Food-Waste-Reduction Based on IoT and Big Data

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IoT technology through ICT infrastructure and smart devices combines to gather huge amounts of data in real-time, which is commonly known as big data. The big data generated by IoT devices will be stored in the big data storage system and will be used for analysis. The importance of Food Wastage Reduction (FWR) is related to the loss of all the natural resources in the supply chain, including expenditures related to the use of land, water supply, and energy consumption. The application of IoT to FWR systems is also examined where use RFID sensors as a key tool to monitor food waste for each individual in accordance with the proposed model, while describe the application of IoT-based technologies to agricultural supply chain management in developing countries.

IoT sensors | food waste reduction | big data | communication technologies

1. IoT and Big Data

IoT technology through ICT infrastructure and smart devices combines to gather huge amounts of data in real-time, which is commonly known as big data. The big data generated by IoT devices will be stored in the big data storage system and will be used for analysis. The relationship between big data analytics and IoT is explained by Marjani et al. [1] by taking into account the architecture, opportunities, and open research challenges.

1.1. IoT

According to Marjani et al. [1] and Al Nuaimiet al. [2], IoT offers a platform for sensors and devices to communicate seamlessly within a smart environment and enables information sharing across platforms in a convenient manner. Smart cities have seen a recent adoption of IoT. This is due to interest in intelligent systems, such as smart offices, smart retail, smart agriculture, smart water, smart transportation, smart healthcare, and smart energy. By using different types of sensors based on their application and communication technology, IoT is used in smart supply chains to reduce food wastage. **Figure 1**, inspired by Jagtap et al. [3], illustrates IoT as a platform for FWR in a smart supply chain. As is illustrated, the four layers of sensing, application, network, and service form an IoT system, which is indicated for FWR applications.

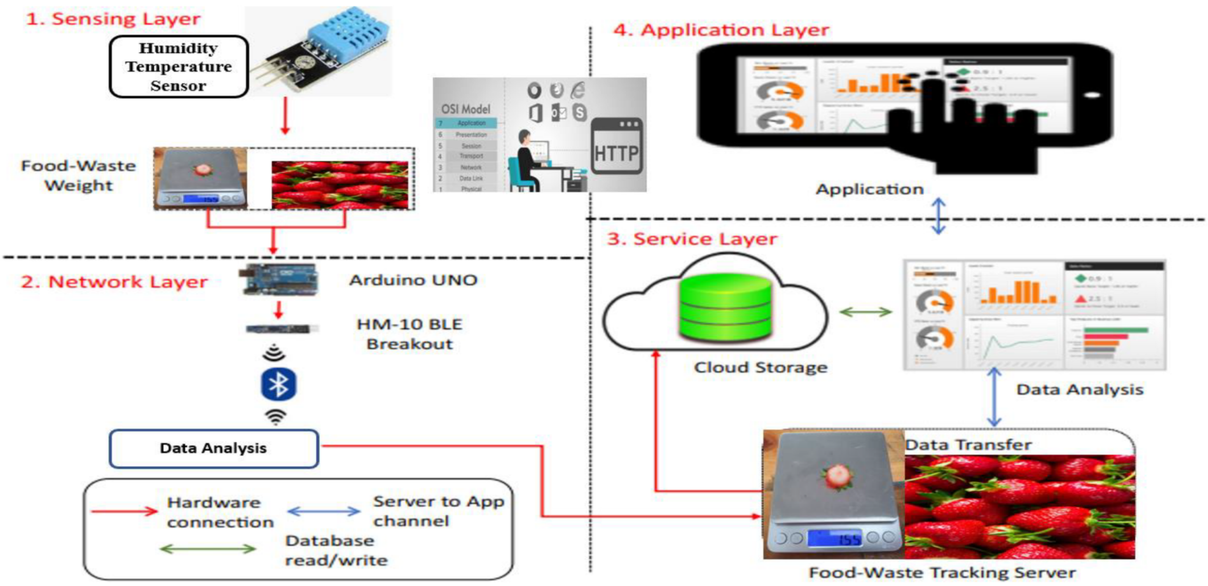

Figure 1. IoT platform for FWR [1].

