



Applications of Artificial Intelligence and Machine Learning in Food Industries-A Study

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Abstract

The widespread use of Artificial Intelligence (AI) is quietly lessening interactive communication between humans, and rapidly turning the world automotive. These advancements facilitate rapid mass production and optimize supply chain management. The ultimate goal is to enhance end-customer satisfaction, which is a primary driver for an industry to thrive and lead in the global market. Robots and data processing mechanisms are the some of the best known leading high-end technologies that make use of Artificial Intelligence (AI) and Machine Learning (ML) for manufacturing, processing, and delivering qualitative and quantitative products with a minimal cost, labor, and time consumption. Today, even the start-ups or small businesses such as cafes, fast food centers, restaurants, etc. are making use of these technologies to start out of the crowd and grow their business rapidly.

Keywords: artificial intelligence (AI), machine learning (ML), food quality (FQ), food industry (FI), food cost (FC).

1 Introduction

Before we talk about the quality of the food, naturally, any food that is edible and nutritious gives a reason at least to survive. The food industries play the role of collecting the raw food materials from the farmers and local provincials and then refine, process, and package into a proper edible source for its customers. Secondly, the motive to make the same food more effective with quality is a serious issue as well as the most important factor for any food processing industry [1]. If a customer invests his money on a particular food item or at least its raw material, there most probably reflects a negotiation, that demands qualitative as well as quantitative [2]. Sellers and buyers sporadically are agreeing to evaluate the standardization of a given product so as to generalize specialized non-systematic principles and discontinue the use of classifier preparations [3]. With this, measurable quality-grading procedures are to be taken care of by the modern markets that has studied the customer behaviors and demands for appropriate execution, helpful for both the marketing managers as well as the customers. The reason why these classifier preparations are quietly not adaptable by the food industries currently is because of its expensive long-drawn-outs that often leaves behind inexperienced training methods, prone to



Submitted: 29 May 2025

Accepted: 25 July 2025

Published: 29 October 2025

Vol. 1, No. 1, 2025.

10.62762/DA.2025.258039

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Citation

Khan, R., & Pujahari, R. M. (2025). Applications of Artificial Intelligence and Machine Learning in Food Industries-A Study. *Digital Agriculture*, 1(1), 10–19.



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repetitive errors, and damaging business convictions [4]. On a contrary, food industries are adopting more inexpensive and precise tests to challenge different human behaviors so that there is hardly any repetitive mistake during the conduction of food quality check [5].

1.1 Technologies used in Food Industries

Food industries are often non-adaptable to technologies and can still survive on its own. However, due to rising competition within agri-food producing and processing sectors, technology helps in refining distributions, packaging, as well as testing more swiftly and faultlessly within a strict cost perimeter. There is less involvement of human-laborers and more usage of robotic mechanisms as well as data processing practices. This effectively guarantees any errors or damages in food quality and sets a seal on its customers about the food safety [6–9].

1.2 Artificial Intelligence (AI)

Artificial intelligence (AI) is the impersonated version of human understanding and functions of intelligence controlled by a computer to perform their exact tasks with an ability of discernment exactly carried out by humans. This type of technology is helpful in continuous learning and swiftly solving any existing technical problems or errors [10]. A 2006 plaque from Dartmouth College revealed at a conference that the word 'Artificial Intelligence' was first used in 1956 during the institute's Summer Research Project. It also reported how human intelligence activities are accredited and hypothetically converted to a machine-based intelligence. According to the plaque, the event was organized and performed by two cognitive scientists John McCarthy from Dartmouth and Marvin L. Minsky from MIT, accompanying the chief architect Nathaniel Rochester from IBM, and Claude Shannon, a mathematician from Bell Laboratories. The main objective of this program was to demonstrate the importance of Artificial Intelligence and hypothetically theorize the capability of a computer to simulate the refining behavior of a human mind and intelligence, precisely substituting human labor force in any type of industry. The concept of artificial intelligence took a specific birth in the year 1955 at the Dartmouth campus workshop when the US Defense financially supported the Rockefeller Foundation for its innovative ideas and visions, and granted the permission for organizing the summer research project [11, 12]. The cognitive scientists were of the opinion that the analytical capabilities of a

