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AI ALGORITHMS IN BUSINESS PROCESS AUTOMATION

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Purpose: The aim of the study is to describe cognitive aspects of intelligent AI algorithms, defined in the context of their evolution, and outline AI functionalities necessary for a given organization to support business process automation. The aim of the research is also to describe process according to the systems analysis method in Graham's approach and the cybernetic systems analysis approach, both of which are elements of organisational preparation for implementing tools enabling business process automation.
Design/methodology/approach: The methodology for defining the factors and the relationship between the factors determining process automation depending on the choice of AI algorithm.
Findings: This paper presents ontological assumptions of business process algorithmization, describes algorithm types and defines new models for managing intelligent algorithms in the development of AI for business process automation.
Research limitations/implications: The limitations of using AI algorithms in process automation include issues with data quality, process complexity, high implementation costs, and difficulties in adapting to changing conditions. Additionally, AI can be problematic due to the lack of decision transparency, dependence on technology, system security, and social resistance.
Practical implications: Depending on the main reason for automating a given process (i.e. repetitive data, actions, or exceptions occurring within the process), one can apply deterministic, organized, or self-programming algorithms.
Originality/value: A matrix of AI functionalities was developed in the context of the rationale for automation vs. the type of algorithm that implements the AI functionalities in automating data flows, activities and the occurrence of exceptions in the business process.
Keywords: algorithms, artificial intelligence, automation, systems analysis, cybernetic approach.
Category of the paper: Conceptual paper.

1. Introduction

The level of business process automation within an organization is determined by the degree of freedom (DOF) in developing algorithms that serve as the basis for programming artificial intelligence (AI) used for process automation. It is assumed that algorithmic intelligence is determined by the method of learning. The less intelligent the algorithm, the more learning it requires, which is primarily based on machine data processing and a machine-to-machine (M2M) interface**.** Thus, if an algorithm relies solely on machine learning, it deals exclusively with data and solves only structured problems within a single-loop of organizational learning. If it employs cognitive learning, it commonly involves a human-to-machine (H2M) interface and relates primarily to information, solving poorly structured problems by applying a double-loop of organizational learning. If an intelligent algorithm is to manage knowledge and solve unstructured problems, it must use a human-to-human (H2H) interface and develop the organization by applying a triple-loop of organizational learning. The cognitive, ontological, and axiological basis of this process involves defining business processes in the context of using management algorithmization functions (Cieśliński, Chomiak, Dudek, 2025). These functions include:

- problem-solving,
- business process optimization,
- artificial amplification of decision-making processes.

To define the assumptions for the present study, it is necessary to describe the model of DOFs in algorithm development, which constitutes a cognitive-methodological and ontological element of the evolutionary stages of management algorithmization. DOFs in the development of algorithms are determined by their ability to learn. The first degree refers to deterministic algorithms, the second to organized algorithms, and the third to self-programming algorithms (based on Lem, 1976, pp. 3-29; Cieśliński, Jasiński, 2024).

In his works, particularly in "Summa Technologiae", Stanisław Lem has explored two types of evolution: biological and technological. Biological evolution is characterized by continuity, where life, once it emerges, develops through a diversity of species, some of which become extinct while others continue to exist. On the other hand, technological evolution, is a dynamic process in which humans create and refine tools and technologies, gradually blurring the boundaries between what is natural and artificial. Lem, referring to Pierre de Latil's book "Thinking by Machine", presents a classification of effectors, which are systems capable of action. He divides them into three main classes: deterministic, organized, and learning systems (including self-learning systems with the highest degree of freedom). By analogy, we can distinguish three basic types of intelligent algorithms, whose management is based on:

- machine processing – deterministic algorithms, coupled to the environment but without feedback (op.cit),
- cognitive processing – organized algorithms, i.e. systems with feedback (negative or positive), built-in determinism, and operational instructions,
- heuristic processing – self-programming algorithms (capable of self-organization), i.e. recursive systems. These are algorithms capable of self-transformation, with their outputs serving as inputs for future events (Buczek, 2009; Tegmark, 2017).

