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Design and Implementation of an Automated CFDI Analysis Algorithm for Accounting and Tax Optimization in SMEs

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Abstract. This study aimed to develop and evaluate an algorithm designed to reduce the time required for the analysis of Digital Tax Receipts (CFDI), with application to small and medium-sized enterprises (SMEs). Using a mixed and experimental approach, the performance of the algorithm was compared with manual review conducted by 170 Financial Engineering students. The results indicated that the algorithm was significantly more efficient, achieving an average reduction of 220.14 seconds and a very large effect size (Cohen's d = 3.77). Furthermore, the algorithm achieved an effectiveness rate of 88% in determining the validity of CFDIs with respect to their deductibility for tax purposes, thereby highlighting its potential to optimise processes, improve productivity, and support decision-making in accounting and organisational contexts.
Keywords: Digital Tax Receipts, process productivity, robotic accounting, sequential algorithm.

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1 Introduction

Artificial Intelligence (AI) has been envisioned as a unique tool in the field of information technologies. However, in reality, its application extends to various domains, including the economic sphere. In this context, the objective is to automate administrative or accounting processes and enable machines to make decisions in a manner similar to humans.

A recent study provides evidence of how AI contributes to improving accounting and auditing practices in the context of an emerging country. The findings of this study may help companies efficiently leverage AI developments to enhance their accounting and auditing operations (Abdullah & Almaqtari, 2024). However, resistance to change, organizational culture, lack of trust, and the high cost of technology represent critical barriers to the adoption of AI in managerial accounting.

On the other hand, the acceptance of AI technology among accountants in Romanian organizations has been evaluated, showing that the implementation of AI solutions in managerial accounting offers multiple options to managers, improves the use of accounting information, and is relatively easy to use due to its high degree of automation and customization (Vărzaru, 2022). One of the areas of AI is logic programming, in which algorithms are described to perform specific tasks in a structured manner. In the accounting field, the use of AI has demonstrated significant benefits, as it maximizes time efficiency in routine tasks and improves both the accuracy and effectiveness of accounting processes (Sánchez & García, 2023).

In recent years, progress has been made in concepts such as robotic accounting, which aims to increase the operational efficiency of accounting processes in companies. In countries such as Argentina, Chile, Colombia, and Peru, investments in technologies during 2021 have positively impacted the automation of accounting processes (Larios & Atoche, 2023). These technologies have been adopted by accounting professionals who have specialized in their use, regardless of the perception that such tools belong exclusively to other areas, such as computer science. However, the most significant challenges for small and medium-sized

enterprises (SMEs) remain management and innovation, due to their dependence on human intervention in administrative processes—an expense that can affect their financial situation (Zapata, 2004).

Management models have attempted to minimize these issues but have not sufficiently addressed the technological elements necessary for continuous improvement. Although, in some cases, productivity in administrative processes has improved, failures still persist that negatively affect the productivity of SMEs (Rizzo & Plaza, 2024). Burga (2023) points out that one of the main problems faced by SMEs is the lack of financial and technological management. These entities, which are essential for the economy due to their production capacity and employability, require urgent attention to these critical areas.
This study focuses on the development of a sequential algorithm for the management of Digital Tax Receipts (CFDI), with the objective of improving accounting management in terms of time efficiency. A mixed methodology, both qualitative and quantitative, was employed to evaluate execution times and accuracy across two methods: the automated method using the sequential algorithm and the manual method performed by humans. The efficiency of the algorithm was compared with manual review, demonstrating how this technology can reduce processing times and increase accuracy in tax validation.

This article addresses the current challenges in accounting management and analyzes how automation through a sequential algorithm can optimize accounting processes in SMEs. Furthermore, it provides a detailed comparison between manual and automated methods, highlighting the practical implications of these findings for improving operational efficiency and accounting accuracy.

2.-State of the Art

Artificial Intelligence (AI) has demonstrated significant improvements in various processes within accounting, particularly in routine tasks such as bank reconciliations and tax procedures. This allows the saved time to be allocated to strategic decision-making within organizations (Sánchez & García, 2023).

In agricultural accounting, AI has contributed to three-dimensional accounting, considering corporate social responsibility, economic-financial records, and social and environmental elements. This facilitates decision-making in uncertain situations and the management of large volumes of information (Cando, 2023).

