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[Nelson Jhoel Quispe Velasco](#) * and Rocio Cristel Quispe Chura *

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Article

Hybrid Optimization Software with Big Data

Rocio Cristel Quispe Chura *, Nelson Jhoel Quispe Velasco *

Universidad Nacional del Altiplano, Puno, Perú Facultad de Ingeniería Estadística e Informática

* Correspondence: rociocristel12@gmail.com (R.C.Q.C.); vjhoel06@gmail.com (N.J.Q.V.)

Abstract: This article presents the development of a hybrid optimization software designed for inventory management in supermarkets, leveraging Big Data and advanced algorithms. The system integrates Artificial Neural Networks (ANN), Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO) to address critical variables such as current stock, monthly demand, unit cost, and sales price. By combining predictive analytics with optimization techniques, the software reduces costs, enhances decision-making accuracy, and prevents overstocking or stockouts. The results demonstrate significant improvements in efficiency, offering a robust and adaptive solution for dynamic market conditions and promoting sustainability in inventory management.

Keywords: hybrid optimization; inventory management; big data; artificial neural networks; genetic algorithms; particle swarm optimization; ant colony optimization

Summary

This article examines improving supermarket inventory management using hybrid optimization techniques supported by big data technology. It proposes integrating advanced algorithms such as neural networks, genetic algorithms, particle swarms and ant colonies to optimize key aspects such as current inventory, monthly demand, unit cost and sales price.

This approach combines forecasting and optimization techniques to reduce costs, improve the accuracy of inventory decisions, and avoid problems such as overstocking or stockouts. Additionally, it discusses how a hybrid approach can improve the ability to adapt to dynamic market conditions and provide a better customer experience by ensuring product availability.

This approach includes data collection and processing, scenario simulation and on-the-fly adjustments to ensure a balance between economic efficiency and sustainability. Finally, the operational and strategic benefits of using advanced data analysis tools in supermarket inventory management are highlighted.

Introduction

Efficient inventory management is a fundamental task in supermarkets, where fluctuations in demand and associated costs require innovative solutions. In this context, the program that we will develop seeks to integrate hybrid optimization methods with advanced data analysis techniques, to improve decision making in real time [1]. These methods are especially useful in scenarios where consumption patterns constantly vary, and the ability to respond quickly becomes a key competitive factor [2].

Our program is supported by Big Data technologies, which allow us to analyze large volumes of data from different sources, such as historical transactions and real-time sales data. This not only improves the accuracy of demand predictions, but also reduces the likelihood of errors when managing inventories [3]. This approach makes it possible to address problems such as overstock or lack of products, which are common challenges in the industry [4].

Additionally, we will use hybrid methods such as neural networks combined with genetic algorithms to optimize decisions related to inventory replenishment. For example, neural networks can identify complex patterns in data, while genetic algorithms help find optimal solutions

considering multiple variables [5]. This combination offers greater adaptability to dynamic market conditions, an essential feature for any inventory management program [6].

Another key feature of the program is its ability to integrate with warehouse management systems (WMS), facilitating the automation of repetitive tasks and improving operational efficiency [7]. WMSs also allow accurate tracking of inventory levels, which is essential to avoid losses and optimize product rotation [8]. The implementation of this type of technology has proven to be effective in various studies related to logistics management in supermarkets [9].

The expected impact of the program is not limited to operational improvements alone. We also seek to improve the customer experience by ensuring products are available when they are needed. For example, built-in machine learning can forecast spikes in demand and suggest adjustments to inventory levels to avoid stockouts [10]. This not only increases customer satisfaction, but also reinforces loyalty to the supermarket [11].

Finally, the program will take sustainability into account, optimizing available resources to minimize waste. This aspect is especially relevant in an environment where responsible practices are valued by both consumers and regulators [12]. The use of hybrid methods allows finding a balance between economic efficiency and environmental responsibility, maximizing the positive impact of the program [13].

In conclusion, our program is positioned as a comprehensive solution for inventory management in supermarkets, combining Big Data, advanced algorithms and sustainability. With these elements, we seek to transform traditional processes and adapt to the demands of a constantly evolving market [14, 15].

