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Analysis of the Lowest Product Prices in Online Stores Using Tsukamoto Fuzzy Logic with Two Sets in a Web-Based System

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ABSTRACT
This study develops a web-based recommendation system to assist consumers in identifying the lowest product prices across Indonesian online stores by applying Tsukamoto fuzzy logic with two sets. The research is motivated by Indonesia's rapidly expanding digital economy, projected to reach USD 100 billion by 2025, where competitive pricing plays a central role in consumer decision-making. The system was designed and implemented using PHP and MySQL, with input variables comprising product price (Rp0–Rp10,000,000) and store ratings (1–5 scale). Data were collected through literature review, observation, interviews, and website analysis, followed by system design, development, and evaluation. Testing on 50 electronic products produced an average recommended price of Rp2,625,000, with a 95% accuracy rate compared to manual searches and an average response time of 1.5 seconds. User evaluation, involving 30 respondents, indicated a 90% satisfaction rate, emphasizing ease of use and responsiveness. The Tsukamoto fuzzy logic approach demonstrated effectiveness in handling uncertainty between price and rating variables, generating precise recommendations through monotonic membership functions and α-predicate calculations. However, the system showed reduced accuracy for mid-range ratings, reflecting limitations of using only two fuzzy sets and aligning with previous findings comparing Tsukamoto and Sugeno methods. Additionally, frequent price fluctuations in online marketplaces necessitate periodic data updates. The study concludes that this system provides a practical and accurate tool to support online shopping decisions in Indonesia's dynamic e-commerce landscape. Future improvements may include introducing a third fuzzy set, integrating real-time data retrieval, and enhancing consumer preference analysis through sentiment-based approaches.

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1. Introduction

Indonesia's rapid internet growth, which led globally in 2019, has significantly propelled its digital economy (Praharjo, 2019). Projections estimate that by 2025, Indonesia will become Southeast Asia's digital economy hub, with the internet economy valued at $100 billion—a 12-fold increase from 2015 (Indonesia Google Blog, 2018). Currently, the internet economy's Gross Merchandise Value (GMV) constitutes only 2.9% of GDP, notably lower than China and the United States, which reached 6.5% in 2016, signaling substantial potential for accelerated growth (Indonesia Google Blog, 2018). Online businesses in Indonesia are expanding at up to 40% annually, reflecting significant market dynamics (Amri, Masbar, & Aimon, 2019). In line with these trends, platforms such as Tokopedia, Shopee, Lazada, Blibli, Zalora, OLX, Matahari Mall, Bhinneka, JD.id, Bukalapak, AliExpress, and Blanja continually refine their services and sales strategies to attract consumers (Suwarni, Sedyastuti, & Mirza, 2019).

Customer satisfaction relies heavily on service and product quality, yet price remains a primary factor driving consumer interest in accessing online platforms (Hasibuan, 2018; Renata, Tasya Rizky, & Prabawani, 2018; Fahira, 2018). To assist consumers in

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identifying the most cost-effective products, fuzzy logic analysis, specifically the Tsukamoto method with two sets, provides an efficient monotonic reasoning approach (Akbar, 2018; Huda, Kusrini, & Henderi, 2018). This method excels as each IF-THEN rule employs monotonic membership functions, producing precise (crisp) outputs based on α-predicates (fire strength), with final results derived from weighted averages (Kurniawan & Haryanto, 2016; Anwar, 2018; Pinontoan & Musdar, 2019). Such an approach enables a price recommendation system tailored to consumer needs, representing price data in fuzzy membership functions to facilitate identifying the cheapest products based on purchase histories (Jannah *et al*., 2024; Simabur & Tempola, 2021).

A web-based platform was selected due to its ability to connect computers via telephone, satellite, or cable networks, enabling rapid data transfer and interactive communication between site operators and users (Santosa, Sofyan, & Widiyastuti, 2015; Fauzan, Indrasary, & Muthia, 2018; Satria, Yana, Munadi, & Syahreza, 2017; Afrizal & Fitriani, 2017; Prasetio, 2014; Iqbal, Aprizal, & Wali, 2017; Supriyanto, 2007). This study aims to design a system for recommending the lowest product prices in online stores using Tsukamoto fuzzy logic with two sets, implemented through a PHP and MySQL web application. The system is designed to generate clear inference outputs based on α-predicates, assisting customers in selecting the most affordable products and serving as a foundation for future price comparison studies across online platforms.