Based on the assumptions presented above, the following research problem can be defined: to what extent and in what manner does the management of intelligent algorithms, in relation to the AI functionalities necessary for business process automation, facilitate the design, programming, and implementation of an AI-based application for solving business process automation problems? The design of intelligent algorithms supporting the generation of efficient AI functions in business process automation must facilitate the collection, processing, and transfer of information regarding the volume and method of processing data, the number and method of processing actions, as well as the number of exceptions within the process and AI algorithm's approach in handling them (Szajna et al., 2022, pp. 359-360). Therefore, from the perspective of managing algorithms, the goal is to design organizations, organize actions based on these algorithms, improve and refine them, as well as analyze their functionalities (Kisielnicki, 1986, p. 40). Thus, algorithms can be used for: designing, organizing, and improving the development of their own functionalities. In turn, each algorithm can be described verbally, using a step-by-step list, a flowchart, a tree structure, a pseudocode, or in the form of a programming language. In other words, an algorithm written in the form of a programming language is called a program, since that language is understandable to the computer (Buczek, 2009, p. 25). Recursive algorithms, which in our opinion serve the function of intelligent algorithms, play a particularly significant role in managing algorithms. They can serve as a foundation for embedding and encoding their structures in a language understandable to computers. This, in turn, can ultimately be used for developing customized Organization 4.0 or AI Organization. On this basis we can put forward the following hypotheses:

- the higher the level of "intelligence" of the algorithm, and therefore its level of complexity, the greater the effectiveness of streamlining and automating business processes,
- an important factor influencing the effectiveness of AI implementation in business process automation is the degree of freedom (DOF),
- deterministic, organized, and iterative algorithms are good for solving structured problems. To solve unstructured problems, it is necessary to use self-programming, recursive algorithms.

2. Algorithms: toward an intelligent amplifier of business process automation. Current state of knowledge

An algorithm is most commonly defined as a sequence of unambiguous instructions designed to solve a specific problem, producing the desired result for any valid input within a finite amount of time (Prakash, 2016, p. 913). Generally an algorithm can be deterministic, consistently producing the same result for the same input, or stochastic, incorporating randomness into its steps. Conventionally, algorithms are classified into (Cieśliński et al., 2024) (Figure 1):

- sequential, iterative, and recursive - based on the processing method they employ,
- linear (sequence) and nonlinear - based on their progression,
- structured, semi-structured, and unstructured - based on the type of problems they solve (they should use: machine, cognitive, or heuristic processing),
- local, mixed, and non-local algorithms - based on their effect,
- with a single, double, or triple loop of organizational learning - depending on the models of organizational learning applied.

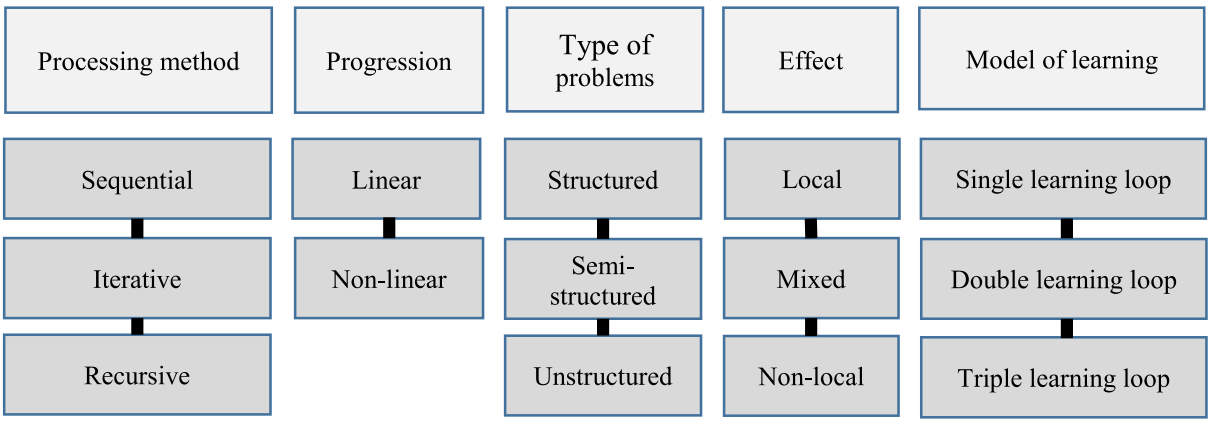

Figure 1. Classification of algorithms according to the adopted assumptions.

Source: Cieśliński et al., 2024.

In turn, an intelligent algorithm is considered a computational method that simulates human thought processes and problem-solving skills to analyze and process complex data. These algorithms most often employ artificial intelligence technologies, including machine learning, deep learning, and data mining (Bouarara, 2017, p. 134).

