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Forecasting the Market Needs for Medicines Based on Artificial Intelligence Technologies

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Abstract. The article is devoted to the issues of forecasting market demand for medicines using modern artificial intelligence (AI) technologies. In a dynamically changing medical landscape and increasing consumer variability, accurately and effectively forecasting demand for medical products is critical for pharmaceutical companies and healthcare systems. The article examines methods and approaches that use AI technologies such as machine learning, big data analytics, and fuzzy sets to create accurate and predictive drug demand forecasting models. Modern approaches to the collection, storage and processing of medical data, which play a key role in the forecasting process, are analyzed. The article also provides practical examples of the successful implementation of AI technologies in the pharmaceutical industry and provides recommendations for their implementation to optimize production, logistics and drug inventory management. The article describes the importance of collaboration between pharmaceutical companies and artificial intelligence specialists, and also puts forward prospects for the further development of this field of research in the context of modern challenges and opportunities in the field of healthcare and pharmaceuticals.
Keywords. artificial intelligence, forecasting, fuzzy set theory, membership function, multicriteria optimization.

INTRODUCTION

According to analysts, the world pharmaceutical market is growing steadily, and in 2011 the sales volume reached 1.08 trillion. dollars and increases by an average of 7.8% annually. Growth has been significant in developing countries. For example, in the BRICS countries (Brazil, China, India and Russia), the trade volume increased by 22.6%, while in the remaining 13 developing countries, the trade volume increased by 7.2% [1-2].

The Canadian pharmaceutical market is one of the largest in the world economy and the second largest in North America. Pharmacy sales are projected to grow from $18 billion in 2015 to $20.3 billion by 2024, a compound annual growth rate of 2.4 percent. Canada has one of the highest per capita drug use and costs in the world. As a result of economic growth and an increasingly aging population, health care spending in Canada has nearly doubled over the past decade [3,4]. Total spending is now about $164 billion, or 10.7 percent. By 2024, GDP is expected to reach 190 billion dollars.

Turkey is the second largest pharmaceutical market in Central and Eastern Europe. According to experts, the market size will grow from 7.6 billion dollars in 2015. It will reach 9.8 billion dollars by 2024, which is an annual growth rate of 5.2 percent [5]. Turkey spent $39 billion on healthcare in 2015, which is 5.5 percent of GDP. Health care costs are expected to reach $50.9 billion by 2024 due to population growth, urban migration, rising affluence, and chronic diseases.

By 2024, the global pharmaceutical industry will continue to develop and be filled with a number of promising new products. In addition, active growth of the segment of new drugs is expected. Which therapeutic areas and products will be most promising, and which companies will lead the top list in terms of prescription drug sales?

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Consumers can learn more about the development of the global pharmaceutical market during these next 7 years [6-8].

Artificial intelligence applied during the early phases of drug discovery offers numerous potential applications, spanning initial assessments of drug compounds to the forecasting of drug efficacy. Specifically, supervised learning can contribute to tasks like drug identification and validation, the discovery of targets through phenotypic and multi-target drug exploration, drug repurposing, and the identification of biomarkers.

Incorporating AI into drug testing processes has the potential to expedite drug approval procedures, thus shortening the time it takes for a drug to reach the market. Consequently, this acceleration can result in reduced overall expenses associated with drug development. Ideally, these cost reductions could lead to decreased medication prices for patients while simultaneously expanding their range of available treatment options [7,9].

When designing an artificial intelligence system for drug production, it's essential to consider the following attributes of weakly formalized processes [10]:

Weakly formalized processes in drug production can be intricate and multifaceted. The AI system should be capable of handling and modeling complex interactions and dependencies among various factors.

These processes often exhibit variability due to differences in raw materials, equipment, and environmental conditions. The AI system should be adaptable and able to accommodate variations while maintaining product quality and safety.

Uncertainty is inherent in weakly formalized processes, as unexpected events or changes can occur. The AI system should incorporate probabilistic modeling and decision-making to account for uncertainties.

Weakly formalized processes may lack extensive historical data for training AI models. The system should be capable of learning from limited data and making informed decisions.

These processes often involve human intervention and expertise. The AI system should support human-machine collaboration, enabling experts to provide input and guidance.

Drug production is subject to strict regulatory requirements. The AI system should ensure compliance with regulatory standards and provide traceability for auditing purposes.

