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Editorial: Artificial Intelligence and Operations Research in the Supply Chain

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1 Artificial Intelligence in Operations Research

Different authors during the development of computer science have dedicated appropriate words to define Artificial Intelligence (AI), almost all of them equally valid. In a wide sense, it has been defined considering its origin and the way that intelligence is coded and transferred to devices to perform operations or to optimize processes for decision-making. In this way, it is notable the relation with multiple areas, for example, Operations Research (OR), which makes use of techniques from mathematical modelling, statistical analysis and optimization for decision-making. As it can be seen, both AI and OR have an intersection in the area known as decision-making, which does not mean that this is the only aspect where they cross.

Even though many areas use AI to solve their problems, it is and will remain a branch of computer science. AI introduces efficient algorithms for computational applications to present an intelligent human-like behaviour while performing tasks with a lot more precision and speed; furthermore, AI aims to simulate human behaviours such as reasoning and even creativity, as in the case of artificial art. AI has made great progress in the last years, which has spread to many areas and also to many different places. An area of interest where many domains, concepts, processes, etc. intersect is OR. For example, OR is usually identified as a sub-area of applied mathematics, however, it includes sundry techniques and methods to improve decision-making and the prized efficiency of a system; these include optimization, queuing theory and simulation.

2 Supply Chain

In the area of models of stochastic processes, the Markov decision process, econometric models, neural networks, expert systems and decision-analysis stand out among others. However, these methods generally require the construction of mathematical models that seek to describe the system, which in turn assumes the existence of a computational link with these tools. OR researchers face the challenge of choosing the right approach that will apply when a problem of this magnitude must be solved. In the beginning, it is common for a researcher or a student to confuse “belongs to” with “is used by” when dealing with an OR tool, due to the multitude of areas and techniques that relate to each other. An illustrative example discussed here is Logistics, which uses OR tools and is applied in Supply Chain (SC) problems. On the other hand, SC also uses AI, as will be described later on.

Two approaches to Logistics allow the understanding of its objective: the first one asserts that Logistics belongs to the supply chain, while the second claims that the logistic networks in supply chains are systems of management networks for the flow of physical goods between the components of the supply chain, conditioned by the geographical distribution and the transportation systems to reduce logistic costs and coordinate the production-distribution processes. On the other hand, Logistics is defined as “the set of corporations formed by suppliers, manufacturers, distributors and vendors (wholesale and retail), efficiently coordinated in their key processes by collaborative relationships to place the supplies or products required in each link of the chain at the precise time and least cost, seeking the greatest impact in the value chain of the members, to satisfy the requirements of final consumers” (See figure 1).

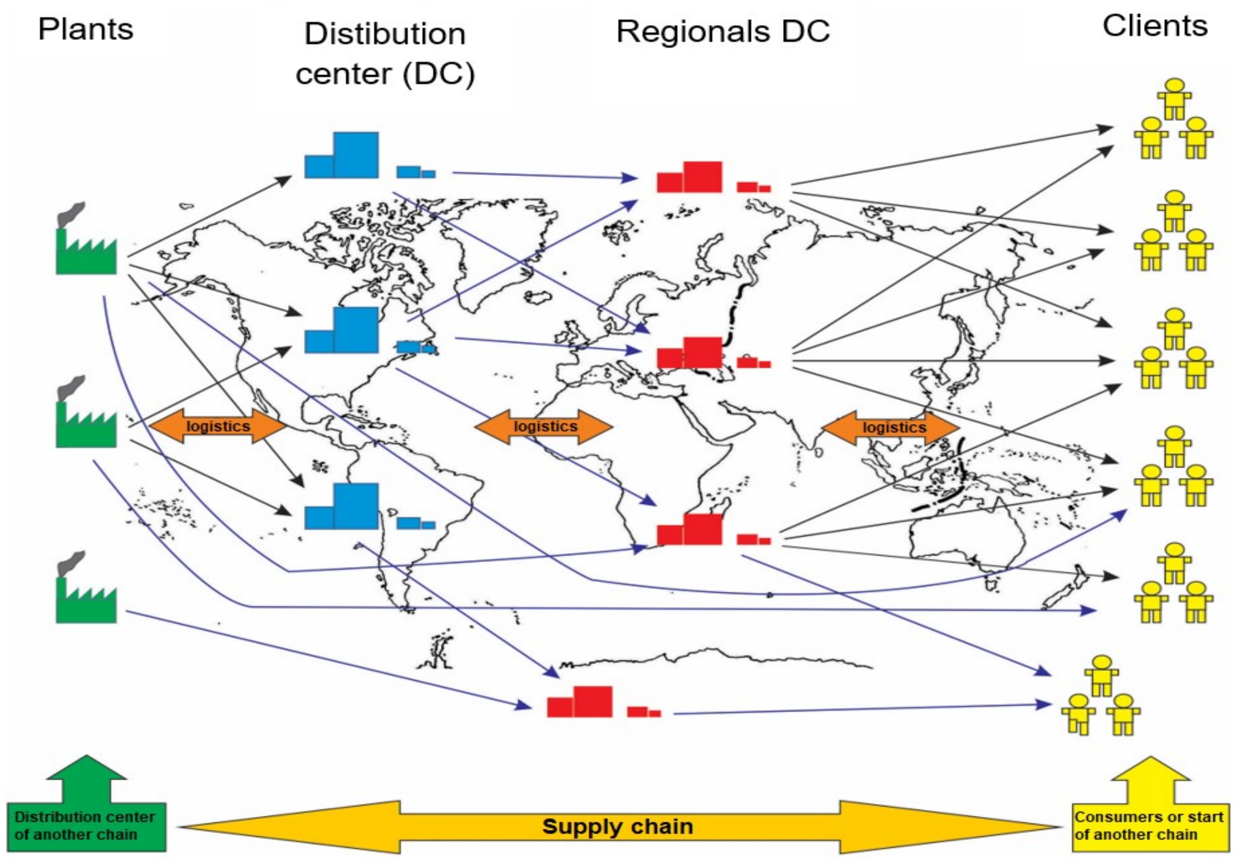

Figure 1. The general structure of a logistic network (own elaboration)

