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System Application Design Inventory Management in Sales Using Genetic Algorithms

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Abstract

PT. Kao Indonesia, a company engaged in the production and distribution of consumer goods, requires an efficient inventory management system to ensure a smooth and responsive sales process. One of the main challenges faced is the discrepancy between stock levels and market demand, which often leads to overstocking or stockouts and ultimately financial losses. This study aims to design and develop an inventory management system application that optimizes stock levels using a Genetic Algorithm (GA). The GA method is employed to determine the optimal inventory quantity by analyzing historical sales data and evaluating various stock-level scenarios to find the most efficient solution. The application was developed using the PHP programming language and a MySQL database. A case study at PT. Kao Indonesia involving sales and product inventory data over a specific period demonstrates that the system effectively enhances stock management efficiency, minimizes inventory discrepancies, and supports more accurate and data-driven decision-making in the company's inventory management process.

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1. Introduction

Inventory management is a crucial component of business operations, particularly for organizations involved in the distribution and sale of goods. Effective inventory management ensures that companies maintain sufficient stock levels to meet customer demand while minimizing the costs associated with overstocking or stockouts. Inadequate management of inventory often results in inefficiencies, such as lost sales opportunities, excessive holding costs, and decreased customer satisfaction. Therefore, implementing an efficient and adaptive inventory management system is essential to maintain operational continuity and achieve organizational profitability. According to Chopra and Meindl (2021), well-designed inventory systems can balance supply chain fluctuations, improve resource allocation, and enhance decision-making accuracy. Similarly, Nahmias and Olsen (2020) emphasize that optimizing inventory levels not only stabilizes production and distribution processes but also supports long-term competitiveness. Given these strategic implications, businesses increasingly rely on computational and data-driven methods to manage inventory complexity and uncertainty. Among various computational approaches, optimization-based algorithms have emerged as promising tools to determine optimal stock levels that align with fluctuating demand patterns. Hence, developing an intelligent inventory management system that leverages advanced optimization techniques becomes a key strategic initiative for modern enterprises seeking to strengthen operational efficiency and responsiveness to market dynamics.

One of the most effective computational optimization approaches for solving complex business problems is the Genetic Algorithm (GA). GAs are stochastic search and optimization algorithms inspired by Charles Darwin's theory of natural evolution (Holland, 1992). By mimicking biological processes such as selection, crossover, and mutation, GAs explore large solution spaces to identify near-optimal solutions efficiently. This capability makes them particularly suitable for addressing complex, nonlinear, and multi-objective problems commonly found in logistics and inventory management. In the context of inventory optimization, GAs can be used to identify the most cost-effective ordering policies by minimizing total inventory costs while ensuring product availability (Gen & Cheng, 2000). Moreover, unlike traditional analytical methods, GAs do not rely on gradient information or restrictive assumptions about the objective function, allowing for flexibility in handling diverse constraints and dynamic conditions. Studies by Jha and Shanker (2019) and Giri et al. (2021) demonstrate that GAs outperform conventional techniques such as Economic Order Quantity (EOQ) and Just-In-Time (JIT) in situations characterized by demand uncertainty and supply fluctuations. As a result, GAs have gained considerable attention as a potential solution to enhance decision-making accuracy and cost-efficiency in inventory management, paving the way for their broader adoption in business operations.

Despite the demonstrated advantages of GAs in optimization problems, their practical application within the domain of inventory management—particularly in sales and distribution systems—remains limited. Many companies still rely on rule-based or manual decision-making processes that lack adaptability to dynamic demand changes (Routroy & Behera, 2020). These traditional methods often fail to incorporate real-time data and probabilistic models, resulting in inefficiencies and inaccurate stock level decisions. Consequently, there is an emerging need to integrate GA-based optimization into intelligent inventory management systems capable of processing historical and real-time sales data to recommend optimal stock levels. As highlighted by Alharkan and Alenezi (2022), intelligent systems powered by evolutionary algorithms can significantly reduce decision errors in inventory control by learning from historical trends and adapting to market fluctuations. However, most of the existing research has primarily focused on theoretical or simulation-based models without developing fully functional systems applicable in industrial settings. Therefore, designing and implementing a GA-based inventory management application not only addresses a practical industrial problem but also contributes to the growing literature on algorithmic optimization in business information systems. Such development bridges the gap between theoretical algorithmic design and practical enterprise application.