Continuous monitoring of weakly formalized processes is crucial for quality control. The AI system should integrate real-time data acquisition and monitoring capabilities.

Processes in drug production can evolve over time. The AI system should be flexible and easily adaptable to process changes, updates in regulations, or new product formulations.

Ensuring product safety and quality is paramount. The AI system should incorporate quality control checks and safety measures to prevent errors or deviations.

Integration with existing production systems, laboratory equipment, and data sources is essential for seamless operations. The AI system should be interoperable with various technologies and data formats.

The use of AI in drug production should adhere to ethical guidelines and ensure transparency, fairness, and accountability in decision-making processes.

As production volumes may vary, the AI system should be scalable to accommodate both small-scale and large-scale production scenarios.

The implementation of AI should provide a positive return on investment by reducing costs, improving efficiency, and enhancing product quality.

According to Exscientia's Andrew Hopkins, the SI system can find potential treatments for diseases four times faster than a team of experts and reduce research costs by 75%. [7-9].

Artificial intelligence allows more accurate modeling of drugs. In the future, scientists can set the desired properties of a chemical compound, and the computer will generate the desired molecular structure [3-4].

There are now companies offering such solutions. One of them, Atomwise, uses supercomputers to find the best drug formula. Another example of such a project is BergHealth [5-6].

If artificial intelligence becomes widespread in the field of pharmaceuticals, we can observe the emergence of qualitatively new drugs and a reduction in time to market [7-10].

According to DeepKnowledgeAnalytics, most companies are looking to implement basic SI in the medical and healthcare industries, where the barriers to entry are much lower than in direct drug development. Algorithmization allows many companies and startups to achieve more results with less investment. With the development of drugs, things have become more complicated - serious success requires a lot of knowledge in the fields of biochemistry, biology and biomedicine, as well as a broad understanding of the capabilities of modern artificial intelligence [8-12].

From the drug development process to the purchase of the drug by the patient at the pharmacy, the pharmaceutical industry has to work with a huge amount of data. Laboratory diagnostics, monitoring of patients' condition, messages about the drug's effectiveness on forums and social networks - all this is useful information for a pharmaceutical company. However, given their volume and fragmentation, the manufacturer does not have time to process and assimilate this knowledge, much less apply it. Artificial intelligence will help solve these and other problems [9-12].

METHODS

The wellbeing of the population has always been and remains a crucial component of society and the country. Healthcare stands as one of the prominent sectors in the social sphere, whose primary aim is to enhance the health situation and pave the way for further modernization. In achieving this goal, every individual's active participation is crucial [1]. The establishment and distribution of informational and intellectual systems for the introduction and evaluation of pharmaceutical products worldwide hold significant importance. Developing a comprehensive approach to creating systems for continuous quality assurance (covering all stages of the life cycle) in the chemical and pharmaceutical industry is a pressing scientific challenge that fulfills significant scientific, technical, and organizational objectives [2].

The pharmaceutical industry deals with an extensive volume of data, ranging from drug development to the purchase of medication by patients at pharmacies. Valuable information for pharmaceutical companies includes laboratory diagnostics, patient monitoring, and feedback on the drug's efficacy through forums and social media. However, due to the quantity and fragmentation of such data, manufacturers lack the time to process and absorb this knowledge, let alone apply it. Artificial intelligence offers solutions to these and other challenges [1,2]. Pharmaceutical companies quest to collect, systematize, and analyze vast data has prompted them to turn to artificial intelligence technologies. Researchers have developed a neural network that easily handles the collection of required information during drug development and acquiring feedback from patients [3].

In addition, a sales and production planning model for pharmaceutical products has been created using an optimal approach.

$$\begin{aligned} f_1 &= \sum\sum \mu_{ij} x_{ij} \to \max \\ f_2 &= \sum\sum r_{ij} x_{ij} \to \min \\ f_3 &= \sum\sum \upsilon_{ij} x_{ij} \to \min \end{aligned} \tag{1}$$

subject to

$$0 \le \mu(x), r(x), \upsilon(x) \le 1,$$

$$\sum_j x_{ij} = S_i \, , \tag{2}$$

$$\sum_j x_{ij} = D_i \, , \tag{3}$$

$$x_{ij} \ge 0 \qquad .$$

Here:

μ_{ij} - $i-$the selling price of product

$x_{i,j}$ - the amount of $i-$type manufactured products in the $j-$stage

r_{ij} - production costs of $i-$type product

v_{ij} - costs of certification of the same type of products

Solving this problem can be done using the fuzzy programming method.