1.2. Big Data

The massive data generation by sensors, devices, social media, healthcare applications, temperature sensors, and various other software applications and digital devices that continuously generate large amounts of structured, unstructured, or semi-structured data results in big data. Mak et al. [4] describe big data technologies as an upcoming generation of technologies and architectures. These technologies aim to take the value out of a massive volume of data in a variety of formats. This is done by enabling high-velocity capture, discovery, and analysis. In the studies conducted by Kambatla et al. [5] and Gantz et al. [6], trends and approaches for big data analysis are discussed. There are various characteristics of big data, such as veracity, value, variability, and complexity. These characteristics include the volume or size of data, variety or different sources of data, and velocity or speed of data creation, which are studied by Gani et al. [7] and Paul et al. [8]. Big data analytics is the process of examining large data sets that contain a variety of data types to reveal unseen patterns.

Data analytics consists of estimating hidden correlations, customer preferences, and other useful business information [9]. Having a clear understanding of data is the most significant objective of big data analytics, which helps food production companies to make efficient decisions. Big data analytics require technologies and tools that can transform a large amount of data into a more understandable data format for analytical processes. There are algorithms and tools that are used for the purpose of data analysis. Tools like these are used to identify patterns in data over time and visualize them as tables and graphs. Therefore, the performance of current algorithms for data analysis is a challenging issue that should be taken into consideration [10]. There are various tools and platforms that are in use for the purpose of data analysis; however, the most critical approach is to process huge data sets within a reasonable amount of processing time [11][12]. The data can be collected through various sources including online food quality databases, smartphones and handheld devices, social media, and satellite imagery. There are different types of data analytics, which are explained as follows:

- Real-time analytics (RTA)

Real-time analysis is typically performed on data gathered from sensors. Clearly, data changes constantly in this scenario, so rapid data analytics techniques are required to get an analytical result. It consists of two architectures: parallel processing clusters and memory-based computing platforms, which are detailed by Pfaffl et al. [13] The applications and challenges of big data analysis are discussed in [14]. A description of RTA architecture in the sustainable industry 4, the fourth stage of an industrial revolution, is provided by Novak et al. [15].

- Off-line analytics (OLA)

Off-line analysis is used when a quick response is not required [16]. For example, many Internet enterprises use Hadoop-driven offline analytics as explained in Zahid et al. [17]. There are other approaches for big data analytics such as memory-level analytics, business intelligence analysis, and massive analysis, which are defined based on the size of data in comparison with the allocated memory based on the application, which is explained in Refs. [18] [19], respectively. The relationship between IoT and big data analytics is explained in **Figure 2**.