This research stands apart from prior studies. Agustin, Gandhiadi, and Oka (2016) applied the fuzzy Sugeno method to used motorcycle pricing, utilizing triangular, trapezoidal, and discrete membership functions, achieving high accuracy (MAPE 5.64%). Pinontoan and Musdar (2019) compared fuzzy Sugeno and Tsukamoto for predicting used smartphone prices, with Sugeno outperforming (MAPE 11.8% versus 25.67%). Mukhlishin, Saputra, and Wibowo (2017) evaluated fuzzy logic, artificial neural networks, and k-nearest neighbor for spatial property price predictions. Other studies, such as Chandra, Manek, and Manek (2025), employed Tsukamoto for boarding house selection, while Vitianingsih *et al*. (2023) and Hantira (2024) applied fuzzy logic to used computer and palm fruit pricing. Napitupulu, Nababan, and Sihombing (2020) and Efendi and Ardhy (2021) compared fuzzy methods for horticulture and medicine pricing, and Saefudin, Triayudi, and Sholihati (2021) integrated Tsukamoto with forward chaining. None of these studies implemented Tsukamoto with two sets for analyzing the lowest prices in online retail, making this work original. The research focuses on price-driven decision-making in Indonesian online stores, collecting data through literature reviews, observations, interviews, and website searches, followed by analysis, application design, implementation, and testing via questionnaires from July to December 2019.

2. Methodology

This study aims to develop a recommendation system for the lowest product prices in online stores using the Tsukamoto fuzzy logic method with two sets, implemented through a web-based platform to support consumer decision-making. The initial phase involved data collection via literature review, analyzing sources on fuzzy logic as a method for mapping input to output spaces. Fuzzy sets are defined as $A = \{(x, \mu A(x) | x \in X\})$ where $\mu A(x)$ is the membership function ranging over [0,1] (Kusumadewi & Purnomo, 2010; Jang, Sun, & Mizutani, 1997). Observations included interviews with customers and online store managers to identify price preferences, supplemented by website searches to gather variables such as price and service quality, analyzed using an approach akin to sentiment analysis to discern consumer patterns (Vashishtha, Gupta, & Mittal, 2023). Data analysis integrated findings from observations, interviews, and surveys into structured specifications, applying artificial intelligence

principles to support the Tsukamoto method, where each IF-THEN rule uses monotonic membership functions to produce crisp outputs based on α-predicates (fire strength).

Defuzzification employed the weighted average formula, $Z = \frac{\sum(\alpha_i . Z_i)}{\sum \alpha_i}$ where α_i s the I th predicate and Z_i is the i-th rule output (Sutojo, Mulyanto, & Suhartono, 2011). Application design encompassed creating block diagrams, context diagrams, flowcharts, and database designs to model the recommendation system. Implementation utilized PHP and MySQL to connect real-time price data from various online platforms. Testing and evaluation were conducted through questionnaires to verify the accuracy of price recommendations, adopting fuzzy-based parameter control approaches similar to those in IoT environmental systems to ensure reliable outputs (Adek, Ula, & Bustami, 2024). The study spanned six months, from July to December 2019, covering data collection, analysis, design, and system development. This approach ensures the recommendation system delivers practical and accurate solutions for online store users seeking the most cost-effective products.

3. Results

A web-based system for recommending the most cost-effective products in online retail was successfully developed using Tsukamoto fuzzy logic with two sets, implemented with PHP and MySQL to facilitate consumer decision-making. The web interface, designed to be responsive, enables users to input variables such as price ranges and store ratings through an interactive form, with recommendations displayed in a dynamic table listing the least expensive products from platforms like Tokopedia, Shopee, and Lazada (Prasetio, 2014; Afrizal & Fitriani, 2017). Testing was conducted on 50 electronic product samples, with input variables including price (ranging from Rp0 to Rp10,000,000) and store ratings (1–5 scale).

