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ARTIFICIAL INTELLIGENCE AND IOT IN FOOD INDUSTRY AND AGRICULTURE

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Abstract:
Internet of Things (IoT) required big data to do the research, often referred to as “big data,” which brings new opportunities to monitor agricultural and food processes. Besides new technologies & sensors, big data from social media is also becoming important for the food industry. In this review, we present an overview of IoT, big data, and artificial intelligence (AI), and their disruptive role in shaping the future of agri-food systems. Following an introduction to the fields of IoT, big data, and AI, we discuss the role of IoT and big data analysis in agriculture (including greenhouse monitoring, intelligent farm machines, and drone-based crop imaging), supply chain modernization, social media (for open innovation and sentiment analysis) in food industry, food quality assessment (using spectral methods and sensor fusion), and finally, food safety (using gene sequencing and blockchain-based digital traceability). A special emphasis is laid on the commercial status of applications and translational research outcomes.

INTRODUCTION

INTERNET of Things (IoT), big data, and artificial intelligence (AI) are perhaps olden days in the tech industry, that are making an impact only in very recent times. In fact, data from Google Trends search history for these topics shows that IoT and big data have drawn the considerable interest of broad-based Internet users within the last five to six years, while AI remains a topic of interest for much over a decade (see Fig. 1). In fact, with the increase in communication devices the volume of data generated is rising and AI is continuing to well integrate into the lives of a big population of the planet in one form or the other. Unlike AI, IoT primarily being industrial technology remains to be of low interest to the general public. A natural topic of interest for agri-food scientists and engineers would be to maximize the impacts of these emerging information technologies for sustainably feeding the planet. As a first aim of this review. First coined by Kevin Ashton, IoT is a technology paradigm contemplated as a vast network of digitally connected devices and machines [1]. Here, the digital connection of the machines or “things” occurs over “Internet.” IoT is sometimes also referred to as the Internet of Everything or the Industrial Internet. The influence of IoT arises from its ability to enable robust communication between the physical world with that of the digital, a concept often referred to as the fourth industrial revolution. In fact, the use of IoT in industry is sometimes also referred to as Industrial IoT (IIoT).

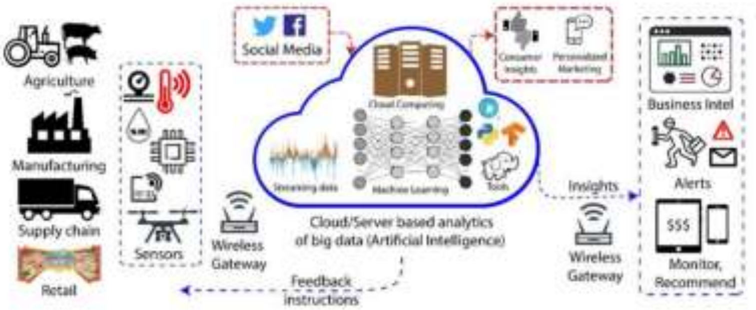


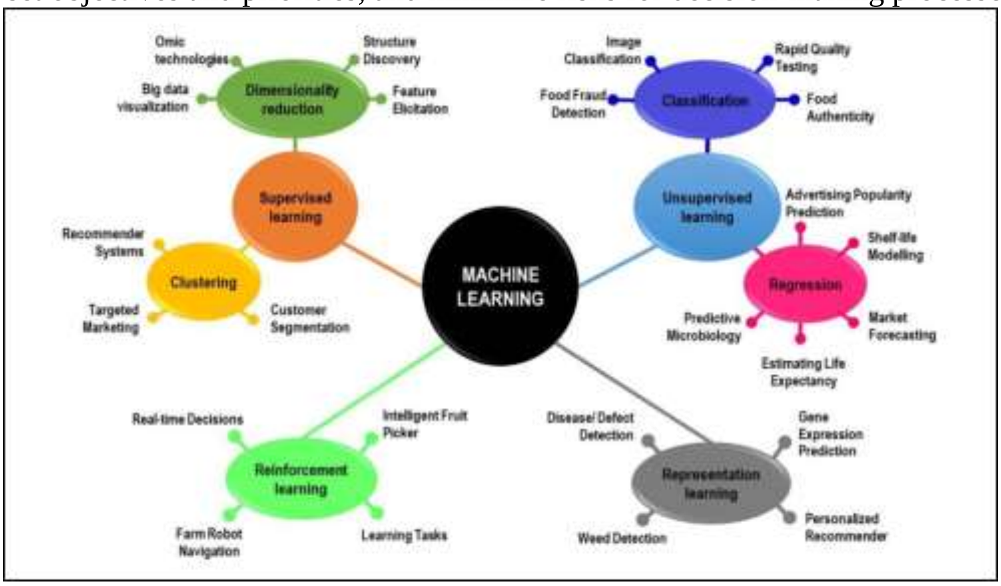
Fig. Pictorial representation of the IoT framework within agri-food industry context.

we provide a graphical summary of the IoT and big data framework in agri-food context to facilitate discussion of several concepts within our review. Here, we note that the data can come from agriculture, food processing/manufacturing, supply chain, traceability, or consumers. While sensors are points of data source in case of IoT, data from consumers comes in the form of opinions shared on social media platforms.