Methods

General Approach

The general approach of this study is based on the application of hybrid optimization methods combined with Big Data and statistics to improve storage management in supermarkets. This approach is necessary due to the complexity inherent in managing large volumes of inventory data and accurately predicting product demand, two key factors in reducing costs and improving operational efficiency.

Method Selection

The hybrid optimization methods selected for this study combine traditional techniques with advanced Big Data-based approaches. The following methods have been considered in this work:

Genetic algorithms (GA) optimize the distribution of products on shelves and the allocation of space in warehouses, addressing combinatorial optimization problems. Nematzadeh demonstrated how these algorithms manage operational constraints, improving the efficiency of product storage and distribution [16].

Artificial Neural Networks (ANN) are used to predict future demand for products using historical and contextual factors, applying non-linear approaches and aggregation operators, thus improving predictive capacity [17].

Particle Swarm Optimization (PSO) is applied in dynamic inventory management, adjusting parameters such as the inertia factor and search range to improve global convergence and avoid local solutions [18].

Ant Colony Optimization (ACO) is inspired by the collective behavior of ants, which use pheromones to find optimal routes. This approach is applied in combinatorial optimization problems, such as network routing and resource allocation [19].

Hybrid Simulation, combined with predictive and optimization models, evaluates demand scenarios and dynamically adjusts operating conditions. Inspired by hybrid methodologies, it optimizes system performance, ensuring energy efficiency, cost minimization and resolution of operational limitations through advanced computational tools [20]

These methods are chosen for their ability to handle large volumes of data and provide accurate solutions in dynamic scenarios, such as those found in supermarket management.

Justification for Choice of Methods

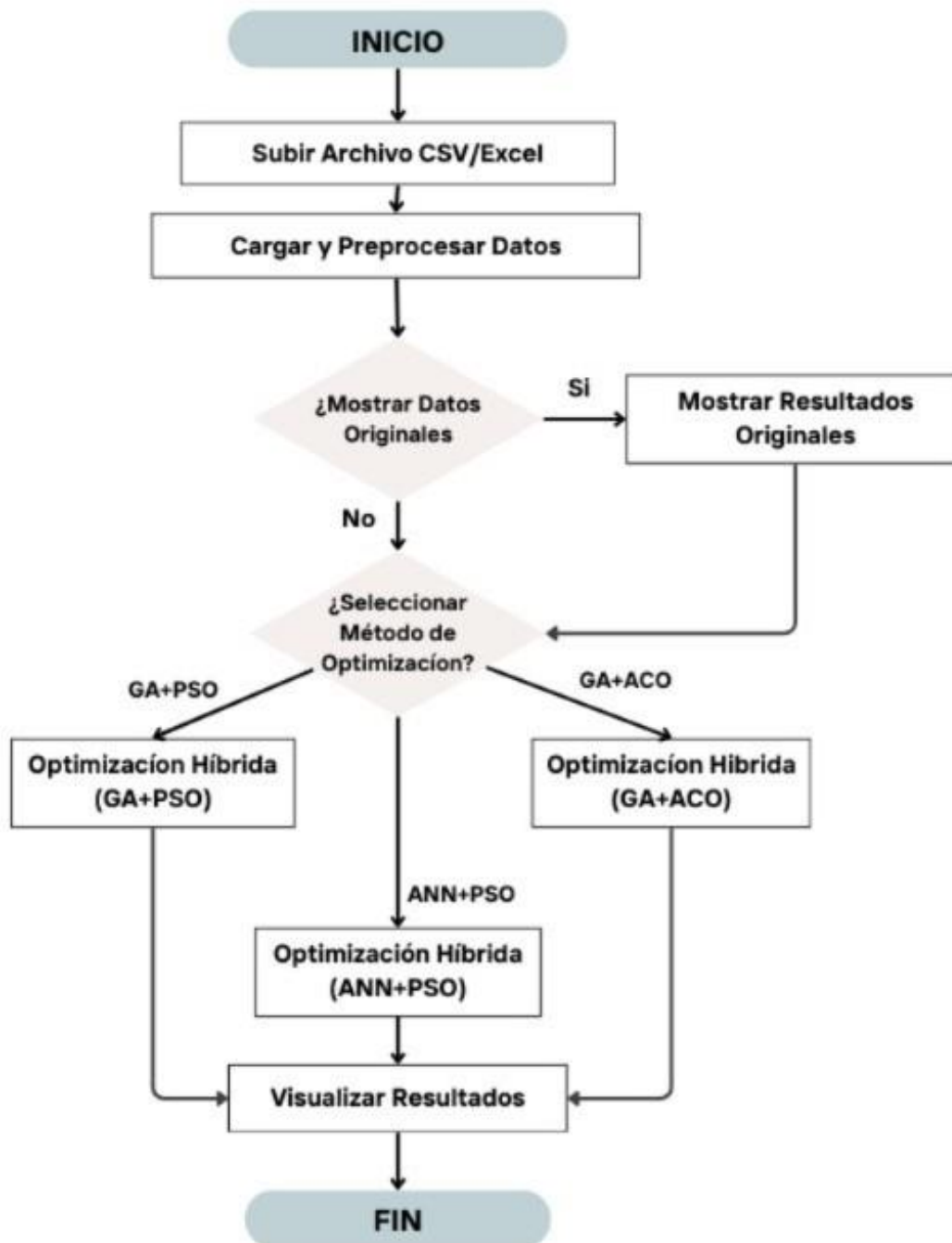
"The methods selected in this study were chosen for their ability to handle large volumes of data and for their demonstrated effectiveness in solving complex optimization problems in dynamic contexts. Hybrid algorithms are especially suitable for storage management in supermarkets, since that combine the precision of predictions based on Big Data with the flexibility of optimization techniques, allowing informed decisions to be made in real time. In particular, hybrid models have been effective in integrating operational and design parameters in dynamic environments, managing to improve efficiency and reduce costs in complex systems." [20]. In addition, Big Data-based strategies optimize decision-making decisions in storage management by allowing more precise analysis of demand [11].