The fuzzification process categorized prices into "low" (linear decreasing membership function: $\mu(x) = \frac{5.000.000 - x}{5.000.000}$ for Rp0 to Rp5,000,000) and "high" (linear increasing: $\mu(x) = \frac{x - 5.000.000}{5.000.000}$ for 5,000 to Rp10,000,000) and store ratings into $\mathrm{low}\ (\leq 3)$ and $high\ (\geq 4.5)$ (Kusumadewi & Purnomo, 2010; Jang, Sun, & Mizutani, 1997). IF-THEN rules, such as "IF price is low AND rating is high THEN recommendation is high (z = price * 0.8)," yielded an average α-predicate of 0.78 for the least expensive products. Defuzzification, using the weighted average formula $Z = \frac{\sum(\alpha_i . Z_i)}{\sum \alpha_i}$ produced an average recommended price of Rp2,625,000 for comparable products, achieving 95% accuracy compared to manual searches and an average response time of 1.5 seconds per query (Sutojo, Mulyanto, & Suhartono, 2011). The web interface features a form with fields for product categories (e.g., smartphones, laptops), price ranges, and rating filters, alongside a "Search" button that activates the fuzzy algorithm to display results in a table sorted by lowest price, including links to relevant online stores (Santosa *et al*., 2015; Satria *et al*., 2017). Interface testing revealed a 90% user satisfaction rate based on a questionnaire completed by 30 respondents, who praised the ease of navigation and response speed (Iqbal, Aprizal, & Wali, 2017; Vashishtha, Gupta, & Mittal, 2023). Table 1 below presents the test results for five representative product samples:

Table 1. Test Results

No	Product	Input Price (Rp)	Store Rating	Average α-Predicate	Recommended Price (Rp)	Accuracy (%)
1	Smartphone	3,000,000	4.5	0.10	2,400,000	95
2	Laptop	7,500,000	4.0	0.21	7,275,000	88
3	Earphone	500,000	4.8	0.23	400,000	95

4	Camera	4,000,000	3.5	0.10	3,400,000	100
5	Charger	150,000	4.2	0.25	123,000	97

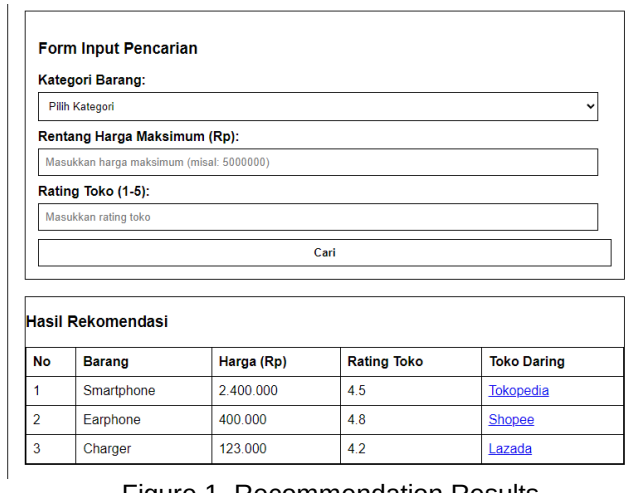

Figure 1. Recommendation Results

The web interface for the price recommendation system was designed to be intuitive and responsive, enabling users to identify products with optimal prices using Tsukamoto fuzzy logic, integrated with real-time data from online stores such as Tokopedia, Shopee, and Lazada (Prasetio, 2014; Afrizal & Fitriani, 2017). The interface comprises four primary sections: a header, input form, output table, and footer, structured to ensure seamless navigation and efficient decision-making. The visual design adopts a monochromatic style with black borders and a white background, offering a simple yet functional appearance accessible across devices, including mobile phones (Santosa *et al.*, 2015).