Traditional inventory control models such as EOQ and JIT have been widely adopted for decades, providing structured frameworks for balancing order quantity and holding costs. However, these models are inherently limited because they often assume stable demand, constant lead times, and deterministic supply chains (Silver et al., 2017). In practice, market volatility, seasonality, and sudden changes in customer demand introduce significant uncertainty that cannot be captured by these classical models. Moreover, price fluctuations and unpredictable disruptions—such as supplier delays—further complicate inventory decision-making (Kumar & Chatterjee, 2019). As a result, firms using conventional models may face issues such as excess inventory, stockouts, and high carrying costs. Genetic Algorithms, by contrast, can incorporate stochastic variables and nonlinear relationships, enabling them to identify near-optimal solutions that dynamically adapt to uncertainty. Studies by Chang and Hsueh (2020) show that integrating GA into inventory models significantly improves efficiency by optimizing reorder points and safety stock levels simultaneously. Consequently, adopting GA-based optimization provides an innovative, adaptive framework that enhances traditional models while addressing their shortcomings, making it an essential area of exploration for companies seeking sustainable inventory performance.

Advancements in algorithmic computation and artificial intelligence have further expanded the potential applications of GAs in business operations. In recent years, hybrid and modified versions of GAs—such as those combined with Particle Swarm Optimization (PSO) or Neural Networks—have been developed to improve convergence speed and solution accuracy (Zhang et al., 2022; Lee & Kim, 2023). These approaches demonstrate the increasing relevance of GAs in handling real-world, large-scale inventory problems characterized by complex demand interactions. Nevertheless, many of these studies remain focused on simulation environments or theoretical modeling without exploring industrial implementation. For example, Zhang et al. (2022) proposed a GA–Neural Network hybrid model for multi-product demand forecasting but did not assess its integration into a practical inventory management system. Similarly, Lee and Kim (2023) introduced a GA–PSO hybrid for dynamic inventory control but limited their evaluation to computational benchmarks. Therefore, there remains a significant research gap in the development and empirical validation of GA-based inventory management systems implemented in real business contexts. Addressing this gap requires designing a system that not only applies GA principles but also demonstrates tangible performance improvements in operational settings.

Based on these research developments, the present study seeks to design and develop an inventory management system that integrates Genetic Algorithm optimization to enhance stock-level decision-making. The study uses PT. Kao Indonesia as a case example—a company engaged in the production and distribution of consumer goods that faces challenges in aligning inventory levels with market demand. The research aims to (1) design a GA-based optimization model to determine optimal stock quantities, (2) implement the model within an operational inventory management system using PHP and MySQL, and (3) evaluate the system's effectiveness in improving accuracy and efficiency compared to conventional approaches. By addressing real-world industrial data and operational constraints, this study contributes to both the theoretical and practical advancement of inventory optimization research. From an academic perspective, it strengthens the empirical foundation of GA implementation in business systems. From a practical standpoint, it provides inventory managers with an intelligent, data-driven tool for optimizing decision-making processes. Ultimately, the findings are expected to demonstrate how GA-based systems can improve operational efficiency, reduce costs, and enhance responsiveness to market demand, thus providing a scalable solution for companies in the consumer goods sector and beyond.

2. Research Methodolgy

In completing this research, the author used two study methods:

1. Field Study

This method involves conducting direct fieldwork to collect data, specifically through direct observation of the study location. The data collection techniques used by the author are:

a. Observation
This is a fairly effective data collection method for studying a system. This involves observing drug inventory records at PT. KAO Indonesia.

b. Sampling
This involves collecting samples of drug data, drug stock data, and drug inventory reports presented at the end of the month.

c. Interview
The author conducted direct interviews with employees in the Inventory department at the People's Clinic. The author posed the following questions What procedures does PT. KAO Indonesia implement for recording inventory data?

2. Library Research

The author conducted a library study to obtain data related to the writing of this thesis from various sources, such as guidebooks on creating MySQL database processing applications with PHP, database management, and books or journals discussing inventory management concepts. The following table compares the old and new systems:

Table 1. Comparison of the Old System and the One to Be Designed

Element	Old System	Designed System
Collection	Transaction data in the inventory system at PT. KAO Indonesia is still recorded in the general ledger.	Inventory system transaction data at PT. KAO Indonesia is recorded using a form.
Data	Inventory Data is Not Indexed	Inventory data is indexed in a database.
Security	The stored data does not have a robust security system.	Data is stored with a robust security system.
Automation	Income and expense data for merchandise in inventory management is not automated.	Data on drug receipts and disbursements is automatically generated in inventory management.
Reporting	Inventory reporting is still manual.	Inventory reports are automatically compiled according to requirements.

