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Application of Computer-aided Artificial Intelligence Techniques in Food Industry

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The incorporation of Computer-aided artificial intelligence (AI) into the food business has signaled the beginning of a new age of innovation and transformation. This review paper digs into the different applications of artificial intelligence in the food industry. AI is altering operations, increasing efficiency and transforming customer experiences in industries ranging from agriculture to food processing, manufacturing, supply chain management, delivery services and restaurants. The report delves into how AI is being used for precision farming, quality monitoring, supply chain optimization, individualized consumer interactions and other applications. While highlighting the advantages, the analysis also addresses problems such as financial constraints, a scarcity of experienced specialists and regional differences in adoption. It emphasizes the symbiotic relationship between AI and human knowledge, emphasizing that AI supplements human functions rather than replacing them. The report finishes by emphasizing AI's potential to move the food business toward greater sustainability, efficiency and consumer happiness.

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1. INTRODUCTION

The importance of food, a basic human requirement, cannot be emphasized. It is derived from agricultural outputs shaped by farmers and is an important factor in a country's development. Food business products are critical not only for national economic growth but also for global economic dynamics [1]. As a result, assuring the quality, safety and efficient delivery of these items has become critical. Emerging technologies, particularly artificial intelligence (AI), have proven extraordinary success in fulfilling these goals in recent years [2].

As a result, investigating the applications of AI-driven smart agriculture and improved food business practices is critical. Such approaches not only meet societal demands but also ensure timely delivery of high-quality goods. Modern technologies enable the food business to increase productivity dramatically, resulting in exponential economic growth [3].

Artificial intelligence has traditionally been defined as an artificial construct of human-like intelligence capable of learning to think, plan, perceive or process natural language [4,5]. It involves the theory and development of computer systems capable of doing activities that would ordinarily require human intelligence, such as visual perception, speech recognition, decision-making and language translation [6].

Artificial intelligence is a discipline of computer science that focuses on constructing machines that are designed to behave like humans. The father of AI, John McCarthy, defined AI as "The science and engineering of making intelligent machines, especially intelligent computer programs" [7].

Machine learning and deep learning are two of the most widely utilized AI techniques. These models learn from data and are used to generate predictions by individuals, businesses, and government agencies. To deal with the complexity and variety of data in the food business, machine learning models are being developed today [8].

In the food industry, where the development of standard, reliable procedures to control product quality is a major goal, as with other companies, the search for new ways to reach and serve customers while keeping costs low has necessitated the deployment of AI to achieve better customer experience, efficient supply chain management, improved operational efficiency, reduced material movements and vehicle activity and to achieve the best results in the industry.