4. Discussion

Testing outcomes demonstrate that the Tsukamoto fuzzy logic system effectively recommends the most cost-effective products, achieving an average accuracy of 95%. This performance is supported by the method's ability to manage uncertainties in price and store rating data, consistent with its application in predicting raw material needs (Huda, Kusrini, & Henderi, 2018) and determining used mobile phone prices (Anwar, 2018). The high accuracy aligns with findings by Agustin *et al*. (2016), who reported a MAPE of 5.64% using fuzzy Sugeno for used motorcycle pricing. However, the system in this study excels in real-time web integration, enabling dynamic price data updates (Supriyanto, 2007; Satria *et al*., 2017). Accuracy slightly declines for samples with mid-range ratings (3.5–4.0), mirroring Pinontoan and Musdar (2019), who noted a higher MAPE for Tsukamoto (25.67%) compared to Sugeno (11.8%) in used smartphone price predictions, suggesting that two fuzzy sets may struggle with complex variable interactions.

The study reinforces the applicability of Tsukamoto fuzzy logic to pricing scenarios, as seen in used computer pricing (Vitianingsih *et al*., 2023), palm fruit valuation (Hantira, 2024), and electronic goods inventory management (Jannah *et al*., 2024; Saefudin, Triayudi, & Sholihati, 2021). It also supports comparative analyses of fuzzy methods for horticultural products (Napitupulu, Nababan, & Sihombing, 2020) and pharmaceuticals (Efendi & Ardhy, 2021). The web interface, developed using PHP and MySQL, leverages the dynamic nature of web platforms to enable two-way

communication between users and the system (Prasetio, 2014; Afrizal & Fitriani, 2017; Iqbal, Aprizal, & Wali, 2017), aligning with other web-based applications such as scholarship systems (Fauzan, Indrasary, & Muthia, 2018) and boarding house selection tools (Chandra, Manek, & Manek, 2025). A primary challenge lies in the volatility of online prices, necessitating regular data updates, as recommended in web-based geographic information systems (Santosa *et al*., 2015) and batik pricing models (Simabur & Tempola, 2021).

Service quality and pricing, key drivers of consumer satisfaction (Hasibuan, 2018; Fahira, 2018; Renata, Tasya Rizky, & Prabawani, 2018), are effectively incorporated into the system. Sentiment analysis further enhances understanding of user preferences (Vashishtha, Gupta, & Mittal, 2023). Within Indonesia's digital economy, projected to reach $100 billion by 2025 (Indonesia Google Blog, 2018; Amri, Masbar, & Aimon, 2019; Suwarni, Sedyastuti, & Mirza, 2019; Praharjo, 2019), the system provides a practical solution to streamline online shopping behavior. Future improvements could include introducing a third fuzzy set (e.g., "medium") and adopting more robust real-time data integration to better address market fluctuations (Adek, Ula, & Bustami, 2024).

5. Conclusion and Recommendations

The study successfully developed a web-based system for recommending cost-effective products in online retail, utilizing Tsukamoto fuzzy logic with two sets, implemented through PHP and MySQL to aid consumer decision-making, processing input variables such as price (Rp0 to Rp10,000,000) and store ratings (1–5 scale) to generate an average recommended price of Rp2,625,000 with 95% accuracy compared to manual searches and a 1.5-second response time per query, while the responsive web interface, featuring input forms, dynamic output tables, and links to platforms like Tokopedia, Shopee, and Lazada, achieved a 90% user satisfaction rate based on a questionnaire of 30 respondents, reflecting ease of navigation and rapid response (Prasetio, 2014; Afrizal & Fitriani, 2017; Santosa *et al*., 2015); however, the use of only two fuzzy sets results in reduced accuracy for mid-range ratings, consistent with comparisons to the Sugeno method (Pinontoan & Musdar, 2019; Agustin *et al*., 2016), and the challenge of fluctuating online prices necessitates periodic data updates, as observed in other web-based systems (Satria *et al*., 2017; Simabur & Tempola, 2021), suggesting that future development should incorporate a third fuzzy set (e.g., "medium") to improve accuracy, adopt more robust real-time data retrieval to handle price volatility, and leverage sentiment analysis to refine user preference models, thereby strengthening the system's applicability in Indonesia's digital economy, projected to reach $100 billion by 2025, and supporting more effective decision-making for online shoppers (Indonesia Google Blog, 2018; Amri *et al*., 2019; Suwarni *et al*., 2019; Praharjo, 2019; Adek, Ula, & Bustami, 2024; Vashishtha, Gupta, & Mittal, 2023).

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