But it was not until 2012 that the company began operating in RPA, launching in 2013 its first product in the industry. In 2015, the company launched its corporate platform and changed its commercial name. Its platform offers many governance capabilities, a developer-friendly UX, enhanced computer vision, and cloud-coordinated RPA. UiPath provides its customers with a platform to create and implement robots that automate any process in various sectors. According to the company, these robots rely on artificial intelligence to perform more complex processes or data analysis. Although its founding is later than its competitors, this is the fastest-growing software company in the industry. The company's growth was driven by major investors such as Google and funds such as Accel and Sequoia. Thus, UiPath currently has a high market value and has 31 offices worldwide.

Automation Anywhere was founded in 2003 in California, developing software for robotic process automation. The company ensures the availability of tools for creating software robots capable of automating any process. Its product, Automation 360, is an RPA platform that includes RPA as a service, Automation Anywhere Robotic Interface (AARI), AI/ML (IQ Bot), discovery processes (Discovery Bot), analytics (Bot Insight), and marketplace integration (Bot Store). From a skilled, flexible, and secure platform, the company guarantees to be the most advanced and complete on the market. Also, the platform exposes the use of cognitive automation to use more complex data and integrated analysis for applications with Operational and Business Intelligence. Currently, the company already has partners in several countries, including Brazil.

Microsoft is in the lead quadrant due to its Power Automate product, which includes Power Automate Desktop (PAD) increased for Microsoft's SaaS-based automation platform in Azure. It also provides API integration and coordination features. Microsoft provides fully integrated features as part of the Power Platform, i.e., Power BI (for analysis), Process Advisor (process mining), Power Apps (LCAP), API connectors, and Power Virtual Agents (chatbots). It is known to the market that in 2021 Microsoft acquired Softomotive, a UK company founded in 2005 and one of the pioneers of robotic process automation. With assisted automation options, interacting with humans, and autonomous (robots acting independently), Softomotive provided customers with a platform that includes, in addition to RPA, AI tools to ensure better performance and results in any process. So, Microsoft is expected to integrate all of its Powers tools soon (Automate, Flow and BI) with Softomotive RPA.

CONCLUSIONS

From the studies analyzed, it can be verified that there is a more significant amount of research on the RPA with machine learning, indicating that this is a new and promising subject with application in several areas.

The review contributed significantly to the chosen theme. It helped to understand the possibilities in developing the theme and demonstrate the potential of using AI techniques. The objective and automated administrative processes mapped in a public university had met the lack of replacement of servers in the administrative areas of the university.

The information gathered here has allowed us to decant which RPA techniques associated with intelligent systems can meet applications aimed at managing people in the public sector. Use these automation techniques in process processing and an innovative approach due to the low number of related articles in RPA but has high visibility and demand in state agencies. The theme also encompasses scientific relevance because it determines a fully expanding approach and increased complexity. After all, the systems involved have increased interaction with their customers, requiring innovative approaches to artificial intelligence in the natural interface with humans, aiming to reduce labor with these activities, reduce the time of service, and mitigate costs.

There are many possibilities to classify the selected papers shown in this paper. Many criteria can be used, including the application filed. A future paper has been prepared with this perspective analyzing the advances proposed by RPA techniques in a specific field of knowledge.

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