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Research on the Ukrainian food market demand forecasting using artificial neural network technologies

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Abstract.
The analysis of demand forecasting processes has shown that manual approaches, especially without AI integration, can be time-consuming, prone to errors, and inefficient in handling complex market variables. Designing software components for demand forecasting using Artificial Intelligence (AI) enables the identification of optimal prediction models and resource allocation strategies across diverse geographical markets. This study aims to improve the accuracy of demand forecasting by automating and optimizing forecasting processes through AI-driven software components. Specifically, the research proposes a mathematical model utilizing neural networks to enhance demand forecasting accuracy. The proposed model is examined using a combination of real-world data from a Ukrainian food production company and various AI algorithms, such as deep learning models, to define optimal forecasting solutions.

Keywords:
demand forecasting
process automation
artificial intelligence
neural networks
optimization model
multi-market analysis

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Introduction. The modern economy increasingly relies on advanced forecasting systems to optimize operations and drive competitive advantage. Demand forecasting, in particular, plays a vital role in resource optimization and business planning. AI's ability to process large amounts of data and detect intricate patterns makes it a valuable tool for enhancing demand forecasting accuracy. This study explores the development and research of software components using AI, particularly neural networks, to address the complexities of demand forecasting influenced by various market factors. By focusing on multi-market scenarios, the research covers regions including Europe, Asia, and Canada, aiming to identify optimal forecasting models for each market or determine a universal model applicable to all regions.

The study evaluates the current state of demand forecasting models, particularly their effectiveness in multi-market forecasting. This research intends to fine-tune these models to improve accuracy. The core goal is to develop AI-based software components that can enhance demand forecasting across multiple markets, helping companies better allocate resources and maintain competitiveness.

Relevance of demand forecasting using AI Accurate demand forecasting is crucial for industries, particularly in food production, where errors in forecasting can lead to overproduction, underproduction, and significant financial losses. This research focuses on a Ukrainian food producer that exports various chicken parts to several global markets, including Europe, the Middle East, and Africa. Demand forecasting plays a key role in determining production volumes and optimizing resource use across these regions.

The study examines organizational structures and material flow dynamics within the Ukrainian food production industry, using AI systems for demand forecasting. The goal is to create software components that enhance the producer's ability to forecast demand accurately across different markets, reducing waste and improving operational efficiency. By evaluating the performance of modern forecasting models, the study seeks to adapt or develop more accurate and flexible AI models suitable for a multi-market environment.

The literature review process identified 77 relevant

articles, which were narrowed down to 4 key studies that provided insights into AI's role in demand forecasting [1]. This process is illustrated in Fig. 1, showing the steps of article selection and inclusion in the study. These studies helped form the foundation for this research, demonstrating AI's potential to handle complex forecasting tasks and its capacity for improving the accuracy of predictions in dynamic and diverse markets.