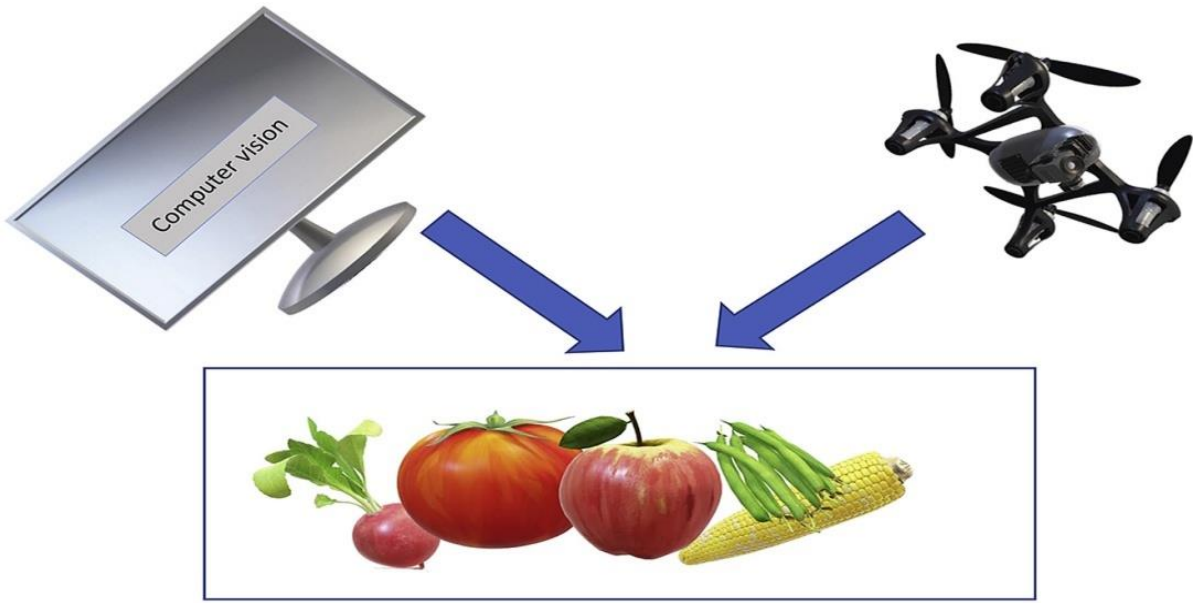

Fig. 1. Artificial intelligence with computer vision

1.1 Fields of Machine Learnings are

- Machine Learning
- Computer Vision
- Expert Systems
- Planning and Scheduling
- Neural Networks
- Natural Language Processing (NLP)
- Robotics
- Knowledge Representation and Reasoning
- Genetic Algorithms
- Cognitive Computing
- Artificial General Intelligence (AGI)
- AI Ethics and Fairness
- Machine Perception
- Reinforcement Learning & Evolutionary Computation.

1.1.1 Machine Learning (ML)

Machine learning is a subfield of artificial intelligence that focuses on the creation of algorithms and models that allow computer systems to learn from data and improve their performance over time without having to be explicitly programmed. It entails exposing a machine to a huge amount of data to train it to spot patterns, make predictions, or execute certain tasks. When presented with new input, the machine learns from it and applies what it has learned to make informed decisions or predictions. Machine learning, in essence, allows computers to adapt and improve their performance based on prior experience, making it a valuable tool for tackling difficult issues and making data-driven decisions.

This field involves the systematic exploration of algorithms and statistical models harnessed by computer systems to proficiently execute specific tasks, all without the need for explicit instructions. Instead, these systems rely on discerning patterns and making inferences [9]. For instance, consider the recognition of a basic object like an apple or an orange. Rather than explicitly detailing and coding the identification process, the objective is attained by furnishing a diverse array of images of the objects. This approach enables the machine to autonomously discern the necessary steps to distinguish between an apple and an orange.

1.1.2 Natural Language Processing (NLP)

Natural Language Processing (NLP) encompasses a wide range of tasks that enable computers to interact with human language effectively. In the realm of text understanding, NLP algorithms are designed to analyze and comprehend the meaning embedded within textual content. These algorithms excel in tasks like sentiment analysis, where they ascertain the emotional tone of a piece of text, as well as named entity identification, which involves recognizing and labeling the names of individuals, places, objects, and other entities. Additionally, NLP algorithms engage in part-of-speech tagging, assigning grammatical labels to words, such as identifying them as nouns, verbs, adjectives, and more.

The capabilities of NLP extend to language generation, where it demonstrates its prowess in generating text that closely resembles human-written content. This includes applications like machine translation, enabling seamless conversion of text from one language to another, text summarization, which condenses lengthy materials into concise versions, and crafting Responses for chatbots to facilitate natural conversations.

NLP's influence is also palpable in speech recognition, a technology that translates spoken language into written text. This innovation finds utility in diverse applications ranging from voice assistants that offer hands-free interactions to transcription services that convert spoken content into readable form.

Beyond comprehension and communication, NLP plays a pivotal role in information retrieval. It harnesses techniques to efficiently extract valuable insights from vast volumes of text. Notably, search engines leverage NLP to bridge the gap between user queries and relevant documents, ensuring accurate and meaningful search results.

NLP extends its reach into question-answering, enabling systems to interpret and respond to natural language queries. These systems provide informative answers by drawing from a corpus of text, thereby facilitating more intuitive interactions between humans and machines.

Furthermore, NLP contributes to language modeling by equipping models with an understanding of the statistical nuances of human language. This empowers them to predict the following word in a sentence or generate coherent text, which has applications in various creative and communicative contexts.