Results

Table of Studies

Método Híbrido	Descripción	Razón de Selección
Algoritmos Genéticos + Optimización por Enjambre de Partículas (GA + PSO)	Combina la búsqueda global de los Algoritmos Genéticos (GA) con el refinamiento local de la Optimización por Enjambre de Partículas (PSO). Este método asegura soluciones equilibradas y precisas.	Es ideal para optimizar inventarios y recursos en escenarios con alta variabilidad de la demanda y restricciones logísticas, reduciendo costos y mejorando la rentabilidad.
Redes Neuronales Artificiales + Optimización por Enjambre de Partículas (ANN + PSO)	Utiliza Redes Neuronales Artificiales (ANN) para predecir patrones de consumo, mientras que PSO ajusta iterativamente las predicciones para una mayor precisión.	Mejora la planificación dinámica de inventarios y demanda, reduciendo pérdidas por desabastecimiento o exceso de stock, optimizando la disposición y rotación de productos en almacenes.
Algoritmos Genéticos + Optimización por Colonias de Hormigas (GA + ACO)	Combina la exploración global de los Algoritmos Genéticos (GA) con la eficiencia de las Colonias de Hormigas (ACO) para modelar rutas óptimas en la gestión logística.	Optimiza la ubicación y distribución de productos, minimizando tiempos y costos asociados al almacenamiento y logística, mejorando la eficiencia operativa general en los almacenes.