Although AI has been of great assistance in accounting, its implementation involves high costs related to infrastructure and staff training. Moreover, AI raises ethical challenges concerning transparency, accountability, and information privacy (García, Juca & Torres, 2023).

In the field of auditing, AI has facilitated strategic oversight by minimizing procedures. However, the lack of regulation and the adoption of International Auditing Standards (IAS) have driven research in this area, particularly in European and Asian countries such as China and Japan (Wassie & Lakatos, 2021).

Despite AI's advances, legal and ethical concerns persist regarding the use of information and data processing, especially in financial market accounting. Therefore, regulation within a legal framework is recommended to ensure trust in the use of AI (Montagnani, Najjar & Davola, 2024).

Handoyo (2024) highlights the importance of integrating new technologies into accounting, including AI, data analytics, and Information and Communication Technologies (ICTs), underlining the need to train accounting professionals to face these new trends.

Resistance to change, organizational culture, lack of trust, and the high cost of technology are critical barriers to the adoption of AI in managerial accounting. A study assessed the acceptance of AI technology among accountants in Romanian organizations, showing that the implementation of AI solutions in managerial accounting provides multiple options to managers, improves the use of accounting information, and is relatively easy to use due to its high degree of automation and customization (Vărzaru, 2022).

Studies emphasize that digitalization and the adoption of advanced technologies are transforming the accounting profession. Moll & Yigitbasioglu (2019) indicate that AI and machine learning offer opportunities to enhance efficiency and accuracy in financial decision-making. Kokina & Davenport (2017) point out that robotic process automation enables accountants to focus on higher value-added activities, such as financial decision-making.

In the context of SMEs, digitalization and automation have been observed at different stages of development. A study examined the current state and trends of digitalization in SME accounting, highlighting users' trust in the collected information and the usability of digital services, while underscoring the influence of Industry 4.0 trends on the accounting profession (Fülöp et al., 2022).

AI has been specifically evaluated through the ChatGPT tool in versions 3.5 and 4, showing unfavorable results in technical aspects of accounting such as preparing financial statements, journal entries, or using accounting software (Cheng et al., 2024).
Scientific evidence projects AI growth of 76% by the year 2030, promising to improve business outcomes and enhance human experience. In the financial sector, software robots have replaced human workers in handling loan applications within microseconds and providing rapid investment advice (Praful, Kurien & Ahmed, 2023).

The success of business operations is increasingly envisioned with the aid of AI, as conventional methods have been replaced by automated processes that, through computational layers, are capable of performing operations that would otherwise take humans an excessive amount of time. In summary, it is about having a system capable of adequately interpreting external data and using that knowledge to achieve specific objectives and tasks (Perifanis & Kitsios, 2023). The AI revolution in accounting is ongoing, and it is expected that the intellectual capacity required to analyze results will increase, even if the need for human labor decreases (Özcan & Akkaya, 2020).

AI has also been regarded as a valuable support for companies in addressing the challenges posed by rapid technological progress in human life and business. This demonstrates that AI, created by humans, impacts all business activities, improving market management (Yathiraju et al., 2023).

Recent research has identified AI as a tool in the financial industry to achieve better customer experiences, efficient supply chain management, greater operational efficiency, and reduced workforce size. The primary objective of AI is to design standard and reliable methods for product quality control and to develop new ways of reaching and serving customers while maintaining low process costs (Pallathadka et al., 2023).

In the tax domain in Mexico, Article 29 of the Federal Tax Code establishes the obligation to issue Digital Tax Receipts (CFDI) for transactions carried out by taxpayers, citing Article 29-A of the same legislation for the requirements that these CFDIs must meet. These requirements include: (I) Name, trade name, or business name of the issuer and receiver of the receipt; (II) Folio number assigned by the SAT; (III) Place and date of issuance; (IV) Taxpayer Identification Number (RFC) of the person to whom the CFDI is issued; (V) Quantity and type, as well as a description of the product or service; (VI) Unit value, total amount, and applicable taxes; and (VII) A valid digital certificate in the CFDI.