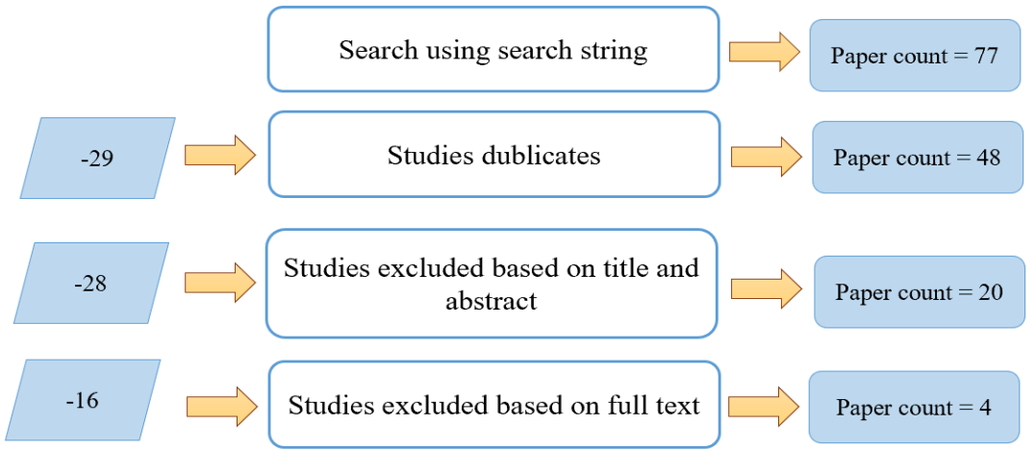

Figure 1
Literature review process

AI in demand forecasting. Recent advancements in AI have led to significant improvements in demand forecasting. Neural networks, in particular, offer a powerful method for analyzing complex datasets and identifying hidden trends that traditional time-series analysis may miss. Zeynep Çetinkaya's research on using neural networks to forecast daily food demand demonstrates the potential of these systems in the food industry [1]. By applying similar methods, this study aims to improve the accuracy of demand forecasting for a Ukrainian food producer.

AI-driven demand forecasting models not only enhance forecasting precision but also help optimize inventory management, production planning, and resource allocation across various markets. The adaptability of these models is

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crucial for handling the diverse conditions in global markets, as shown in studies that integrate AI-based methods to address complex forecasting challenges [3-5].

Problem Statement. The complexity of demand forecasting has been significantly increased by the globalization of markets, the growth of data availability, and the ever-changing market conditions. The manual forecasting methods traditionally used by enterprises are increasingly unable to cope with the demands of modern business environments. In particular, businesses operating in multiple regions face significant challenges due to diverse market factors such as consumer behavior, economic conditions, seasonal influences, and geopolitical stability.

The analysis of recent research papers [1, 2, 4, 5] has shown that artificial intelligence (AI) and machine learning techniques, particularly neural networks, are gaining popularity for addressing the shortcomings of traditional time series analysis methods. These technologies have proven effective in improving the accuracy of demand forecasting by processing large datasets and identifying complex patterns that manual methods cannot. However, the application of AI in demand forecasting for multi-market environments, particularly for industries like food production, remains a relatively new and evolving field.

Therefore, the study of automating demand forecasting processes using AI is a relevant problem. The existing forecasting models and tools on the market have various capabilities, but they often lack flexibility, adaptability, and scalability for multi-market demand forecasting. This study is intended to facilitate the work of business analysts, data scientists, and supply chain managers by developing software components that can automate and optimize the demand forecasting process using AI models. This will help to reduce time, improve accuracy, and provide more efficient resource planning across multiple geographical markets.

Thus, the following research objectives should be addressed to improve the accuracy of demand forecasting through the development and study of AI-based software components:

1. propose an algorithm to solve the demand forecasting

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problem using artificial intelligence;
2. formulate the requirements for the software solution;
3. justify the choice of tools for developing software components;
4. design the AI-driven software components for demand forecasting;
5. develop the proposed software components;
6. test the functionality of the software solution for AI-based demand forecasting;
7. conduct experiments and analyze the results to evaluate the effectiveness of neural networks in improving forecasting accuracy compared to traditional time-series analysis methods.

Methodology. The methodology employed in this study began with a comprehensive systematic literature review aimed at identifying the most relevant academic sources and recent advancements in demand forecasting, particularly those leveraging AI-based models. The review encompassed multiple forecasting techniques, with a focus on deep learning approaches such as convolutional neural networks combined with gated recurrent units (CNN-GRU) and clustering methods. These models were selected for their demonstrated effectiveness in complex multi-market environments, where various economic, geographic, and socio-political factors play significant roles in shaping demand.

The core of the research involved evaluating the effectiveness of these AI-based forecasting models by applying them to real-world data from diverse markets. This allowed for a comparative analysis of different approaches to identify which models performed best under specific market conditions. The research incorporated external variables, such as weather conditions and regional economic trends, into the models to enhance their predictive accuracy and adaptability. For instance, weather-sensitive markets like food production were tested to determine how integrating external factors impacted forecast accuracy [3].