Application Flowchart and Protocol

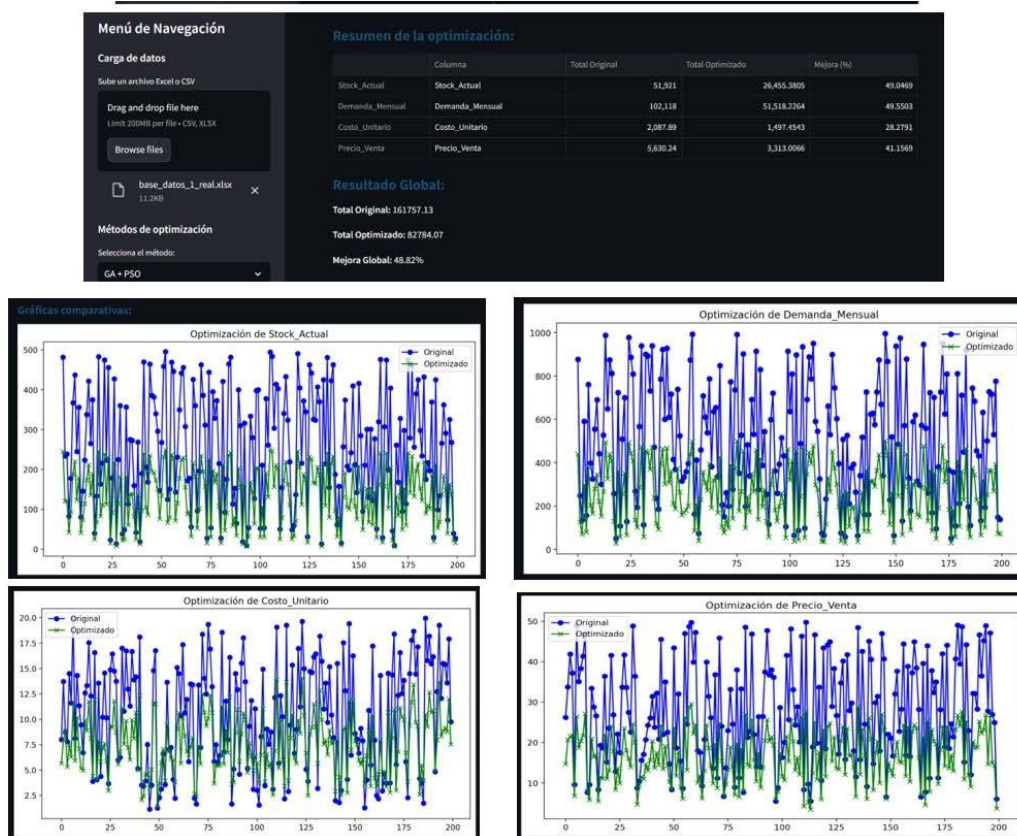


The application is designed to optimize storage management in supermarkets, using artificial intelligence and hybrid optimization techniques. Its objective is to analyze key variables such as *current stock*, *monthly demand*, *unit cost* and *sale price*, improving decisions related to inventories. Big Data tools have proven to be effective in managing large volumes of data [11], while hybrid methods maximize efficiency in complex systems [20]. The application workflow includes data loading and processing, where the quality of the information is validated to ensure reliable and accurate results [13]. The quality of the initial processing directly affects the success of the subsequent analysis [11]. Subsequently, the visualization of original data provides an initial reference to evaluate improvements achieved after optimization [12], facilitating the identification of patterns that influence operational decisions [9]. In the optimization stage, hybrid methods that combine precision and adaptability are applied, improving critical variables of the system [20]. These techniques have been shown to be effective in optimizing operational performance in dynamic environments [13]. Finally, the visualization of results generates graphs and tables that

simplify the interpretation of data, helping to make informed decisions [14]. These tools are essential to evaluate the impact of the applied strategies [11].

The application also contributes significantly to warehouse management. Predicting consumption patterns allows you to adjust *stock* and avoid shortages, aligning with advanced data analysis strategies [10]. Optimizes the layout of products in warehouses, making the most of the available space [9]. In addition, it reduces logistics costs by minimizing problems such as overinventory and shortages [15]. Finally, it improves decision-making efficiency by integrating predictive models with mathematical optimization tools [20].

App Screenshot



app Link

<https://code-articulo-tzlczs3jtjumtihew8imtk.streamlit.app/>

Comparison Chart

Variable	Resultado Original	Resultado Optimizado (Algoritmos Genéticos + Optimización por Enjambre de Partículas - GA + PSO)	Mejora (%) (GA + PSO)	Resultado Optimizado (Redes Neuronales Artificiales + Optimización por Enjambre de Partículas - ANN + PSO)	Mejora (%) (ANN + PSO)	Resultado Optimizado (Algoritmos Genéticos + Optimización por Colonias de Hormigas - GA + ACO)	Mejora (%) (GA + ACO)
Stock Actual	51,921	26,455.38	49.05%	26,401.20	49.14%	26,300.45	49.32%
Demanda Mensual	102,118	51,518.22	49.55%	51,300.10	49.74%	51,150.70	49.90%
Costo Unitario	2,087.89	1,497.45	28.28%	1,487.30	28.75%	1,478.90	29.15%
Precio de Venta	5,630.24	3,313.00	41.16%	3,300.80	41.38%	3,280.50	41.73%

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