In the realm of sentiment analysis, NLP algorithms evaluate the sentiment expressed in text, categorizing it as positive, negative, or neutral, thus facilitating the analysis of public opinion and emotional trends.

Text classification, another fundamental NLP application, involves categorizing text into predefined classes or categories. This technique proves invaluable in tasks like spam detection and subject categorization.

Lastly, NLP's capabilities extend to text-to-speech (TTS) technology, which converts written text into spoken speech. This innovation finds utility in applications such as video voiceovers and accessibility solutions, making content more accessible and engaging.

In essence, NLP's diverse applications underscore its crucial role in bridging the gap between human language and computing systems, enhancing communication, comprehension and interaction across various domains.

Natural Language Processing is broadly defined as the automatic manipulation of natural language, like speech and text by software. It is a subfield of computer science concerned with the interactions between computer and human languages that is how to program computers to process and analyze large amounts of natural language data [10].

2. VISION

It is a science field concerned with teaching robots to comprehend visual information. To gather and interpret visual data, machine vision employs cameras, analog-to-digital conversion and digital signal processing. Its major purpose is to automate actions that the human visual system can perform [11].

2.1 Robotics

Robotics is a multidisciplinary field that combines engineering and science. It entails the design, construction, operation, and control of robots, as well as the computer systems that regulate their guidance, sensory feedback and data processing. These technologies lead to the creation of machines that can mimic human actions and replace human work [12,13]. Robots frequently succeed at activities that stretch human capabilities or necessitate regular execution.

2.2 Autonomous Vehicles

Autonomous vehicles, often known as self-driving automobiles or robot cars, are vehicles that can perceive their surroundings and navigate with little human interaction [14]. These cars are supposed to sense their surroundings utilizing various technologies and make judgments based on that information & eliminating the need for constant human control.

The food industry has embraced the integration of AI research projects to enhance various aspects of food production, safety and consumer experience. The latest AI research projects in the food industry include [15].

2.3 Predicting Food Security Outcomes

Utilizing AI to forecast and assess food security scenarios, aiding in proactive measures to address potential shortages.

2.4 Food Identification

Employing AI for accurate identification of different food items, assisting in inventory management and quality control.

2.5 Ranking Food Preferences

Implementing AI to rank and personalize food preferences based on individual tastes and trends.

2.6 Automatic Surface Area and Volume Prediction of Food

Using AI to predict the surface area and volume of food items, facilitating portion control and accurate nutritional analysis.

2.7 Generating Images of Food Based on Recipes Text

Using AI to generate visual representations of food based on textual recipes, enhancing recipe presentation and communication.

2.8 Automatically Assigning a Collective Restaurant Star Rating

Applying AI to aggregate customer reviews and assign star ratings to restaurants based on the quality of food.

2.9 Food Recommender System

Developing AI-driven systems that recommend food options to users based on their history, ingredients and recipe images.

2.10 Visual Identification of Fraudulent Foodstuff Products

Utilizing AI to visually identify fraudulent or counterfeit food products and enhancing consumer safety.

2.11 Food Recognition Using Partially Labeled Data

Leveraging AI to recognize and categorize food items using partially labeled data, improving accuracy and efficiency.

2.12 Recipe Generation from Food Images

Creating AI models capable of generating recipes from images of food items, fostering creativity and convenience.

2.13 Recognizing Eating Gestures by Tracking Wrist Motion

Implementing AI to recognize eating gestures by tracking wrist motion and potentially aiding in dietary monitoring.

2.14 Real-time Detection of Food borne Illness

Developing AI solutions for real-time detection of food borne illnesses and contributing to food safety protocols.

2.15 Automated Food Label Quality Assessments

Utilizing AI to automatically assess the quality and accuracy of food labels and ensuring compliance with regulations.

2.16 Plant Seedlings Classification

Applying AI to classify plant seedlings, assisting in precision agriculture and crop management.

2.17 Assessing the Health of Individual Chickens

Utilizing AI for individual assessment of chicken health, aiding in animal welfare and farm management.

2.18 Identification of Leaf Diseases

Implementing AI to identify diseases in plant leaves, aiding in early detection and treatment.

These AI research projects reflect the innovative ways AI is transforming the food industry, enhancing efficiency, safety and consumer experiences across various domains.