Figure 1 represents the components of a generic supply chain as a four-level network of 3 plants, 3 distribution centres, 4 regional distribution centres and clients. Note that plants and clients can be part of another supply chain and that the network has three stages between its levels 1) Plant-distribution centre, 2) Distribution centre-regional distribution centre and 3) Regional distribution centre-clients. The network shows that at each stage a logistic distribution plan must be implemented, forming a logistic network along the chain.

It follows that logistic networks in the supply chain are systems of management networks for the flow of physical goods or services between the components of the supply chain, conditioned by the geographical distribution and by the transportation systems to reduce/minimize logistic costs and to coordinate the production-distribution processes (CP).

Towards Artificial Intelligence in Location-Allocation

Two important features must be considered in the design of logistic networks: 1) the balanced geographical distribution of the units that form the supply chain, based on client's demands and 2) the satisfactory performance of logistics in the supply chain is determined to a high degree by the location of the distribution centres (location-allocation problem). This last point means a territory design problem is involved, which is informally understood under the logistical approach as the division of a territory with a centre in each group that attracts the nearest objects called clients. However, the general description of a territory design problem involves the grouping of small geographical areas (called basic areas or units) into larger areas called territories, where an acceptable grouping meets predetermined criteria for the problem at hand. Depending on the context, these criteria can be financially motivated (potential sales average, number of jobs, number of vendors) or can have a demographic background (number of inhabitants, voting population) or even distribution-supply or service location, among others [3]. These territory design criteria, in a theoretical definition, tend to be framed as objective functions and/or restrictions in an optimization model, and have been demonstrated to be an NP-hard problem.

Thus, considering that some approaches and methods used to solve territory grouping are combinatory, the computational complexity of a supply chain is warranted, given that it involves territory distribution, which is NP-hard. At this point, we are closer to identifying the intersection between supply chain problems (which uses OR tools) and AI, specifically the use of AI in the logistical problems of the supply chain (like the location-allocation problem, which has been identified as a territory design problem).

Let's keep in mind that hard problems are those where the number of operations necessary for an algorithm to solve the problem is a non-polynomial function, hence it is necessary to develop strategies to find good solutions at a reasonable computational cost and thus meta-heuristic methods can help to find near-optimal solutions.

Meta-heuristics are approximate methods designed to solve combinatorial optimization problems when the classical heuristics are not effective. The meta-heuristics produce a general framework to create new hybrid algorithms, combining different concepts derived from AI, biological evolution and statistical approaches.

The complicity between SC and AI can be observed at this point because they share at least concepts derived from nature that AI provides to build bio-inspired hybrid meta-heuristics, that are needed to solve location-allocation problems. That is, considering that location-allocation problems require territory design for their solution, which in turn is NP-hard, then it is necessary to integrate meta-heuristics (that might as well be based on AI) that emulate the behaviour of living beings or are based on other biological aspects of nature. Some of the algorithms rightly labelled as bio-inspired in AI are genetic, evolutionary, swarm intelligence and artificial ecosystems.

It is important to point out that Logistics is part of SC and uses tools from OR to solve logistical problems of facility location and client assignment, routing, goods or services distribution, inventory, material supply and transportation.
Another definition establishes that a supply chain (SC) is a network of corporations that produce, sell and deliver a product or service to a second given market and includes the manufacturers and suppliers, carriers, warehouses, retailers and the clients themselves, among others.

For a successful network, it is important to oversee the relationship between the participants and their resources, such responsibility falls to the Supply Chain Management (SCM), which has among its tasks the planning process, implementation and control of the supply chain operations.

Due to technological improvement, specifically in areas such as communications, computational processing, management and storage of information, it is possible to support the management of supply chains making it more efficient. In this context, AI has been applied in different SCM processes like materials purchase management, transportation management, production management, warehouse management and inventory management, among others. However, it is of interest to find the AI approaches more commonly applied to SC processes, as previously mentioned, it has been found in the literature that the following approaches from AI are used in SC: Data mining, Genetic algorithms, Fuzzy logic, Neural networks, Ontology, Decision trees, and Intelligent agents.

Finally, the previous paragraphs help explain the use of AI in OR. The expectation for AI in organizations that use OR for resource optimization is to improve the development of tools that allow cost reduction, resource distribution, fraud detection, online help and knowledge capture, in addition to improving product quality, allowing error minimization and manufacturing defects, since with process automation and control it is possible to achieve higher quality standards, by incorporating intelligent decision agents, neural networks, expert systems, genetic algorithms and programmable automata. This AI approaches seek to control independently and in coordination with other agents, industrial components such as manufacturing or assembly cells and maintenance operations. There exists an increasing tendency to implement more intelligent and autonomous manufacturing/assembly systems due to the market demands for products with very high levels of quality, which are not easy to achieve with manual operations.

In general, AI has contributed to building more efficient production and quality control systems with satisfactory results, therefore, the inclusion of AI is important in decision-making for organizations to minimize errors and maximize quality.