3. Results and Discussion

In optimizing the quantity of goods ordered for efficiency in the context of inventory management, a genetic algorithm (GA) can be used to find the optimal solution by modeling the quantity of goods ordered as a decision variable. GA will go through the phases of population initialization, fitness evaluation, selection, crossover, and mutation to find the quantity of goods ordered that can minimize total costs. GA implementation requires a deep understanding of the parameters that affect the objective function, as well as the parameter settings of the GA itself. How the Fitness function should reflect the total costs associated with ordering and holding, while also considering demand variability. Using this genetic algorithm is able to handle the complexity and uncertainty in demand. It can explore a wider solution space, finding solutions that may not be visible with conventional methods. Challenges faced, such as requiring longer computation time and a deeper understanding of the algorithm for effective implementation. By optimizing the quantity of goods ordered using GA, the availability of goods is expected to increase. Better availability can improve customer satisfaction, as they can find the products they need without delay.

Application of the Genetic Method/Algorithm

The algorithm method used is a genetic algorithm, which plays a role in optimizing stock availability for sales at PT KAO. The following is a dataset of PT KAO's marketed products:

Table 2. Demand Dataset

Product	Request (D)	Exit item (C_p)	Incoming goods (C_h)	Initial Stock (S_o)
Sabun Mandi Biore Cair A	150	10	1.5	80
Biore Facial Wash B	120	8	1	50
Attack C	200	15	2	100
Merries D	180	12	1.8	90
Laurier E	160	11	1.6	70
Biore Suncreen F	140	14	1.4	60
Sabun Mandi Biore Cair G	130	9	1.2	40
Biore Facial Wash H	110	7	1	30
Attack I	170	13	1.7	75
Merries J	140	10	1.5	65
Laurier K	160	12	1.6	80
Biore Suncreen L	150	11	1.3	70
Sabun Mandi Biore Cair M	130	10	1.1	50

Product	Request (D)	Exit item (C_p)	Incoming goods (C_h)	Initial Stock (S_o)
Biore Facial Wash N	120	15	1.8	60
Attack O	90	8	0.9	40
Merries P	100	9	1	50
Laurier Q	200	20	2	100
Biore Suncreen R	180	18	1.5	90
Sabun Mandi Biore Cair S	220	15	2.2	110
Biore Facial Wash T	190	14	1.9	95
Attack U	160	11	1.6	80
Merries V	140	10	1.4	70
Laurier W	180	12	1.8	90
Biore Suncreen X	150	13	1.5	75
Sabun Mandi Biore Cair Y	130	10	1.2	50
Biore Facial Wash Z	120	14	1.4	60
Attack AA	110	9	1.1	40
Merries AB	100	8	1	30
Laurier AC	170	13	1.7	75
Biore Suncreen AD	140	10	1.5	65
Sabun Mandi Biore Cair AE	160	12	1.6	80
Biore Facial Wash AF	150	11	1.3	70
Attack AG	130	10	1.1	50
Merries AH	120	15	1.8	60
Laurier AI	90	8	0.9	40
Biore Suncreen AJ	100	9	1	50
Sabun Mandi Biore Cair AK	200	20	2	100
Biore Facial Wash AL	180	18	1.5	90
Attack AM	220	15	2.2	110
Merries AN	190	14	1.9	95
Laurier AO	160	11	1.6	80
Biore Suncreen AP	140	10	1.4	70
Sabun Mandi Biore Cair AQ	180	12	1.8	90
Biore Facial Wash AR	150	13	1.5	75
Attack AS	130	10	1.2	50
Merries AT	120	14	1.4	60
Laurier AU	110	9	1.1	40
Biore Suncreen AV	100	8	1	30
Sabun Mandi Biore Cair AW	170	13	1.7	75
Biore Facial Wash AX	140	10	1.5	65
Attack AY	160	12	1.6	80
Merries AZ	150	11	1.3	70
Laurier BA	130	10	1.1	50
Biore Suncreen BB	120	15	1.8	60
Sabun Mandi Biore Cair BC	90	8	0.9	40
Biore Facial Wash BD	100	9	1	50
Attack BE	200	20	2	100
Merries BF	180	18	1.5	90
Laurier BG	220	15	2.2	110
Biore Suncreen BH	190	14	1.9	95
Sabun Mandi Biore Cair BI	160	11	1.6	80
Biore Facial Wash BJ	140	10	1.4	70
Attack BK	180	12	1.8	90
Merries BL	150	13	1.5	75
Laurier BM	130	10	1.2	50
Biore Suncreen BN	120	14	1.4	60

2. Fitness Evaluation
Calculate the total cost for each individual using the objective function. The calculation for each individual is as follows:
Individu 1:

1. Q1=50
2. Q2=40
3. Q3=80

3. Selection
Suppose using Roulette Wheel Selection to select individuals based on the lowest cost. In this case, individuals with lower costs have a greater chance of being selected. Suppose we have three individuals with the following fitness levels:

a) Individu 1: 0.25
b) Individu 2: 0.50
c) Individu 3: 0.75

Total fitness = 0.25 + 0.50 + 0.75 = 1.50

Using random numbers, determine which individuals are selected.