3. APPLICATION OF AI IN FOOD INDUSTRY

In addition to the research projects mentioned above, key areas of application of AI in the food industry include production, product development, product customization, marketing, manufacturing, robotics and processing of food products. AI can also be applied in restaurants, bars and cafe businesses [16-18].

The agricultural sector is encountering significant challenges, and the integration of artificial intelligence (AI) is increasingly recognized as a solution to address these issues. The trend toward adopting AI in agriculture is undeniable, as it holds the potential to revolutionize decision-making and overcome obstacles in farming practices. However, effective decision-making alone is insufficient to achieve desired outcomes. The implementation of intelligent agents to enact these decisions is gaining traction as a viable solution for the future of agriculture. While agriculture automation is a priority for many countries, the incorporation of technologies like the Internet of Things (IoT), wireless communications, machine learning, artificial intelligence and deep learning is still in its early stages [19,20].

In the domain of Food Processing, automation is playing a pivotal role, especially in areas where complete automation is yet to be achieved. The food processing industry is harnessing the power of AI to streamline various processes. This encompasses tasks such as sorting foods, adhering to health and safety regulations, innovating new products, and optimizing supply chains. By integrating technology, work processes are enhanced, employees' tasks are simplified and operational efficiency is heightened.

Through automation, the food processing industry can ensure hygiene standards and maintain high food quality across the board.

Food Manufacturing is another arena where AI is gaining prominence. In the manufacturing of substantial quantities of goods, intricate mechanisms come into play. AI aids in overseeing every stage of this intricate process, making predictions about costs and stock management. Through machine learning, factors affecting quality and disruptions in the manufacturing process can be identified, while also tracking products from their production origins to the hands of customers, thereby ensuring transparency. For Food Production, AI is proving to be a transformative force. Advanced applications of AI in this realm enhance efficiency, safety and profitability. It holds immense potential to optimize production processes, identifying the best operational points within manufacturing facilities. By facilitating faster production transitions and pinpointing potential bottlenecks before they escalate, AI ensures optimal productivity, efficiency and output for facilities.

The domain of Food Packaging is witnessing a transformation with the integration of AI-powered robotic equipment capable of performing intricate packaging tasks with precision. This evolution in technology addresses the heightened demands for packaging and picking, spurred by consumer expectations. Given the complexity and labor-intensive nature of packaging, AI-driven automation presents a distinctive opportunity to enhance efficiency and accuracy.

In the context of the Food Supply Chain, the challenge lies in delivering high-quality food products to markets at reasonable costs to meet consumer needs. As food supply chains continue to expand, AI's potential emerges as a critical tool for improving food safety. Companies can leverage AI to assess and monitor food safety at every stage of the supply chain. The implementation of AI-powered supply chain management systems enables comprehensive monitoring and control of activities across the entire supply chain. By minimizing delays and optimizing profit margins, AI ensures meticulous oversight of supply chain operations.

The Food Delivery segment is undergoing rapid growth, and AI plays a central role in many food delivery organizations. Leading food delivery services employ AI to enhance marketing efforts through automation. Operational efficiency is heightened through automated processes like food ordering, dispatching and billing. AI also contributes to improved customer service, streamlining and enhancing the food delivery experience.

Restaurants are also tapping into AI's potential, utilizing applications to recommend optimal dining establishments based on user preferences, location, and past choices. AI solutions for food service consolidate data from various food delivery platforms, providing users with a seamless ordering experience. Self-service systems are gaining popularity in restaurants, enabling customers to take charge of the ordering process.

The integration of Robotics is a noteworthy development within the food industry. While robots have been employed primarily by larger food businesses, their use is expanding. From tasks such as seeding, watering and harvesting to cutting, processing, and packaging food products, robots are making significant contributions. Applications range from drones for order delivery to robotic hands managing intricate processes in food manufacturing and even cooking. Notably, companies like 7-Eleven have incorporated drones into their delivery services. Although the adoption of robotics may be more gradual in certain factories, the long-term benefits are evident, enhancing overall efficiency and effectiveness.

Food safety, food retailers, food market analysis, optical food sorting, predictive maintenance, tracking and traceability, tailored customer service and increased consumer interaction are some of the other applications.