Based on theoretical descriptions of business models concepts formed by Konieczny (Konieczny, 1986, pp. 33-39) and ourselves using management digitalization and algorithmization (Cieśliński, Chomiak, 2024; Cieśliński, 2024, Cieśliński, Tomanek, 2023; Cieśliński et al., 2023; Hauke, Perechuda, Cieśliński, 2022; Cieśliński, Perechuda, Szewc, 2022; Cieśliński, Chomiak, Dudek, 2025), we propose that AI algorithms used in the management of business process automation and business digitalization must meet several conditions to be applied effectively. We conducted a practical analysis and theoretical synthesis of how intelligent AI algorithms (Cieśliński, Chomiak-Orsa, Dudek, 2025) fulfill the functions expected by AI users in the context of business processes automation. Our thorough analysis demonstrated that these algorithms should meet specific requirements, including the need for a continuous training process (Cieśliński et al., 2025).

Algorithms are the opposite of heuristics. A machine based on a conventional algorithm will never surpass developmental boundaries that enable learning. An algorithm is equipped with instructions that are strictly determined and unchanging until termination. However, it can use instructions that, through feedback, transform themselves, adapting and learning, into a form different from the initial input (Lem, 1974, p. 123). After a certain number of iterations, the algorithm is instructed to apply free search and operate through trial-and-error, which is a step toward heuristics (Lem, 1974, p. 123).

The machine begins to think, and the amplifier of natural intelligence, i.e. Ashby's machine (Lem, 1974, p. 126), starts operating not according to strict deterministic instructions but based on probabilistic reasoning and intuition, which characterize cognitive algorithms and, most importantly, heuristic algorithms (Cieśliński, Chomiak-Orsa, 2023; Cieśliński, Chomiak-Orsa, Dudek, 2025). Due to the fact that recursive algorithms and their mechanisms are based on future events, i.e. predictions necessary for decision-making (Zieliński, 2000, p. 25), the outputs for a given business process serve as inputs for future events. In other words, if the input data is processed into information and the output is knowledge, a predictive process occurs. Namely, this generated knowledge can initiate the creation and forecasting of future events, enabling the organization to make better decisions, adapting and learning to navigate the new reality. This means that instead of starting with data as initial input, the algorithm starts with knowledge, which is then assigned new meaning by forming predictions. The brain contains structures that computer scientists refer to as recurrent neural networks. Recursion is a method of defining a function that invokes itself to solve a problem. In mathematics and computer science, this is a common technique used to solve complex problems by breaking them down into smaller, more manageable sub-problems. Information flows in multiple directions, allowing the current outputs to become inputs for future events (Tegmark, 2017, p. 105).

In turn, intelligent algorithms are computational methods that simulate human thought processes and problem-solving skills to analyze and process complex data. These algorithms use methods such as machine learning, deep learning, and data mining to extract valuable information and patterns from Big Data, thus supporting decision-making processes (Pu, 2024, p. 2). “Intelligent algorithms” (optimization, evolutionary, heuristic) is a general term referring to methods and procedures that imitate certain aspects of human intelligence. These are usually algorithms designed to solve problems that require an "intelligent" approach. Intelligent algorithm management plays a key role in solving organizational problems (Szpringer, 2020; Jiang, 2024; Li, 2024; Koehler, Sauermann, 2024; Hillebrand, 2025), particularly in the areas of process optimization, forecasting, automation, and decision-making, as these algorithms form a structure based on which they themselves are transformed into AI programs (Buczek, 2009, p. 9). Intelligent algorithms are a crucial component of managing Organization 5.0, forming the foundation for solving various types of problems through machine, cognitive and heuristic processing. These algorithms can be classified in various ways (e.g. sequential-linear, iterative-laminar, and recursive-nonlinear). Each of these types has unique properties and applications in the context of organizational problems, organizational learning strategies, and methods of processing data, information, and knowledge. Thus, algorithms, are "recipes" (Cieśliński, 2020; Cieśliński, Tomanek, 2023), that outline all the steps necessary to: automate tasks, actions, activities, and processes; solve problems based on variables such as goals, conditions, and actions; and optimize decision-making by relying on recursions within a finite number of steps and finite time. However, there is a risk of "looping" of recursive operations, i.e. those calling functions, algorithms, and their own processing results (Buczek, 2009; Bhargava, 2017). Thus, an algorithm is only an algorithm when the input data is unambiguously defined and finite, and the output is a clearly specified final result in the form of meaning (Cieśliński, 2020; Buczek, 2009, p. 6). Recursive algorithms are meant to generate input data based on future events rather than historical ones. This is the essence of managing intelligent, recursive algorithms.