Once the optimal forecasting models were identified, the study proceeded with fine-tuning the neural network configurations. This iterative process involved adjusting parameters such as learning rates, hidden layer

architectures, and training epochs to suit the specific needs of each geographical market. The models were rigorously tested under various scenarios to assess their robustness and ability to generalize across different regions. This was crucial for ensuring that the forecasting solutions were not only accurate but also flexible enough to accommodate dynamic shifts in market conditions, such as sudden fluctuations in consumer demand or changes in geopolitical stability.

In addition to the neural network adjustments, the research incorporated a multi-step evaluation framework for assessing model performance. This involved using performance metrics such as mean squared error (MSE)

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2, \quad (1)$$

root mean squared error (RMSE)

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}, \quad (2)$$

and mean absolute error (MAE)

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|. \quad (3)$$

to quantify the accuracy of the forecasts. These metrics provided clear insights into how well the models performed in comparison to traditional time series analysis methods, with a particular emphasis on identifying any overfitting or underfitting issues that could hinder the model's real-world applicability [1, 4].

The study also paid close attention to the scalability and computational efficiency of the models. Given that demand forecasting in multi-market environments requires processing vast amounts of data, it was essential to evaluate the models' performance in terms of computation time and resource consumption. This aspect of the methodology was crucial for determining the feasibility of implementing these AI-driven solutions in real-world business environments, where timely and cost-effective forecasting is essential for maintaining

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a competitive edge [2].

Finally, the research involved extensive simulation testing, where the optimized forecasting models were applied to historical demand data from multiple regions. These simulations allowed for a practical assessment of how the models would perform in live market scenarios, helping to identify potential areas for further optimization and refinement. The results of these simulations were analyzed to determine the overall effectiveness of the proposed AI-based demand forecasting models in enhancing resource allocation, minimizing waste, and improving business efficiency across different markets [5].

Results and discussion. The study's results showed that AI-based models, particularly those using neural networks, outperformed traditional time-series analysis methods in forecasting accuracy. By analyzing real-world data from the Ukrainian food producer, the AI models demonstrated a significant reduction in forecasting errors, leading to better resource allocation and increased operational efficiency.

The CNN-GRU model (Fig. 2), adapted for the food production industry, proved effective in handling large datasets and recognizing complex demand patterns. This model, previously tested on retail data [4], showed promising results when applied to the multi-market scenario in food production.

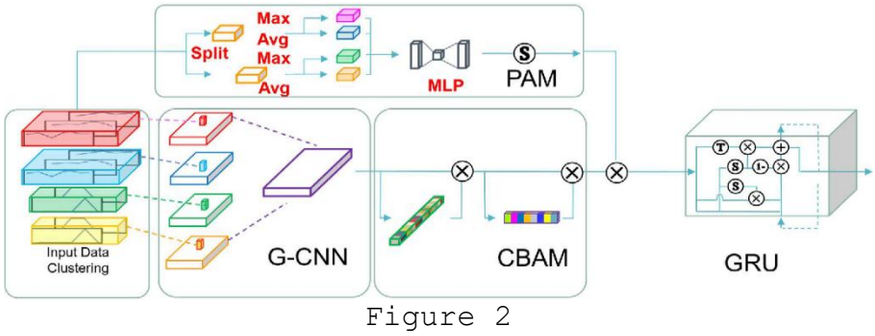

Figure 2

Architecture of the CNN-GRU model proposed in [4]

Additionally, clustering methods (Fig. 3) provided valuable insights into demand fluctuations during promotional events, helping to optimize stock levels and meet customer

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demand effectively [5].

