Optimizing Nanofluids Properties Using Artificial Intelligence for Applications in Food Processing Industry

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The term "artificial intelligence" (AI) was coined by researchers at the Massachusetts Institute of Technology (MIT) during the organization of an academic conference in the same year. The inaugural AI program, known as Logic Theorist, was presented at the Dartmouth Conference, showcasing its proficiency in proving mathematical theorems (Shukla et al., 2013). Presently, AI research has diversified across various domains, prominently including expert systems, neural networks, and robotics (Hemmat and Afrand, 2020).

AI encounters intrinsic physical constraints within its operational scale, where governing principles significantly deviate from the macroscopic realm (Bahiraei et al., 2019). The assessment of thermal, kinematic, and physical properties represents a highly intricate, time-consuming, and resource-intensive process. The integration of AI into the food industry has revolutionized conventional approaches to food safety and quality assurance. As technological advancements continue, it is imperative to explore future trends that will define the next frontier of AI in ensuring the safety and quality of our food supply.

Properties of Nanofluids

The nature of nanoparticles (NPs) and base fluids are the key factors that decide the nanofluid (NF) preparation methods to get the desirable properties. There are two methods of NFs preparation, one-step and two-step methods but it is found that the two-step method is more efficient for preparing NFs with metal oxides (Eastman et al., 2001). Although one-step method has benefits of simultaneously producing and dispersing particles in base fluid, due to high cost of production, its applications get constrained to lab-scale production only (Yu and Xie, 2012).

But two-step method is comparatively economical and thereby adopted for large scale production of NFs (Mukherjee and Paria, 2013). In this method of production, NPs are first synthesised in dry powder form and then dispersed in base fluid with the help of homogenization, high shearing, magnetic stirring or ultrasonic agitation. Suitable surfactants can be used to overcome the sedimentation and agglomeration of NPs by creating a repulsive force among NPs.

Machine Learning (ML) Techniques for process optimization

The application of machine learning (ML) techniques becomes pertinent in NF research. Several ML methodologies, including artificial neural networks (ANNs) such as the multi-layer perceptron artificial neural network (MLP-ANN) and radial basis function artificial neural network (RBF-ANN), group method of data handling (GMDH), adaptive neuro-fuzzy inference system (ANFIS), category and regression tree (CART), random forest (RF), and support vector machine (SVM) including the least-square support vector machine (LS-SVM), have been investigated.

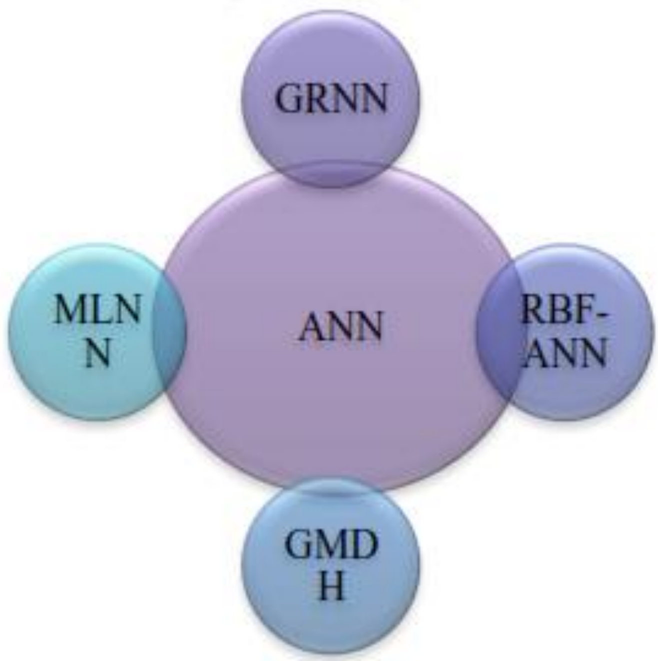

Fig. 1: Algorithms for Artificial Neural Network

Additionally, these ML approaches can be effectively combined with metaheuristic algorithms such as genetic algorithm (GA), particle swarm optimization (PSO), and imperialist competitive algorithm (ICA) to further enhance prediction accuracy and computational efficiency (Ma *et al.*, 2021). Artificial neural network Artificial Neural Networks (ANNs) stand out as the foremost and widely adopted algorithms in the realm of AI (Gao et al., 2018a). ANN has four types of algorithms as shown in figure 1 (Gao *et al.*, 2018b).