The analysis of a large volume of CFDIs implies the possibility of errors in data processing aspects such as amounts and taxes, as well as in determining their validity for tax purposes, turning this task into a routine. This has led to situations where, in audits conducted by the Mexican tax authority (Servicio de Administración Tributaria), judicial procedures have been carried out to establish the reasonableness of the origin of the services or products indicated in the CFDIs. In the last decade in Mexico, 72% of the cases presented before the Federal Court of Administrative Justice (TFJA) were related to disputes arising from the incorrect recording of CFDIs in the accounting records of entities (individuals or corporations) (INEGI, 2015).
Since the issuance of CFDIs became mandatory in Mexico in 2009, eliminating the concept of paper invoices, the number of issued receipts has increased significantly, resulting in a high volume of digital invoicing. This growing frequency of CFDI issuance over the years underscores its importance in the tax sector, particularly regarding effective revenue collection from 2012 to 2024. Figure 1 shows the constant annual increase in CFDIs, which has created a heavy workload for the tax authority that must analyze these documents and verify compliance with tax regulations. Likewise, taxpayers must ensure that the items are valid for tax purposes.

3.- Methodology and Method

3.1 Methodology

This study adopted a mixed methodological approach. In the qualitative phase, human performance in executing accounting tasks was observed and compared with that of an algorithm designed to manage Digital Tax Receipts (CFDI) in a real environment. The quantitative phase focused on a descriptive statistical analysis to evaluate and contrast the processing times between human operators and the computational system. The experimental design included the controlled manipulation of variables, which

allowed the identification of optimal automation strategies aimed at improving efficiency in the accounting management of small and medium-sized enterprises (SMEs).

3.2 Method

In the initial phase, the manual process of reviewing a tax receipt was analyzed, evaluating its deductibility and verifying the recorded amounts. Based on this analysis, a flowchart was developed that described each stage of the procedure in detail. Using this model, an algorithm was implemented that could automatically read the Digital Tax Receipts (CFDI) of an organization, extract and automatically incorporate the relevant numerical data, and determine their validity according to the criteria established by Mexican tax legislation.

In the second stage, corresponding to the experimental phase, efficiency was evaluated and compared—measured in terms of processing time—in the acquisition of information from CFDIs using two approaches: manual data entry performed by individuals and automated processing executed by the algorithm.

3.2.1 Participant Selection

A total of 170 students from the Financial Engineering program were randomly selected, applying the finite population sampling formula. This sampling method ensured a representative sample of sufficient size to enable robust statistical analysis, with a 95% confidence level.

$$n = \frac{(Z^2 * N * p * Q)}{(e^2 * (N-1) + Z^2 * p * q)}$$

Where:

- N is the total population of Financial Engineering students,
- Z is the confidence coefficient corresponding to the 95% confidence level,
- p and q are the expected proportions of success and failure, respectively,
- e is the allowed margin of error.

3.2.2 Manual Data Entry Procedure

For the manual data entry phase, 20 computer stations with uniform specifications were made available: 11th Gen Intel (R) Core (TM) i7-1165G7 @ 2.80 GHz processor, 16 GB of RAM, and a 64-bit operating system. The students, organized into groups of 20, used these stations to manually record CFDI information in a Microsoft Excel spreadsheet (version 2016).

Prior to the start of the task, a detailed explanation of the procedure was provided, which included:

- Recording data such as the issuer's name, RFC, amount, and applicable taxes.
- The decision rules to determine the deductibility of the CFDI.

The time spent by each student to complete the data entry was timed and recorded individually in order to carry out a subsequent analysis.

Figure 1. Explanation given to the students for manually recording CFDI data in an Excel spreadsheet. Source: Author's own work.

3.2.3.- Algorithm Execution

Once the manual data entry was completed, each student used the developed algorithm to automatically acquire information from the CFDIs. The execution of the algorithm was carried out under the same hardware and software conditions used in the manual phase, thereby ensuring uniformity across the tests.

Based on the developed algorithm, it performs the automatic reading of the tax receipt provided to it, subsequently displaying the extracted data on the screen. The visualization can be carried out either in an external window or within the same interface where the algorithm is executed, beginning with a startup process that enables the automatic analysis and processing of the CFDI.