3. Overview of AI algorithms

AI algorithms are a more specific subset of intelligent algorithms. They are designed to create machines capable of performing tasks that normally require human intelligence, such as learning, reasoning, problem-solving, and decision-making (Rojas, 2024, p. 2). These algorithms are a particular group of algorithms designed to mimic human cognitive abilities and intelligence, such as machine learning, reasoning, and pattern recognition. In other words, AI algorithms are a subset of intelligent algorithms, but all AI algorithms are intelligent in the sense that they attempt to mimic the human ability to solve problems (Kurp, 2023, pp. 16-32; Kurp, 2022, pp. 9-27).

AI algorithms are a fundamental component of AI technology, designed to enable machines to perform tasks that typically require human intelligence. These algorithms are autonomous sequences of instructions that guide computational machines through a series of well-defined steps to achieve a specific outcome (Deng, 2017, p. 173). AI algorithms are sets of rules, instructions, or computational procedures that enable computers to make decisions, learn from data, solve problems, and perform tasks that have traditionally required human intelligence. They form the basis for AI systems and define how machines analyze data, identify patterns, and generate responses based on input information. Based on the up-to-date subject literature, specifically a review of AI algorithms, we have identified basic types of these algorithms. However, we would like to emphasize that this classification does not entirely align with what we describe in this study. Stated otherwise, we present a typology of algorithms used in AI programming that is in line with current knowledge, but which we creatively challenge and reinterpret. AI algorithms are sets of rules and techniques that enable machines to learn, make decisions, predict outcomes, and solve problems. They are applied in nearly every field of life, enhancing efficiency and accuracy, and automating complex tasks.

AI algorithms have the following characteristics:

- learning – data is used to improve performance over time (e.g. through machine learning),
- adaptability – algorithms adjust to changing conditions or input data,
- autonomy – tasks are performed with minimum human involvement,
- optimization – target solutions aim to maximize efficiency or minimize costs.

AI algorithms are predominantly applied in areas such as (Kathpal, 2024; Williams, 2024; Callier, Sandel, 2021; Biglarfadafan, 2024; Wei, 2023; Ng et al., 2021; Jingxuan et al., 2024; Silviu, 2025): process automation, service personalization, Big Data analysis, improvements in security, medicine and healthcare, transportation and logistics, agriculture, entertainment, education, scientific research, and more. Algorithms implemented in AI enable enhanced manufacturing and service efficiency, save time through automation, reduce operational costs, improve precision, and minimize human errors. Addressing the needs of an AI-driven environment relies on the chosen approach to problem-solving, commonly referred to as the model. These approaches include (Sen, 2020; Xie, 2020; Uddin, Mashwani, 2024):

- supervised learning,
- unsupervised learning,
- reinforcement learning,
- deep learning,
- evolutionary and metaheuristic algorithms,
- natural language processing (NLP),
- hybrid algorithms.

AI algorithms strive for greater interpretability, computational efficiency, and applications in sectors demanding a high degree of autonomy and precision, such as medicine, aerospace, and finance. Advancements in such disciplines as federated learning and quantum computing are also opening up new perspectives for AI algorithm application.

4. AI algorithms as tools for business process automation

Based on the research assumptions presented above, we propose that business process automation can primarily involve deterministic algorithms, i.e. those that, through machine processing, allow for relieving employees from tedious, monotonous, and repetitive tasks focused on data. If the actions in a process are repetitive, occur in large quantities and with high frequency, and the process involves not only the management of data but also of complex actions and tasks, organized algorithms should be applied (according to the typology proposed). These are algorithms whose processing mechanism is slower compared to deterministic algorithms, but through feedback (positive or negative) they are able to efficiently process the information necessary to handle thousands of repetitive actions over time and within a specific process. In turn, self-programming algorithms based on heuristic processing can be used in the automation of processes where exceptions cannot be excluded (they are suitable for automation but anticipate the occurrence of exceptional situations). In such cases, the algorithm must adapt to the situation through recursive mechanisms, where the outputs serve as inputs for future states, and the subject of analysis is the knowledge the algorithm has within a given process. The intelligence of the algorithm must be directly proportional to the main subject of automation.