human brain get distracted whenever its substantial effort is exercised on the postwar operations of systems engineering and cybernetics, and its cognition is extracted by drawing mathematical logics and psychology on the framework. Appropriately, the principles remain sticker to the ground as long as the initial ones keep replicating to innumerable subjective frameworks [13]. Herbert Simon and Allen Newell suggested that the human intelligence and advanced digital computers together belong to the same family such as symbolic information processing systems, as both of these assets input data distinctively to operate it along to the provided principles. They thus, help in solving problems, and contrive judgements, decisions and its conclusions [14]. As the 1956 AI workshop grew into popularity and authoritative, these cognitive scientists and researchers ventured into active curriculums such as medical operations and diagnosis, games like chess and play-stations, space research, mathematics, food industries, defense, research analysis, etc., along with AI technologies to replicate the behavior of human activities in any of those areas but soon was discarded by many subjects by the end of the twentieth century. Their ambition was to replicate every type of intelligent human activity into the machines so as to perform those very tasks automatically without the need of human labor work and intelligence. Today these automated artificial systems are developed by many researchers to substitute man-made methods and to help a domain in solving several issues and hindrances that may lead to serious damages later on [15]. The artificial substitutions to human activities today mainly aim at quick advanced tactics such as for instance, the gaming platforms with a constant measurable track record of every movement allows a player to practice for a match without even depending upon a human guidance or opponent [16, 17]. In a truer sense, the Dartmouth workshop was legit a failure according to McCarthy because people when assembled there for the event neither fairly understood their concept nor exchanged any ideas because ideas are interchanged when someone had a solid confusion or question in mind. He lamented that it was absolutely a new concept for those decades and visitors hardly paid serious attention to what AI research was all about [18]. Some supporters of McCarthy and team disregarded the ideologies that designated human intelligence as a complicated one. Instead, they concluded that the human intelligence is nothing but a simple but never-ending loop that keeps on formulating unless a human is satisfied with a certain piece of work or

action. It develops as much as one uses its brain and stops developing for those who do not care for working on a methodology [19–21]. Edward Feigenbaum, a well-known AI scientist once put forward a theory in 1977 that experiences prepare humans to resolve issues deliberately because it is instinctive in their consciousness compared to those of the secondary intelligent agents, such as technologies. The input knowledge keeps on developing their intelligence as they keep learning on their own. To unburden work-loads on humans, ‘knowledge engineers’ keep on interviewing human experts and analyze different problem-solving strategies, so as to inscribe these features for the automated usage [21].

1.3 Machine Learning (ML)

Enlarging data quantities, computer resources along with improved learning algorithms in past few years boosted artificial intelligence to fresh start once again. Although it is not a newer concept, it is a quiet refreshing strategy for the food industries. However, artificial intelligence won’t likely help them without the use of machine learning. On joint effort, both artificial intelligence and machine learning are used today to get into grips with the industrial issues during food processing such as Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA). The major most issue in these industries is the accurate time prediction that forecasts food sales but by using radicalized algorithms along with powerful vector machines makes the production more methodical and modular [22–25].

1.4 Food Industry and Technologies

On rapid growth in human population, the demand of food significantly grows. On a contrary note, the food supplying industries majorly depend on fuels in which a restriction on carbon footprints are just not enough. Due to disruptive climatic conditions in recent years, the average global temperature has risen swiftly causing massive sub-standardized vegetation. Since the amount of vegetation produced on a daily basis isn’t sufficient to feed enough populaces, the industries tend to sell their goods at a higher cost forcibly to remunerate their daily workers as well as vendors and dealers [26, 27]. Therefore, with the use of substantial amount of advancing technologies, human labor force can be substituted with automated mechanism systems for manufacturing food using biotechnical methods and experiments [28]. When it comes to food production, climate is the first-most concern that affects the vegetation. They result in

obstructions due to massive industrial revolutions in past certain decades and centuries, and also due to Greenhouse Gas emissions (GHG). However, United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the Paris Agreement are some of the renowned results that are working hard collaboratively with several governments to restore climates, floras as well as faunas [29]. Processed foods are quiet popular at Tier I and Tier II cities majorly. But these processing facilities demand more amount of supplies, raw materials, and energy resources such as fuels and its variants [30, 31]. A hasty decrease in raw energy resources on earth likely coal, carbon, wood, have put a ban on further fetches by several government and private institutions. Instead, they have suggested to find other alternative options to produce fuels such as low-carbon technologies, or organizing economic products that costs cheaper due to less usage of energy on it. Using artificial intelligence, machine learning, as well as advanced algorithms in agricultural sector, there has been seen a good start in producing natural, scalable foods using whole variety of standards and satisfied procedures [31]. Some of the best examples of these standards are:

- PAS 2050 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services;
- ISO/TS 14067:2018- Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification;
- ISO14040:2006 - Environmental management-life cycle assessment: principles and framework;
- ISO14064-1:2018 - Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.

A Carbon Footprint (CF) is calculated against a whole basket of frozen vegetable in the CFOOD project using CF expert software system to reduce CF from those given frozen vegetables. Here, PAS 2050 and ISO/TS 14067:2018 are evaluated to the given CF during the optimization process. This makes it very clear the CF calculators work and found effective to the individuals associated with food production. The calculator is easily found online and anyone can access into it using internet. The use of the methods of machine learning not only helps in the CF calculation but also substantiates the quality of food as well as its

parameters used during the production [32, 33].

2 Literature Survey

One of the most critical issues food industries regularly face is the food revenue forecasting because any decision over this would decide the rise or fall of the company at the market place in next recent days. However, it doesn't remain volatile always. It also helps in reducing expenses and progressive inclining revenues. While a number of prediction tasks get on hold primarily, various types of algorithms make a match with the time series interdependently [34]. Food industries are enhanced carefully using computer vision and artificial intelligence (AI). The sole motive behind these technologies is to access big data for actively operating real time start machines and predictable models so that Agri industries are modernized systematically to sustain qualitative as well as quantitative food production. Besides these technologies, we have Internet of Things (IoT), a sustainable aid to stream data in a large number and constantly surveil food and agricultural industries with a proper examination. On top of this, food industries have to regularly deal with safety concerns, quality assessments, and modernizing of supply chains. Therefore, along with AI, ML, IoT, and big data, the digitized blockchain traceability and gene sequences are equally accredited for laying their advantages on validating industries like food manufacturing and production [35].

Besides Artificial Intelligence (AI), machine learning methods also have core advantages in the food processing sector. They validate the standardization of a food and the parameters required for their processing such as natural energy resources, raw materials. The carbon footprint extracted from raw materials are caused due to unnecessary pollution created by man. To minimize these carbon footprints is one of the greatest factors that needs to be controlled as quickly as possible but with only relevant energy resources that doesn't get depleted nor causes serious pollutions. To handle this case, machine learning fits accurately here. With the help of AI technology, machine learning will set up programs to closely monitor the root-causes and estimate the required carbon quantity that can be used for training the machineries. This way, the cost of the energy will grow even with a limited amount of resources [36]. Be the work for slicing meat, or picking up or shifting things or fruits and vegetables from one counter to the other, robotic mechanisms can do every of those works that are worth time saving.

These advancements run and execute their tasks on the orders given presented to them using AI and machine learning (ML). The major but initial issue faced by the mechanics at first are how does the machine handles a certain food product. There are certain raw products that need to be handled tenderly because quality is the foremost target. If grasped tightly, delicate foods may go disruptive and wasted. Therefore, we cannot assume that there is no functioning of human labor, but a trained employee can facilitate the robots or machines according to the requirement and adjustment. But one thing is sure here that an industry doesn't need to pay for workers for simply slicing, picking or shifting materials from one counter to the other. Instead, they should be highly trained to make them work on quality checks, adjust or regulate temperature or grasping jaws, etc. where it is necessary only [37].

3 Using AI in Food Industry: Machine Learning applications in Food Manufacturing

Food safety regulations bound the manufacturing industries to pay more thorough attention upon the paths of the food supply chain. The task gets easier when AI is put to use instead of a labor force as it keenly monitors each stage specifically without any repetitive errors [38]. This is the reason why manufacturers maintain a transparent track record about their goods to its customers. Customers at the end get to know every minute details about the food processing and quality including transportation, inventories as well as listed expenses.