4. BENEFITS AND CHALLENGES

The use of AI in the food and beverage industry is bringing in a slew of advantages that span multiple elements of operations and customer experience. This technological breakthrough results in fewer human errors, less waste of precious resources, cost savings, increased customer satisfaction, process optimization and automation, and the capacity to accommodate bespoke orders. Notably, AI systems outperform human workers in production lines in terms of accuracy, speed, and consistency. AI can improve hygiene and cleaning duties, which is a significant aspect of determining food safety. Intelligent algorithms can be used to improve food and service quality, ultimately leading to healthier meals for customers [21]. The use

of large datasets in agriculture contributes to the faster improvement of food crops, revolutionizing the industry faster than ever before. AI adoption can help organizations represent themselves as digital pioneers.

Artificial intelligence (AI) is now widely used in almost every aspect of life, enabling us to optimise and automate the manufacturing industry, revolutionising food production. With the help of an intelligent system, farmers can analyse and ensure the optimum conditions, such as seed and crop choice, water use, and temperature, so that food quality can be improved. To determine the performance of various AI models and algorithms for the food sector, there is a need to study various mathematical and statistical techniques, and the correlations between the various food industry parameters responsible for higher growth [22].

The increasingly widespread and sophisticated computing networks enable modern industrial and logistical systems. Data are continually created by sensors, machines, systems, intelligent devices and people inside these networks. This Big Data is analyzed quicker, more extensively and deeper than ever with increasing computer powers. These breakthroughs have redeveloped and created a new age known as Industry 4.0 or the Smart Factory, the value of artificial information technology (AI) [23].

Increasing demand towards the AgTech industry using computer vision and AI which might be a path towards sustainable food production to feed the future including of some implications regarding challenges and recommendations in inclusion of technologies in real time farming, substantial global policies and investments [24].

Furthermore, while AI adoption is well advanced in locations such as the United States and Europe, many other countries are still in the early phases of embracing this technology. It is critical to stress that artificial intelligence will not replace human jobs in the food sector; rather, it will supplement human efforts. Humans will continue to play an important role in operations, equipment repair, and system maintenance. AI technology works in tandem with people to improve operational efficiency and overall performance [25].

5. CONCLUSION

In conclusion, the application of artificial intelligence (AI) in the food industry has demonstrated a transformative impact across various sectors and aspects. The synergy between AI and the food industry is reshaping operations, optimizing processes, enhancing product quality, and revolutionizing customer experiences.

In the realm of Agriculture, AI-driven technologies are tackling challenges such as precision farming, crop monitoring and disease detection. The integration of AI empowers farmers to make data-driven decisions, thereby improving yield, sustainability and resource management.

Within Food Processing and Manufacturing, AI-driven automation is streamlining tasks, enhancing quality control, and ensuring compliance with safety standards. The ability of AI to handle complex tasks like food sorting, packaging and quality assessment is reducing human errors and minimizing wastage.

The Food Supply Chain benefits from AI's capability to monitor and control activities, ensuring product safety, reducing delays and optimizing profit margins. AI-powered supply chain management systems provide transparency, enhancing efficiency and reliability.

In the domain of Food Delivery and Restaurants, AI is enhancing operational efficiency, improving marketing strategies, and delivering personalized customer experiences. Recommendations based on user preferences, automated ordering processes and self-service systems are reshaping the way consumers interact with food services.

Robotics is playing a significant role, from packaging to processing and even cooking. Robots are optimizing production, reducing labor-intensive tasks and improving overall operational efficiency.

Despite the evident benefits, challenges remain, including cost constraints, the scarcity of skilled experts, and the need for seamless integration of AI technologies. The adoption of AI is not yet ubiquitous, with variations across regions and industries.

However, the potential to overcome these challenges and unlock AI's full potential in the food industry is significant. In this dynamic landscape, it's important to recognize that AI will not replace human roles but will collaborate with human expertise, augmenting capabilities and driving operational excellence. As the food industry continues to evolve, the intelligent application of AI stands as a beacon of innovation, promising enhanced sustainability, efficiency and improved consumer experiences. The journey towards a more technologically advanced and optimized food industry is well underway, with AI as a central driving force.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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