If the subject of automation comprises solely large volumes of data records to be processed, the main functionality of AI expected by the user is quick and flawless processing of large amounts of data by the algorithm through an M2M interface. If the subject of analysis constitutes actions within a process, the algorithm must use feedback in such a way as to optimize these actions. If exceptions occur within the process, the algorithm must be capable of operating through trial and error until it learns through recursions how to respond to changes.

Table 1 presents an AI Functionality Matrix in the context of automation determinants relative to the type of algorithm that implements AI functionalities in automating data and action flow, and in handling exceptions within a business process.

Table 1.
AI Functionality Matrix in Process Automation

Intelligent algorithm/ subject of analysis	Data	Actions	Exceptions
Deterministic	AI sequentially processes a large volume of repetitive data within the process - OPTIMIZATION	AI functionalities based on deterministic machine processing algorithms are inadequate for the complexity of the subject of analysis	AI functionalities are insufficient to handle exceptions within the process - INSUFFICIENCY OF AI FUNCTIONALITIES
Organized	AI based on intelligent algorithms using feedback is too time-consuming for analyzing large volumes of data records	AI iteratively processes a large number of repetitive actions within the process - OPTIMIZATION	AI can loop while handling exceptions

Cont. table 1.

Self-programming	AI based on a self-programming algorithm is redundant - REDUNDANCY OF AI FUNCTIONALITIES	AI based on a self-programming algorithm can be useful when repetitive actions involve the risk of exceptions to the established rules, norms, patterns, and operational models	AI recursively processes knowledge about exceptions occurring during the process that is being automated - OPTIMIZATION

Source: own work.

The matrix describes the relationships between factors determining process automation (the amount of data, the number and frequency of actions performed in the process, or the possibility of exceptions occurring in the process that is being automated) in relation to the type of algorithm. It shows whether AI is based on a deterministic sequential algorithm, an organized iterative algorithm, or a self-programming algorithm – in this context, a recursive algorithm, meaning one where the outputs serve as inputs for future events. Therefore, depending on the main reason for automating a given process (i.e. repetitive data, actions, or exceptions occurring within the process), one can apply deterministic, organized, or self-programming algorithms. The use of an algorithm that is inadequate for the subject of analysis may result in operational redundancy, such as applying complex algorithms to simple tasks, and vice versa, i.e. using overly simple algorithms for complex problems (Cieśliński, Jasiński, 2024). Therefore, the methodology for selecting an algorithm to handle the process that is being automated must take into account two aspects: the subject of automation and the type of algorithm applied for automation (https://academy.uipath.com/learning-plan; https://www.uipath.com; Sobczak, 2024; https://www.analitykarchitekt.pl/strategia-ai).

5. Conclusions

Algorithms with high complexity, based on recursion mechanisms, can be used to program AI for automating processes associated with the occurrence of exceptions. Organized, iterative algorithms can be used to program AI for managing the automation of processes that involve a large number of repetitive actions. Simple, deterministic, sequential algorithms can be used to program AI for automating processes that involve handling large volumes of data. They do not require iteration or recursion; they are simply designed to operate automatically without unnecessary time delays.

The research has shown that the use of different types of algorithms for automating business processes enables enterprises to tailor the level of automation to their individual requirements. Organizations can choose the appropriate type of algorithm based on the nature of the problem. The DOF theory demonstrates how the algorithmic degree of freedom serves as a solution for harnessing AI capabilities in business processes. The higher the level of intelligence (e.g., self-learning algorithms), the greater the flexibility in solving unstructured problems. Application of intelligent algorithms leads to significant improvements in business process management - increased efficiency, reduced operational costs, and the ability to adapt flexibly to changing circumstances.

The AI functionality matrix proposed by the authors allows for the empirical matching of appropriate algorithms with business process automation requirements, based on factors such as the volume of data, functionalities, and handling exceptions.

The article indicates that the use of artificial intelligence algorithms is associated with several ethical and regulatory challenges. The authors point out problems related to data quality, process complexity and high implementation costs. Particular attention is paid to the issue of transparency of decisions, which may give rise to concerns about "black boxes", i.e. the inability to explain how the algorithms make decisions and the steps they take. Additionally, the article emphasizes the dependence on technology and the problem of system security, especially in the context of using local AI models trained on company data, which indicates potential privacy and security threats related to the use of AI. An important aspect is also social resistance, which may result from employee and user fears of automation, being treated unfairly, being too closely monitored and observed or analyzed, and a lack of understanding of how AI works.

Introducing AI into business processes requires taking these challenges into account - both at the solution design stage and in the implementation process.

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