3.1 Sorting food: Optical Sorting Solutions

As discussed previously, the food processing units do not need to hire human workers for sorting out food products, or cut and slice a particular type of food or shift from one counter to the other. Instead of keeping fixed to traditional methods like manual working, a food processing industry need to adapt to modernized methods such as automatic mechanisms and the use of advanced technologies like AI, ML, IoT, etc. This way sorting won't cost any unnecessary expense at least at a small-scale industry who cannot afford to pay for each and every method or equipment. Still majority of small-scale industries believe that it is quite a heavy expenditure on the purchase of these advanced tools and systems. They are not completely wrong with it, but it is also necessary to understand that adaptation to modernized methods, tools, and equipment's is a one-time investment for at least a margin of ten successive years. It has a

good face value and helping in reserving a standard space at the global competitive market [39]. On the other hand, the use of advanced peeler, choppers and sorting tools and equipment's during processing of food manufactured by a Norwegian corporation, TOMRA solves the problem of better processing. They precisely sort raw and manufactured products with absolute cleanliness and safety using highly consistent technologies so that the food is inspected in terms of color, characteristics, shapes, as well as sizes. Some of the best known equipment include Field Potato Sorting Machine (FPS), Optical belt sorting machine, Blizzard Sorting Machines for individually and quickly freezing vegetables, meat, and fruits, QV-P in-line analyzer, and many more [40].

3.2 Predictive Maintenance, Remote Monitoring, and Condition Monitoring

It is quiet odd to think that machineries don't require any expenditure. When the demand in products increase, the manufacturing units do require periodical and predictive maintenance at any cost. If not treated, they may lead to serious damages, loopholes, and repetitive errors causing serious problems itself upon the products [41]. Customers demand quality products and therefore to maintain this principle, every food or non-food manufacturing industries much possess Root Cause Analysis system that can terminate the problem fundamentally at the very spot when detected. On predicting maintenance and on-time repairs, at least 50% of time and cost is reduced or saved during the production process. Similarly, condition monitoring is also a necessary step for every industry to monitor a particular equipment's health and capacity to outreach OEE (Overall Equipment Effectiveness) on a high note.

4 Data Science in the Food Industry

Apart from artificial intelligence technologies and machine learning, data science also plays a major role in heading food industries to the leading market. Some of the befitting approaches of data science include the following listed below:

4.1 Matching customer tastes with your business strategy

Food industries often land to a debate whether they are tech companies or not. Well, the truth is the term "tech" only applies to them if they have optimized their processing units into advancing methods such as implementation of AI, machine learning, big data,

IoT, etc. When US based start-up "Gobble" owner Ooshma Garg labelled these industries as a technoid, she was heavily criticized but people new little how advancing these days' food industries. They are bringing food before technologies hand-in-hand to prove that food production isn't an outdated task and shall remain in demand until the last survivor on planet. Everybody, every creature needs food to survive so is the demand. After AI undertook food industries into circumferences, the constant rise in global population got better ways to survive with food even though there was a notice of deficiency at certain corners of the globe. Gobble, thus, is a quick dining method that is exercised using data science and AI to regulate its customers on a daily basis, and supply them foods according to the choices of their customers [42]. This demand-driven prompting 10-to-15-minute dinner kits predicts before time the exact amount of demands put forth during a particular time period, and also maintains quality food structure and loyal customers on the list.

4.2 Reinventing Food Delivery

Even food delivery systems have changed into modernized versions where every preferential data is collected and subjected to different categorizing patterns to satisfy customers on every end. Using AI and machine learning algorithms, the client approach and product dispatchment becomes more cost and time efficient both for the food delivery driver as well as the customer [43].

5 Machine Learning Applications in the Restaurant Business

5.1 Analytical solutions for a better customer experience

In restaurant businesses, Machine learning helps the associates to control traffic, maintain systematic orders for food and reservation, as well as initiate accurate inventories according to the forecasting up on demand and supply chain for given time period. Such customer engaging and cost-plus time effective methods and equipment's developed using machine learning are CIP or SOCIP (Self-Optimizing-Clean-In-Place) used for detecting microbial debris, if any, found in foods; KanKan AI are implanted camera monitors for the restaurant or café in-charges to check whether their kitchen workers and serving-men are following food safety protocols or not; optical food sorting solutions; Cloud Big Data solutions; and many more [44].