FROM DATA TO ACTION

Agri-food Industry produces a large number of diverse datasets, both in content, structure, and storage format with the use of various IoT devices [3]. Common characteristics of big data include heterogeneity, variety, unstructured nature, noise, and high redundancy [4].

Such huge amounts of data require complex methods for data curation and storage, as well as intensive statistical approaches and programming models to extract relevant information. The conditioning and preprocessing of primary data results in the information required to understand the state of the (agri-food) system. By applying advanced algorithms and measuring the performance of the system with respect to the desired outcome, a system can be made capable of making independent localized decisions and take appropriate actions. This level of independence allowing autonomy in sensing, decision making, and actuation is what makes an IoT system "intelligent." The field of AI involves the development of theory and computer systems capable of performing tasks normally requiring human intelligence, such as sensorial perception and decision making. Kaplan and Haenlein [5] defined AI as "··· a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation." Thus, AI acts on external information sourced from IoT and other big data sources, uses knowledge-based rules (provided by developers) or identifies the underlying rules and patterns using ML, to drive the systems toward set objectives. A truly intelligent system can learn, generalize (if there be such scope), accumulate knowledge, set objectives and priorities, and minimize risks for decision-making processes

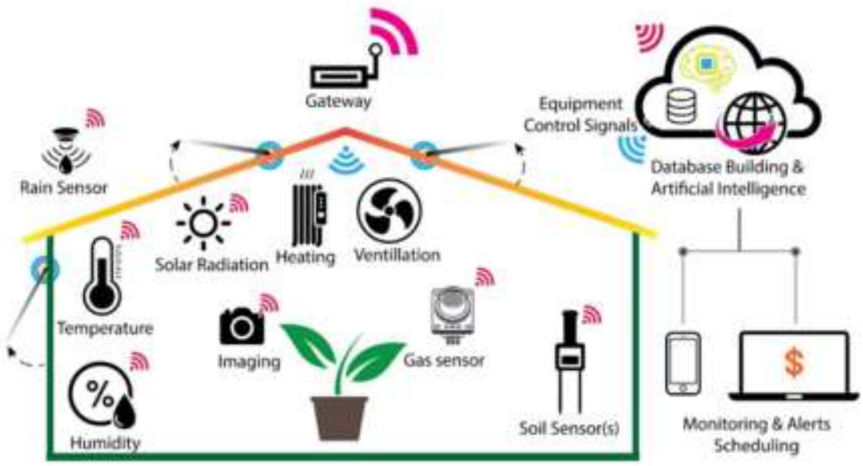


ML paradigms and their applications in the agri-food space.

A. Connected Field Sensors and Machines

Precision agriculture (PA) is a management concept that recognizes variability within the soil environment and maximizes economic agricultural production while minimizing the environmental impact for a specific location [16]. PA is all about applying the right material in the right amount at the right location and right time, which is known as the 4R concept [17], [18]. Since its introduction in the 1990s, PA has had high expectations to increase the efficiency of agricultural operations especially in commercial production where the fear of losing yield has led to management practices that are based on the excessive implementation of chemicals.

Though crop yield monitoring has been around for almost two decades, the development and implementation of smarter farm machines, crop sensors, and the software to analyze data that these devices collect have recently become a game changer in yield results. The technology development over the last few decades has enhanced the position of PA as an emerging management concept. Digital sensors that monitor real world parameters continue to be presented in the market at affordable prices. For instance, digital temperature sensors priced at a few dollars and as small as few cubic millimeters are available for placing at any place in an agricultural field to obtain accurate temperature data, provided they are correctly enclosed and powered .Also, machine-to-machine communication protocols via electronic components have been revolutionized, among which the Internet stands out as a global communication protocol that can pass data and information between a set of remote computers anywhere in the globe expand this system to other crops via development of specific prediction models for each disease while using the same hardware to collect and visualize data.



IoT-based monitoring and control of greenhouse cultivation environments. The greenhouse environment is monitored using a variety of IoT-based sensors, and the automated control is implemented through heating, ventilation, or opening of windows using actuated motors.