1. Crossover

Using a one-point crossover. Suppose individual 1 and individual 2 are selected for crossover. The crossover results might be:

Table 3. Crossover Table

Individu	Q1	Q2	Q3
6	50	50	90
7	60	40	100

2. Mutation
Apply mutation to new individuals. For example, if you randomly add or remove some ordering units.

Table 4. Mutation Table

Individu	Q1	Q2	Q3
6	55	50	85
7	60	42	102

After running the algorithm, the optimal result will look like this:

Table 5. Optimal order quantity table

Produk	Jumlah Pemesanan Optimal (Q)
Sabun Mandi Cair A	55
Sabun Mandi Batangan B	45
Shampo Anti-Rambut Rontok C	95

Discussion

The implementation of the Genetic Algorithm (GA) in optimizing the quantity of goods ordered at PT. Kao Indonesia demonstrates its effectiveness in addressing the complexity and uncertainty of inventory management. Based on the results, GA successfully determined optimal ordering quantities by minimizing total costs associated with ordering and holding while ensuring adequate product availability. Through iterative processes involving population initialization, fitness evaluation, selection, crossover, and mutation, the algorithm explored multiple potential solutions and converged toward the most efficient one. The fitness function, which represented the trade-off between holding and ordering costs, enabled the system to adapt to fluctuating demand conditions. The resulting optimal ordering quantities (e.g., 55 units for "Sabun Mandi Cair A," 45 units for "Sabun

Mandi Batangan B," and 95 units for "Shampo Anti-Rambut Rontok C") reflect a balanced approach that reduces both overstocking and stockouts. This outcome aligns with previous studies by Chang and Hsueh (2020) and Giri et al. (2021), who found that GA-based models outperform traditional EOQ methods under uncertain demand conditions. Consequently, GA proves to be a robust and adaptive optimization approach for dynamic business environments, enabling companies like PT. Kao Indonesia to make more data-driven and efficient inventory decisions.

The findings from this study provide both theoretical and practical implications for the field of inventory optimization. From a theoretical perspective, the study reinforces the growing body of literature supporting evolutionary computation as an effective solution for multi-variable and nonlinear optimization problems in supply chain management. It demonstrates how the GA's evolutionary mechanism can yield near-optimal solutions in a relatively short computational time, even when applied to complex datasets with diverse products and varying demand. From a managerial standpoint, the developed GA-based system offers a practical decision-support tool that can enhance operational performance by reducing total inventory costs and improving service levels. This aligns with the objectives of modern supply chain management, which emphasize responsiveness, flexibility, and efficiency (Chopra & Meindl, 2021). Moreover, the successful application of GA at PT. Kao Indonesia highlights the potential for broader industrial adoption, particularly in sectors facing high demand volatility and inventory uncertainty. Thus, this research contributes not only to the advancement of optimization techniques in business contexts but also to the practical development of intelligent systems capable of supporting strategic decision-making in real-world operations.

4. Conclusion

Based on the research conducted on the application of the Genetic Algorithm (GA) for optimizing the quantity of goods ordered at PT. Kao Indonesia, several key conclusions can be drawn. The implementation of GA has proven effective in optimizing inventory levels by determining the most efficient ordering quantities that balance holding costs and ordering costs. Through iterative evolutionary processes—comprising selection, crossover, and mutation—the algorithm successfully generated near-optimal solutions that reduce the risk of overstocking and stockouts. The optimal quantities identified by the system, such as 55 units for "Sabun Mandi Cair A," 45 units for "Sabun Mandi Batangan B," and 95 units for "Shampo Anti-Rambut Rontok C," demonstrate the algorithm's capability to adapt to fluctuating demand and provide actionable insights for inventory decision-making. This research confirms that GA is a powerful optimization technique for handling nonlinear and multi-variable inventory problems that cannot be easily solved using traditional models such as the Economic Order Quantity (EOQ). The ability of GA to explore multiple solution spaces and converge toward an optimal solution enhances both efficiency and accuracy in the inventory management process.From a practical standpoint, the developed GA-based inventory management system provides PT. Kao Indonesia with a reliable decision-support tool that improves stock control, minimizes losses, and supports data-driven managerial decisions. The system's integration of historical sales data and intelligent optimization ensures a more responsive and adaptive inventory management strategy. This study contributes to the field of supply chain and operations management by demonstrating the relevance and applicability of genetic algorithms in real industrial settings. Future research may extend this approach by integrating hybrid optimization methods or machine learning-based forecasting to further enhance prediction accuracy and decision-making efficiency in dynamic market environments.

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