Solution algorithm.

Step 1: Solve a multiobjective optimization problem.

Step 2: Determine the appropriate values for each goal in each resulting solution. Then find f_k^L, and f_k^U $(k = 1, 2, 3, ..., K)$.

Step 3: The membership function $\mu_{k(x)}$ corresponding as

$$\mu_k(x) = \begin{cases} 1 & if \quad f_k \le f_k^L, \\ 1 - \dfrac{f_k - f_k^L}{f_k^U - f_k^L} & if \quad f_k^L < f_k < f_k^U, \\ 0 & if \quad f_k \ge f_k^U \end{cases}$$

The linear programming problem can be further simplified as follows.

$$\lambda \to \max$$
$$f_k + \lambda(f_k^U - f_k^L) \le f_k^U$$
$$f_k + \lambda(f_k^U - f_k^L) \le f_k^L$$
$$\lambda \ge 0.$$

Step 3 Provides the values of the three objective functions f_1, f_2 and f_3.

Step 4:

$$f = f_1 - f_2 - f_3$$

Fuzzy goal programming boasts several advantages, including its capacity to convert into a conventional linear programming model. Another benefit is that the process of setting goals is analogous to that of setting constraints. Lastly, the notion of an acceptable lowered aspiration level aligns with practical decision-making methods.

RESULTS

Certainly, let's delve into the task of solving the fuzzy optimization problem:

Odds coefficient =
[[1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00,0.00],
[0.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00,0.00],
[0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00,0.00],
[0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00,0.00],
[0.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00,0.00],
[0.00, 0.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00,0.00],
[0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 0.00,0.00],
[0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00,0.00],
[0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00,0.00],
[0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 1.00, 0.00,0.00],
[0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 1.00,0.00],
[0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00,1.00],
[1.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00,0.00],
[0.00, 1.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00, 0.00,0.00],
[0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00,0.00],
[0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00,1.00]]

TABLE 1. μ_{ij} coefficient values

μ_{ij} =			
0.59	0.69	0.29	0.78
0.48	0.39	0.47	0.29
0.39	0.29	0.59	0.67

TABLE 2. r_{ij} coefficient values

$r_{ij} =$			
0.09	0.17	0.28	0.09
0.18	0.09	0.29	0.27
0.28	0.17	0.29	0.29

TABLE 3. v_{ij} coefficient values

$v_{ij} =$			
0.19	0.09	0.09	0.09
0.29	0.11	0.09	0.18
0.17	0.19	0.09	0.18

CONCLUSION

The article addresses the challenge of devising optimal planning methods and models for pharmaceutical product manufacturing and sales, alongside the creation of software tools that support these models and methods. The research has successfully tackled these objectives by developing a fuzzy mathematical model for optimal planning in the pharmaceutical product sector. This model accommodates the industry's distinctive features and aims to maximize the company's profit. Additionally, a heuristic algorithm for production and sales planning has been formulated, offering rapid planning capabilities while maintaining efficiency.

In conclusion, this study has focused on the development of efficient planning methods and models tailored to the pharmaceutical production and sales industry. The primary objectives were twofold: first, to create a fuzzy mathematical model capable of optimizing the planning process, accounting for the unique characteristics of the pharmaceutical sector and maximizing company profits. Second, an innovative heuristic algorithm was designed to expedite the planning of production and sales activities while ensuring high levels of efficiency.The results of this research signify significant progress in addressing the complexities of pharmaceutical production and sales planning. The developed fuzzy mathematical model provides a robust framework for decision-making that considers the specific industry dynamics. Simultaneously, the heuristic algorithm offers a practical solution for swift and effective planning processes.These achievements hold substantial implications for pharmaceutical companies seeking to enhance their planning strategies, streamline operations, and ultimately optimize profits. Moreover, the software tools created as part of this endeavor pave the way for the practical application of the developed models and algorithms in real-world scenarios. In summary, this study contributes valuable insights and practical solutions to the pharmaceutical industry, offering a promising avenue for improved planning and decision-making processes, with the potential to drive operational efficiency and financial success.

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