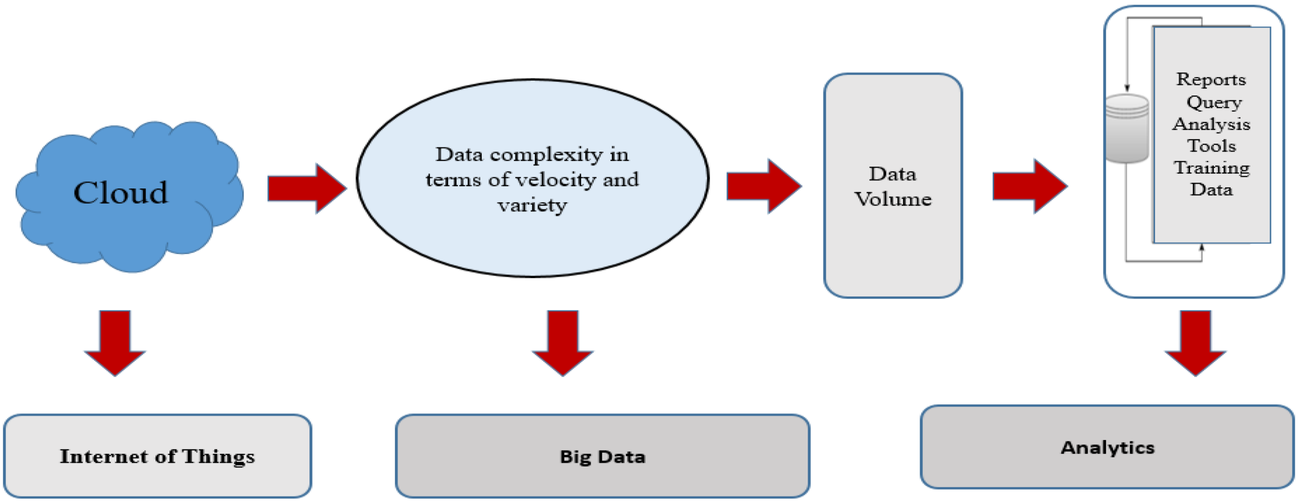

Figure 2. Relationship between IoT and big data analysis [1].

Nguyen et al. [20] present a state-of-the-art literature review on big data analysis for supply chain management. Arora et al. [21] provide an overview of big data analysis methods and procedures. Additionally, a comparison between various big data analysis techniques is provided as well.

2. Food Wastage Reduction (FWR) Based on IOT and Big Data Analytics in Smart Supply-Chains: Sensing and Measurement Layer

In the work by Anagnostopoulos et al. [22], a visual tree for waste management is developed. It can be further developed to reduce food waste. **Figure 3** illustrates how to classify the technologies that reduce food wastage.

Anagnostopoulos et al. [22] review the literature related IoT-based technologies for reducing food waste in different layers of sensing and measurement, processing, and data transmission. As illustrated in **Figure 3**, there are various technologies that are used for the purpose of minimizing food waste. Sehrawat et al. [23] review various types of IoT sensors. **Table 1** provides a definition of these sensors and their applications in the food supply chain.

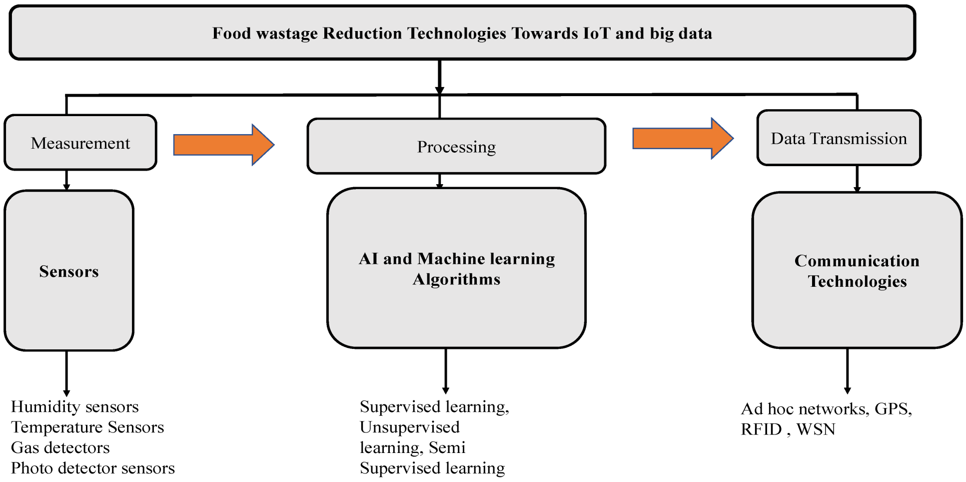

Figure 3. Ingredients of smart food waste reduction technology based on IoT and Big data analysis.

Table 1. Categorisation of the sensors for FWR and the applied technology.