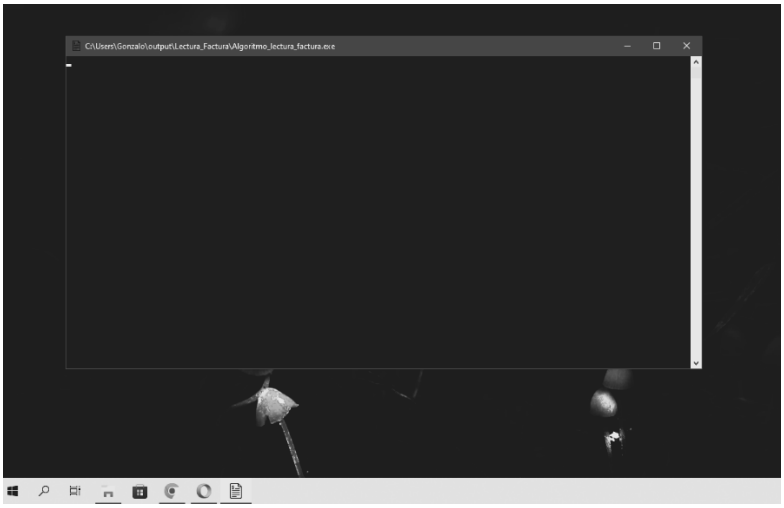

Figure 2. This image shows the algorithm's initial interface with the user.
Source: Own elaboration.

Subsequently, the algorithm has the capability to enable the selection of the Digital Tax Receipt over the Internet (CFDI) through an external window. This functionality, integrated into the main interface, provides the user with a preview and control over the files they wish to upload.

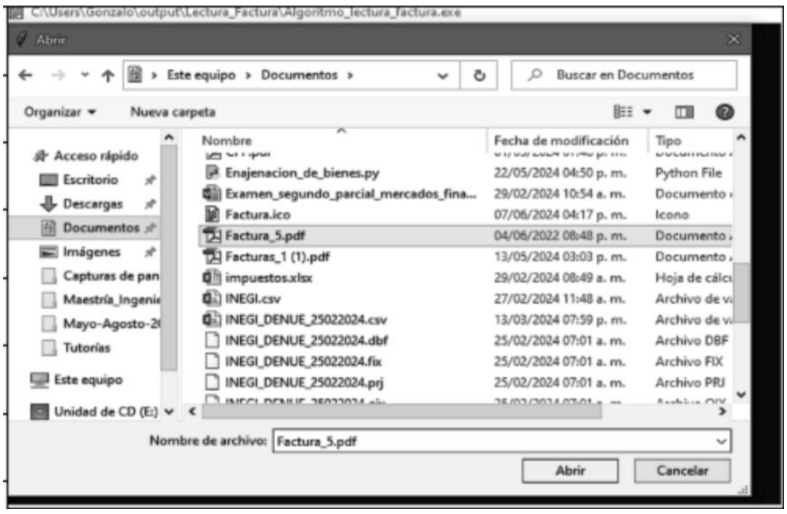

Figure 3. This section loads the CFDIs that are to be analyzed by the algorithm.
Source: Own elaboration.

Once the file is loaded, the algorithm displays the complete information of the Digital Tax Receipt over the Internet (CFDI) in an external window, allowing the user to review the document before exporting the data to the system's main interface.

Figure 4. In this section, the CFDIs are analyzed externally to the algorithm, creating a window for CFDI visualization. Source: Own elaboration.

Once the CFDI information is read, it is transferred to the algorithm's internal screen, where it becomes available for the user to select data such as the amount and description. Based on this information, the system automatically determines the deductibility of the receipt in accordance with Mexican tax legislation. Subsequently, after registering the CFDI's description and subtotal, the algorithm automatically calculates the Value Added Tax (VAT) and the total of the invoice, and then stores and exports this data to an external Excel file. Upon completing the export process, the algorithm uses the previously registered description to automatically determine whether the CFDI is tax-deductible, displaying a dialog box to the user that confirms the successful generation of the result.