5.2 Food-selling sites and applications

Owning a café or a restaurant or a food corner is just not enough unless one thinks of supplying food only to the nearby local people only. To turn a business to a bigger image, an online presence is a must. This makes many unknown customers understand that there is a food outlet at a certain area. Food is not always a luxury, but at times a necessity for travelers and tourists. They search for good food nearby tourist areas, highways, hill-stations, rural areas, etc. On keeping an online presence, visitors find easily find the outlet and alternatively satisfying business goals. There are various methods for having a social presence online such as website, mobile applications, e-commercial food platforms, google search engines, etc. These applications help customers as well as business owners to reach out to each other with their automated services and significantly maintain records of the past orders [45]. These effective administrative functions developed using machine learning and AI formulates a new positive space for both the businessmen and their customers intact.

5.3 Innovations in Robotics for the Food Industry

AI and machine learning based robotic solutions include hyperkinetic drones that can deliver food to accurate customers without even worrying about travelling issues such as road traffics, etc., or nay reliable worker's expert in the delivery profession. Everything these days are becoming faster so are the demands of the customers [46]. To fulfill both the criteria, adopting drones as an advancing asset in food serving industries over human labor force is one of the greatest achievements of the food processing and servicing sector. 7-Eleven is one of those major food-based tech firms that concentrates on drone-based food deliveries, after Walmart.

5.4 Restaurant Revenue Prediction Using Machine Learning

Besides food and service quality in a restaurant or café business, the third important factor need to be acknowledged periodically is its revenue. The initial predictions made on revenues provide standard catalogues for subsequent performances and operations [47]. The sales forecast using befitting machine learning algorithm potentially advocates the business's managing associates to take considerable steps without any possible inconvenience in the near future.

5.5 AI Culinary Uses in the Real World

After AI has been legitimately availed to sorting, monitoring, as well as managing supply chains, the technology has grown closer to culinary spaces such as kitchen. And to turn this impossible factor into possibility in the real world, IBM developed an AI based digital culinary research assistant cum application known as Chef Watson. It simulates closely and accurately to a professional chef that instructs anyone anywhere in a kitchen. It is accessible to every household, and proves to be a replica of real chefs assisting quality cooking methods and opinions. This user-friendly AI-based application helps many beginners, moderates as well as experts to resolve cooking issues that isn't quietly settling with nominal internet search [48].

5.6 Machine Learning in Food Delivery

The main purpose of machine learning in food delivery system is to make sure that the food is delivered to the exact customer without any hassles, frequent call to customers, or without any time consumption. If you own a restaurant business or café or any type of food outlet, you must make sure that the delivery system is the crux of your business. It is hardly possible that customers show interest to those concessions that do not have home delivery service even though they haven't ordered anything yet from there [49]. This is because customers choose delivery options for being ready for any type of situation such as COVID-19 lockdowns. During these lockdown periods, majority of the people preferred to stay at home and order their comfort foods from different restaurants and food outlets directly to their homes. These outlets either were regular ones or were tried for the very first time. With the use of accurate and advancing algorithms of machine learning, orders for the deliveries were recorded and analyzed within less time, as well as provided delivery boys and men to ensure which route is the best, and the shortest one for delivering instantly to the required customers, with hardly any error.

6 Artificial Intelligence in Food Safety

One of the best reasons to include AI and robotic mechanism in food processing and production industries is that robots always remain sterile i.e., uninfected. While humans carry lot of germs, and diseases, even them breathe exhausts are dangerous especially while working in the food production sector. On using robots, the continuous rising in foodborne diseases will alternatively drop down to a large extent.