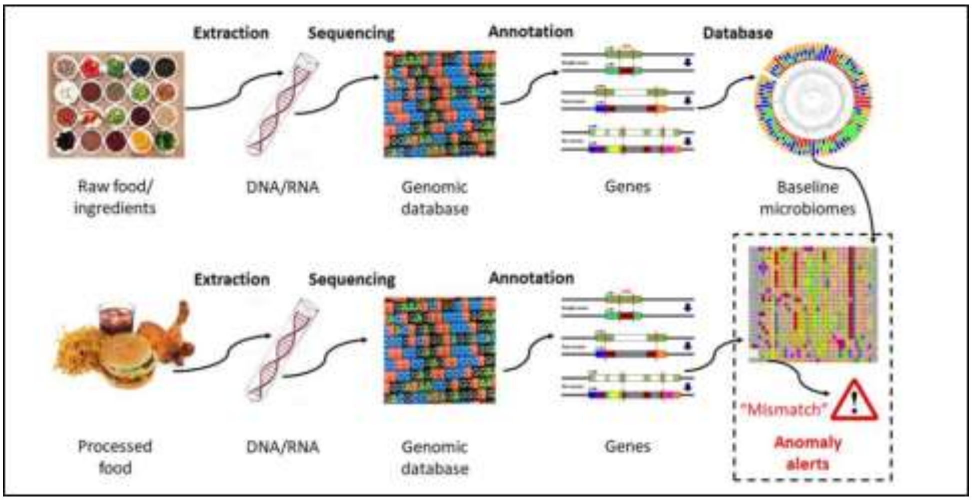
B. Advances in Intelligent Farm Machinery

The traditional farming equipment companies are engaged in designing of smarter equipment that can integrate with computing environments, connect to IoT devices, smart tractors, and pumps, capable of sensing their environments and responding in real time to anomalies. In recent years, attempts to build agricultural autonomous systems for implementing PA techniques have significantly increased and being implemented by many startups in farms. Cameras have followed the same trend of environmental sensors of becoming smaller and cheaper. Their ability of collecting spatial and spectral data made them subject of research although the need for high spec processing units in comparison to other sensors was one of the main initial concerns for its application in real-time conditions. However, this has changed in the recent years as powerful processing units are widely accessible. The high cost of applying herbicides and the increasing awareness about the impacts of excessive usage of chemicals on the environment and human health, are driving the efforts to implement cameras as sensors in the field of agriculture to detect weeds. There has been traditionally, two approaches to control weeds, which are chemical and mechanical. In principal, mechanical control has the advantage of being environment friendly but labor intensive whereas chemical control has the opposite features. Recently, some startups have emerged as providers of intelligent and autonomous weeding machines based on cameras for sensing weeds in the fields. We will provide a few examples of recent commercial developments in this area.

FOOD SUPPLY CHAIN MODERNIZATION

The United Nation reports that one-third of the world's food is thrown away each year, which adds up to $750 billion that is completely wasted. That means that about 28% of the world's agricultural land is used to produce food that is eventually wasted. The supply chain management in a food business is very challenging owing to the need for advanced control systems for coping with perishables, fluctuating supply–demand variations and narrow food safety, and sustainability goals. Consequently, the use of IoT networks involving humidity, temperature, light, and microbiological and product quality sensors for real-time monitoring of products in transit is useful for the food industry in rescheduling, recalling, or taking appropriate actions. According to a report by Zion Market Research, the global AI application in the supply chain market stood at $491 million in 2017 and is projected to reach about $6548 million by 2024, at a CAGR of around 44.76% between 2018 and 2024 [51]. An exhaustive review of the role of IoT in supply chain management, in general, has been made by Ben-Daya et al. [52], while one specific to agri-food industry is presented by Lezoche et al. [53].

FOOD SAFETY



Process flow to build genetic index of food and its normal microbiome. Adapted from Beck

Food safety from farm to fork has emerged as an international priority for all the stakeholders around the globe. The recent foodborne outbreaks of fresh produce in the United States, with two large occurrences of Escherichia coli contaminated romaine lettuce in 2018, a lot of food (which also included large quantities of the safe produce) was dumped to protect public health [94]. Knowing that the demand for food is expected to increase by 50% from 2012 to 2050 [95], the current practices to defending public health from foodborne outbreaks might not be the viable option of the future. Realizing the significant economic impact of outbreaks, technological advancements and integrated measures from informatics can play a crucial role in the mitigation of food safety risks and prevention of future outbreaks, saving millions and lives of many [96]

CONCLUSION

IoT is recognized as one of the most important areas of future technology and is gaining considerable attention from a wide range of industries. With the implementation of IoT infrastructure in farming, farmers will be more efficient, intelligent, and connected, feeding vast amounts of information to analysts regarding crop yields, soil mapping, fertilizer applications, weather data, machinery, and animal health. The use of sensors is steadily increasing in early reporting of issues pertinent to crop health in farms, thereby enabling early checks for public health and safety. Efforts leading to easy integration of various IoT devices in terms of data and instruction flow from farm to consumer chain is important to obtain a viable and efficient IoT system.

In conclusion, the key performance indices that IoT and big data technologies will be potentially impacting are economical (e.g., increased productivity, lower production cost, and higher quality), environmental (e.g., less resource consumption, lower emission, and carbon footprint) as well as social (e.g., improved public health, consumer demand driven, and quality of life improvement). The pace of innovations in the field of IoT, big data, and AI are astounding and tasks that seemed impossible a few years ago have now been implemented with great success. Embracing the technology innovations and putting them to advantage are important for the success of modern agriculture and food industry.

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