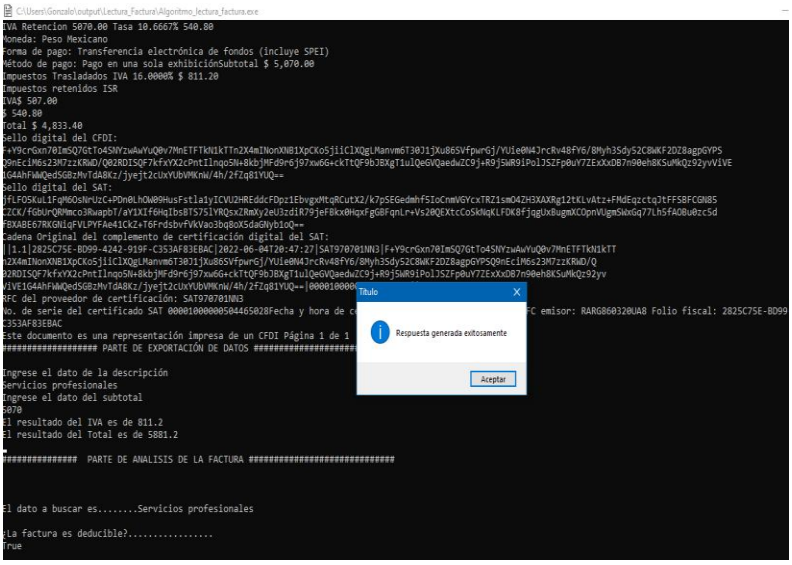

Figure 5. In this section, the algorithm displays a dialog box where the process determines whether the CFDI is deductible. Source: Own elaboration.

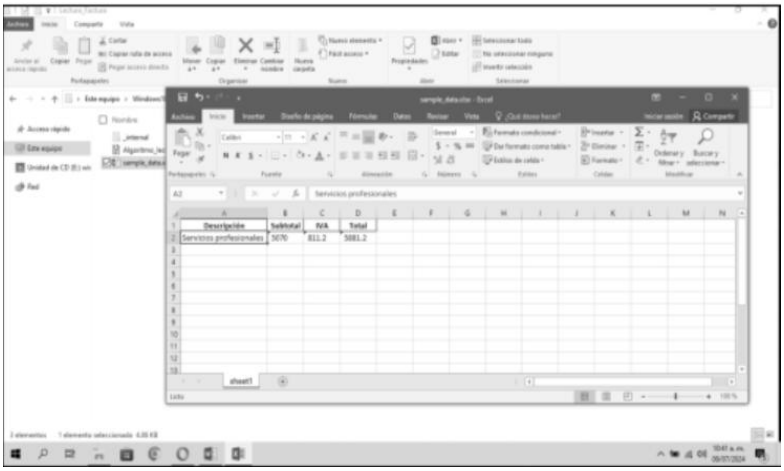

Figure 6. This image shows how CFDI data is automatically exported to an external file. Source: Prepared by the author.

4. Results and Discussion

The time required by the algorithm to process CFDI data was recorded, with one execution performed per participant, resulting in a total of 170 measurements. These records provided a robust statistical basis for quantitatively comparing the efficiency of the algorithm against the manual method.

To compare execution times between the manual and automated methods, a two-stage statistical analysis was conducted. In the first stage, a paired-samples t-test was applied to determine whether the difference in processing times between the two methods was statistically significant. This test was chosen because the measurements under both conditions came from the same participants, allowing for a direct and controlled comparison.

In the second stage, the effect size was estimated using Cohen's d for paired samples to quantify the magnitude of the difference between the manual and automated methods and to assess the practical relevance of the results. The calculation was based on the

mean of the differences in times and the standard deviation of those differences, providing a precise measure of the improvement achieved through the use of the algorithm. All statistical analyses were performed in RStudio (version 2024.04.2+764).

The paired-samples t-test showed that the difference in execution times between the students and the algorithm was highly significant. On average, the algorithm was 220.14 seconds faster than manual data entry, with a 95% confidence interval ranging from 206.90 to 233.30 seconds. The extremely low p-value ($p < 2.2 \times 10^{-16}$) allowed rejection of the null hypothesis of equal means, concluding that the algorithm is significantly more efficient than manual entry by the students.

Complementing the inferential analysis, the effect size was estimated using Cohen's d, resulting in a value of 3.77. This corresponds to a very large effect size, indicating that the observed difference between the algorithm's execution times and those of the students is not only statistically significant but also practically substantial. The 95% confidence interval, ranging from 3.13 to 4.42, supports the consistency and robustness of this finding.

Figure 13 presents the comparison of execution times for capturing and analyzing Digital Tax Receipts over the Internet (CFDI) using two methods: an automated algorithm and manual entry by students. The boxplots show the distribution of times (in seconds) for each method, highlighting substantial differences. The median times were 45.7 seconds for the algorithm and 266 seconds for manual entry. The interquartile range (Q1–Q3) was 44.4 to 47.2 seconds for the algorithm and 202 to 322 seconds for the manual method. Minimum and maximum values, defined within 1.5 times the interquartile range, were 43 to 49 seconds for the algorithm and 71 to 489 seconds for manual entry; points outside these limits represent outliers. The visualization clearly confirms the greater efficiency of the algorithm compared to the manual procedure.