Other reasons include the uncompromising necessities lodged by FSMA (Food Safety Modernization Act) to followed during the entire supply chain. In this, certain food items such as cereals won't be refrigerated to avoid any contamination. Here, however, robots would simply clean suitable fruits and vegetables and won't either transfer any type of illness. On a contrary note, AI enabled techniques concerned majorly for food safety include NGS (Next Generation Sequencing) and Electrical Noses. NGS helps in finding out vulnerable reasons that deteriorates the quality and safeguard of the food product. It substitutes the traditional methods in the food testing labs with DNA methods to precisely and quickly carry out the test processes. On the other hand, the electrical noses are nothing but type of alternatives for the human noses where workers could easily detect various chemical odors during the food production processes as well as testing labs [50]. This will prevent the environment from getting affected from even any minute existing infection.

7 The Future Application of AI in Food Industry

AI in a food industry can predict several types of issues in advance in the ongoing agricultural firms. For instance, Gamaya, a Swiss agricultural tech firm known to manufacture and supply hyperspectral cameras such as drones for agricultural purposes, has funded over 3.2 million USD for different global AI projects and workshops. Their AI integrated drones help farmers and agricultural associates to snap accurate shots of crops by generating surveys for crop fields and farm lands. It potentially threats and alerts the associates to take measurable steps on the damaging issues before hand [51]. Other effective measures of AI in the futuristic food manufacturing and processing industries are to reduce excessive wastage of water supply to the farm lands. This turns up to 550 billion liters of water wasted as per the records from the Institution of Mechanical Engineers, Britain which make a grant that almost 60% issues detected in food industries will be resolved.

8 AI in Food and Beverage Industry Statistics

The expected growth of the global food and beverage market by the end of the year 2021 was roughly supposed to be 6196.15 billion dollars or more at a CAGR of 6.1%. However, due to the impact and interruption of COVID-19, this expectancy extended to the year 2025 with roughly 8163.61 billion dollars or more at a CAGR of 7%. Since, North America is

the strongest asset for the US region in terms of food industry, have a look at the core concepts maintained by the region to stature its dominance at the global market:

Artificial Intelligence in Food and Beverages Market - Growth Rate by Region (2019 - 2024)

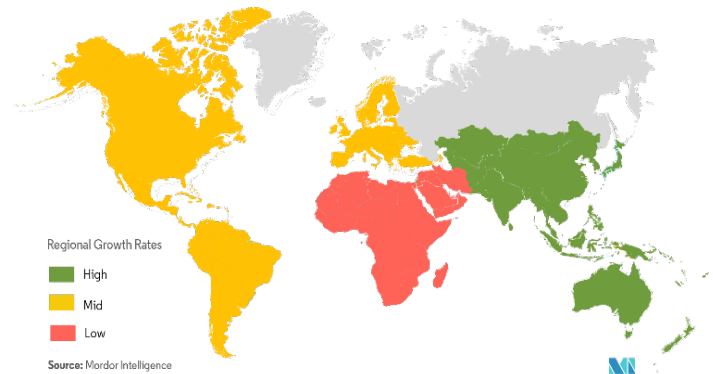


Figure 1. Artificial in food and beverage market (2019-2024).

- US has been always the leading region for adapting to periodical AI based food industries since the year 2017. It ranked second in line with a total market share value of 29.1% alone from the Northern American region as shown in Figure 1.
- North America has always been an active region in terms of food processing. Due to their periodical rise in potentiality, the global economic experts suggest that the region will dominate the market during 2019 to 2030, most probably.
- Not only this, the food processing plants in US is also responsible for producing a shipment value of 16% alone every progressing year.

The reason why the US is a leading power today in the global food market is because of its low-water mark on perimeters and high proportions with strategic initiatives that strengthen its market to produce capabilities and not just food products [52].

9 Conclusion

Those food manufacturing and processing industries, or businesses such as that of a restaurant and bakery, that previously labeled AI and ML technologies as an unnecessary investment soon realized their importance in making their own business better with growth and strategies. They understood that their survival lies within the stand in the competitive market because services are accepted from only those who promise to provide qualitative and quick service. And in order to retain in this industry, every associate must adopt

to advanced equipment's and devices that aids to minimize repetitive mistakes and wastage of limited products, low-cost deliveries, transportations, instant services, accessible wireless communication systems, as well as to yield satisfying results and customers.

Data Availability Statement

Not applicable.

Funding

This work was supported without any funding.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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