Other applications of AI in food industry

Predictive Analytics for Early Risk Detection

One of the key future trends is the widespread adoption of predictive analytics in food safety. AI algorithms can analyse vast datasets to identify patterns and potential risks, allowing for early detection and prevention of food safety issues. This proactive approach minimizes the likelihood of contamination and ensures a swift response to emerging threats.

Blockchain and AI Integration

The synergy between blockchain and AI is anticipated to play a pivotal role in enhancing transparency and traceability in the food supply chain. Blockchain's decentralized and secure nature combined with AI's analytical capabilities will create a robust system for tracking and verifying the journey of food products from farm to fork. This integration is poised to revolutionize accountability and reduce the risk of fraud or contamination.

AI-driven Sensory Evaluation

The future will witness advancements in AI-driven sensory evaluation techniques. Smart sensors and AI algorithms can mimic human sensory capabilities, leading to more accurate and consistent assessments of taste, texture, and overall quality in food products. This technology ensures that consumer preferences are met consistently, contributing to improved product development and customer satisfaction.

Robotics in Quality Control

The introduction of robotics, empowered by AI, will redefine quality control processes in food manufacturing. Robots equipped with advanced vision systems can perform intricate inspections, identifying imperfections or anomalies that may go unnoticed by human inspectors. This automation not only ensures precision but also speeds up the inspection process.

Personalized Nutrition with AI

AI applications will extend into the realm of personalized nutrition, tailoring food products to individual preferences and dietary needs. By analyzing consumer data and health profiles, AI algorithms can recommend or create personalized food options, contributing to healthier choices and catering to the growing demand for personalized diets.

Ethical Considerations and Transparency

As AI becomes more deeply ingrained in the food industry, ethical considerations surrounding privacy, data security, and transparency will come to the forefront. Future trends will focus on developing frameworks and standards that prioritize consumer privacy, ensuring that AI applications adhere to ethical principles and build public trust.

The future of AI in food safety and quality assurance holds immense promise, with innovations ranging from predictive analytics to personalized nutrition. As these technologies evolve, stakeholders in the food industry must navigate the ethical landscape and embrace transparency to harness the full potential of AI in ensuring a safer, more reliable food supply for consumers worldwide.

Conclusion

The utilization of Artificial Neural Networks (ANN) is favoured due to their precision and ease of formulation without requiring complete knowledge of the system. These AI algorithms are simple to apply, adapt, and can overcome lengthy time delays. Among various neural network models, the Multilayer Perceptron (MLP) neural network has been extensively studied and employed in the field of NFs due to its simplicity. In NF research, the most commonly used neural network model is MLP, while the Radial Basis Function Neural Network (RBF-ANN) is the preferred training method. Although MLP is widely employed, RBF neural networks have also found significant application in the NFs domain. Despite requiring more neurons than standard feed-forward ANNs, RBF-ANN can be developed in a shorter time compared to MLP neural networks. Furthermore, the Generalized Regression Neural Networks (GRNNs) exhibit a simple structure that reduces learning time, making them particularly suitable for NFs modelling when ample training vectors are available. Consequently, for NFs with a large number of samples, the use of RBF-ANN is recommended. However, it is important to acknowledge that despite the efficiency of neural networks in predicting NF characteristics, selecting the appropriate ANN type and determining its configuration still pose challenges. Further research and exploration are needed in this area.

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