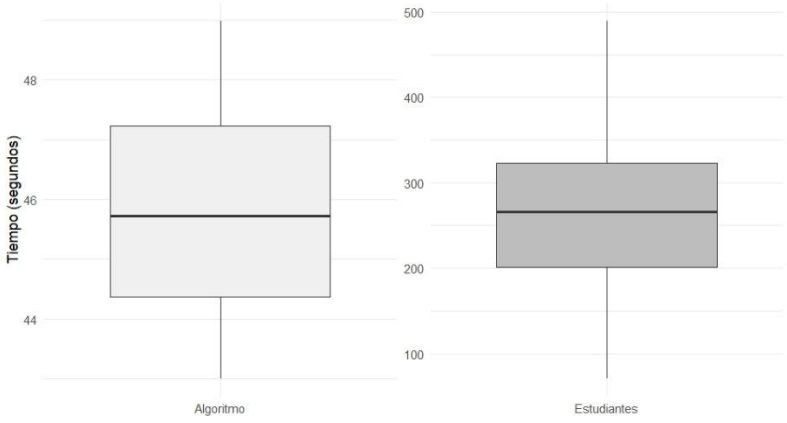

Figure 7. Comparison of execution times between the algorithm and the students.
Source: Own elaboration.

The results demonstrate that the implementation of the algorithm constitutes an effective tool for CFDI analysis, as it processes information more quickly on average than manual entry by a person. This finding aligns with Wassie and Lakatos (2024), who note that artificial intelligence contributes to the strategic oversight of organizations by reducing processing times and supporting more accurate decision-making, ultimately leading to increased productivity.

Similarly, Handoyo (2024) emphasizes the importance of integrating and reinforcing this type of knowledge both in accounting education and in organizational practices. Despite growing evidence of the benefits of automation in the business environment, these tools remain relatively unknown among accounting professionals, particularly in small and medium-sized enterprises (SMEs). Implementing automated processes in the accounting area allows more time for planning and strategic decision-making, generating a positive impact on the efficiency and competitiveness of SMEs.

The relevance of these tools extends beyond accounting to areas such as auditing. Automated analysis of financial information can significantly reduce the time required and improve the quality of decision-making, optimizing organizational processes.

The use of these technologies is highly recommended for SMEs, as digital management of documentation can reduce personnel costs and allow the reallocation of resources toward investments that strengthen operational processes. However, the developed

algorithm must account for the internal particularities of each organization, since, although the analysis of a CFDI may follow a general structure, the specific procedure can vary according to the characteristics and internal policies of each entity.

In this regard, the determination of a CFDI's deductibility should be based on differentiated criteria: 1) for legal entities, on the established corporate purpose, which would allow refining the algorithm's logic, and 2) for individuals, on the history of their operations, which would facilitate identifying patterns and expected concepts in future transactions, improving the system's training for decision-making.

Finally, knowledge of the information gain index constitutes a key metric for evaluating the algorithm's efficiency based on the available data. A value above 70% indicates adequate system learning; however, if it falls below this threshold, additional volume and quality of information will be required to ensure optimal performance.

Together, these findings demonstrate that integrating automated analysis algorithms in CFDI processing not only optimizes time and resources but also enhances the strategic capacity of organizations. This reinforces the relevance of the research, highlighting its practical applicability and potential for adaptation across different business contexts, thereby contributing to digital transformation in the accounting and financial domains.

5. Conclusions

The algorithm developed for the analysis of Digital Tax Receipts (CFDI) demonstrated an average advantage of 220.14 seconds over manual data entry, with a very large effect size (Cohen's d = 3.77). This result shows that automation not only speeds up processing but also significantly enhances operational efficiency.

In addition to reducing processing times, the use of algorithms frees human resources for strategic tasks and improves productivity. Its implementation in accounting education and in SMEs is key to optimizing processes and maintaining competitiveness.

Adapting the algorithm to the specific characteristics of each organization and continuously evaluating its information gain are essential to ensure optimal performance. The integration of artificial intelligence and automation in accounting and auditing strengthens decision-making and fosters more productive and efficient environments.

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