Sensor Type	Technology	Application	Reference	Year
Proximity Sensor	The position of any nearby object is detected without any physical contact by emitting electromagnetic radiation such as infrared and looking for any variation in the return signal	Multi-application, depending on the type. There are various types such as inductive, capacitive, ultrasonic, photoelectric, and magnetic. Mostly used in applications demanding security and efficiency. Main applications of FWR are cutting number of items, measuring the amount of rotation for positioning of objects, and measuring movement direction.	[23][24][25]	2019, 2020, 2021
Position and occupancy sensors	Detection of the presence of human or objects in a particular area by sensing the air, temperature, humidity, light, and motion of a nearby object	Security and safety purposes, smart agriculture, smart FWR	[26][27]	2017
Motion and Velocity sensors	Motion sensors detect all kinds of physical movements in the environment and the velocity sensors calculates the rate of change in position measurement at known	Smart city applications for intelligent vehicle monitoring, for example, acceleration detection of the boxes of food in the trucks for food protection during transmission	[28][29]	2015, 2016

Sensor Type	Technology	Application	Reference	Year
	intervals in linear or angular manner			
Temperature sensors	Measurement of heat energy	FWR and smart farm	[30][31]	2016, 2018
Pressure sensor	Measurement the amount of force and convert it to signal	Smart FWR, smart refrigerator	[32]	2018
Chemical sensors	Conversion of a chemical or physical property of a specific analyte into a measurable signal that its magnitude is normally proportional to the concertation of the analyte.	FWR and smart agriculture	[33]	2020
Optical sensors	Light intensity measurement	Food industry, FWR For instance, assessment of wine grape phenolic maturity based on berry fluorescence	[34][35]	2021, 2008

omagnetic radiation such as infrared by detecting variations in the return signal. There are various types of these sensors, such as inductive, capacitive, ultrasonic, photoelectric, and magnetic [23]. These sensors are widely used in the food industry and in FWR systems [24].

- Position Sensors: The position sensor senses the motion of an object in a certain area to detect its presence. It can be used in smart agriculture and in IoT-based FWR systems [26]. There are also motion sensors that can be considered in this category that are designed to sense all kinds of kinetic movements of an object, as described by Ref. [36]. Ndraha et al. [37] apply various types of sensors including position sensors for the improvement of cold chain performance and improper handling.

- Occupancy Sensors: These sensors are used for the remote monitoring of variables such as temperature, humidity, light, and air [27].

- Motion or Kinetic Sensors: The sensor detects all kinetic and physical movement in the environment [36] and could be used in a truck to detect possible movement of fruit boxes to provide needed information to estimate the rate of food deterioration in a certain period for better decision-making.

- Velocity Sensors: The velocity sensors calculate the rate of position variation, which might be linear along a straight line or angular related to device rotation speed at known intervals [28]. These sensors can be used in crates to determine the variation of food position during food transfer. This will enable to monitor the parameters that can affect food quality and make the appropriate decisions.

- Temperature sensors: Temperature sensors are widely used for the monitoring of environmental conditions of the surroundings [30]. This type of sensor is also widely used in FWR systems and more, especially for smart agriculture to enable farmers to increase their overall yield and product quality by getting real-time data on their land [31].

- Pressure Sensors: Pressure sensors sense the amount of force and convert it into signals. Sensors of this type can be used to measure the amount of pressure in boxes of food and send the data to the server for decision-making to avoid food waste caused by excessive pressure in boxes during transport. The sensor triggers a notification to the user as soon as the applied pressure is below a certain value that affects the quality of the food [32][38].

- Chemical Sensors: These types of sensors sense any chemical reaction and can be used for reducing food wastage in smart agriculture [33].

- Optical Sensors: Optical sensors are a broad class of devices for detecting light intensity. Optical sensors are suitable for IoT applications related to the environment. Therefore, they can be used for food quality control applications, in the food industry [35], and in smart agriculture [34].

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