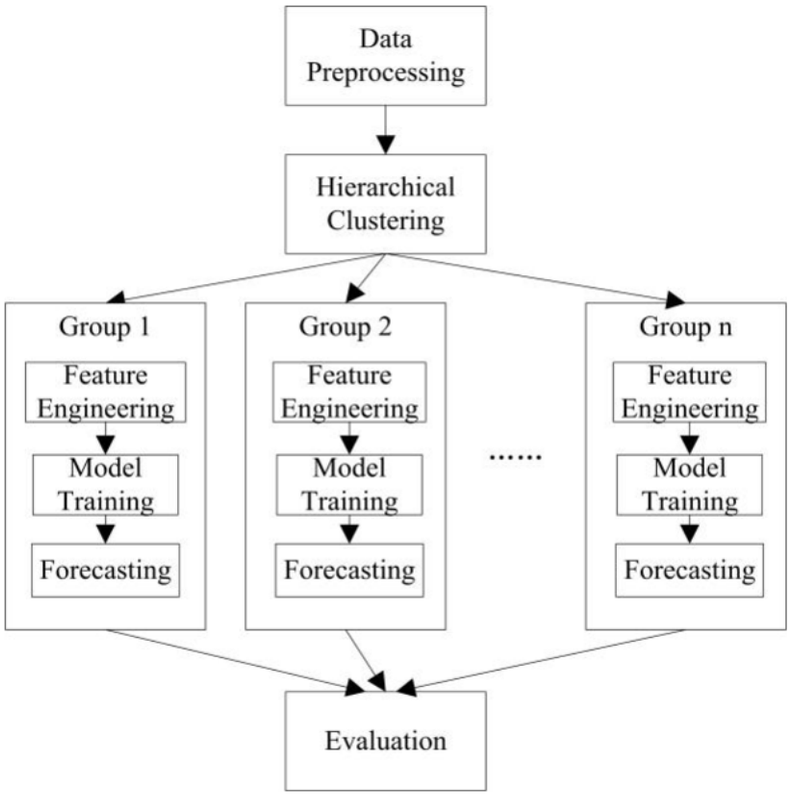

Figure 3
Forecasting framework based on clustering used in [5]

Conclusion. This research demonstrates the significant potential of AI-based software components in enhancing the accuracy of demand forecasting, particularly in complex, multi-market environments. By employing advanced neural network models, such as CNN-GRU and clustering-based methods, the study has shown that companies can significantly improve their decision-making processes and optimize resource allocation. The ability to analyze large datasets and detect intricate patterns that traditional methods might overlook gives businesses a distinct advantage in competitive global markets. AI-driven models have proven to be highly adaptable, allowing companies to respond quickly to dynamic market conditions, such as sudden shifts in consumer demand or

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external factors like economic and political changes.

Furthermore, the integration of external factors such as weather conditions into demand forecasting models opens new avenues for improving forecast accuracy. As seen in this study, incorporating these variables into neural networks can enhance their predictive power, especially for industries such as food production, where demand is often sensitive to external influences. This capability enables more precise forecasting and resource planning, ultimately leading to reduced waste, more efficient production cycles, and improved operational performance.

The study also emphasizes the need for continuous model refinement and optimization. The iterative process of fine-tuning neural network configurations, adjusting parameters, and adapting to specific market requirements ensures that the models remain robust and relevant across various industries and regions. However, while the results are promising, the scalability and adaptability of these AI models require further exploration. As businesses increasingly operate in interconnected and volatile global markets, the ability of these models to scale efficiently and adjust to new environments will be critical.

Future research should focus on expanding the application of these AI-based forecasting models to other industries beyond food production. This could include sectors such as retail, healthcare, and manufacturing, where demand forecasting plays a critical role in resource management and operational efficiency. Additionally, exploring the integration of even more external variables, such as geopolitical events, social trends, and market disruptions, could further enhance the adaptability and accuracy of these models.

In conclusion, this research confirms the transformative potential of AI-based demand forecasting tools. Companies that leverage these technologies can achieve a competitive edge by making more informed decisions, optimizing resources, and adapting to rapidly changing market conditions. Further advancements in AI and machine learning will undoubtedly continue to push the boundaries of what is possible in demand forecasting, making it an essential area for continued innovation and research.

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