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'Internet of Things': Transforming Biotechnological Practices

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Abstract

In this modern world 'Internet of things' (IoT) is observed as an ecosystem which empowers computers to interconnect with sensors, networking and gather information to provide an environment in which smart services are being used by the end users. 'Internet of things' when practiced in an applied field as Biotechnology in aspects as pharmaceutical, food, agriculture, research, healthcare and others has wider amplitude. Review of the information about IoT connected Biotechnological devices and their applications can be helpful to the multi-disciplinary researchers to develop a better understanding. Biotechnological research has been supplemented with artificial intelligence with the use of IoT. The use of IoT in biotechnological instruments have made acquisition of various data from different sensors elementary and also simplified the data retrieval process to a larger extent. All these applications of IoT in biotechnological aspects have also resulted in significant cost reductions to the biotechnology industry as a whole. In the recent past, different IoT based applications have been developed providing an ease of work for personnel from biopharmaceuticals, diagnostics, agriculture, healthcare, research and other biological sciences. Thus, promulgation of IoT with biotechnology has been accepted on an all-inclusive basis attributed its cost efficiency, ease of work and results reproducibility.

Keywords

Internet of things, Smart Services, IoT in Biotechnology, IoT applications, Artificial intelligence

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1. Introduction

In Today's advanced world the internet of things is becoming the fastest growing technology. The Internet of Things (IoT), an extraordinary network stage that connects, shares and communicates information from vigorous and heavy machinery and apparatus to portable devices like mobile and wearable accessories with a central internet system [1]. According to varieties of working areas such as cities, homes, colleges, industrial factories, agriculture environments, clinics,etc IoT has different criteria and mechanisms [2-6]. The productive advancement in biotechnological developments require an essentiality for incorporation of IoT in this area for enhancing the accuracy, reproducibility, productivity which is unfolding a new perspective in the biological research, innovationand creation [7].Biotechnology is used extensively for the betterment of man and mankind. It is sub divided majorly into four sub-fields, red, white, green and blue biotechnology. Red biotechnology includes procedures which are utilized for healthcare purposes such as engineering microbial species to produce molecules of medicinal use or utilizing stem cells to reconstruct broken human tissue and with a possibility to re-grow the whole organ and others. White (also known as grey) biotechnology includes industrial processes such as manufacture of the latest chemicals and engineered fuels for vehicles and industries. Green biotechnology applies to agriculture and includes such procedures due to the development of grains resistant to pests or the accelerated evolution of disease resistant species and blue biotechnology is for marine and aquatic ecosystems such as dominant proliferation of the harmful water-borne organisms [8].

2. IoT Tools

The IoT is a system based on its connected devices that provides data collection, access, monitoring and management services developed with the advent of technologies such as cloud computing, wireless communication and networking [8, 9]. The basic components of IoT tools can be divided into the following categories as mentioned further.

2.1 I/O interfaces (Sensors and Actuators)

Sensors and Actuators are important tools of IOT systems. IOT systems receive data from sensors and response is generated by actuators. A sensor is also called "transducer", which converts one form of energy into another. In case of IOT systems, the output of sensor is an electrical pulse. This pulse is fed to the actuator or in some cases series of actuators via a network system. A sensor collects data from its environment or surrounding which are some sort of physical quantities such as pressure, movement, humidity, temperature, chemical composition, etc. convert them into electrical signals. There are many types of sensors such as sound sensor, ultrasonic sensor, gas sensor, smoke sensor, water flow sensor etc. Actuator is used to get the response with respect to the electrical signals provided by sensors via the network system. The response can be different types of motions such as linear, rotary, translation etc. depending upon the requirement. Actuators require an outside energy source to run. Actuators are of different types such as electric, hydraulic, pneumatic[10]. In this system two different sensors are used; one is a temperature sensor and another one is a soil moisture sensor. They used to detect heat and water level in soil. Then sensors send the signals to the processor and processor through the water sprinkler which is an actuator to turn on the sprinkler for water.

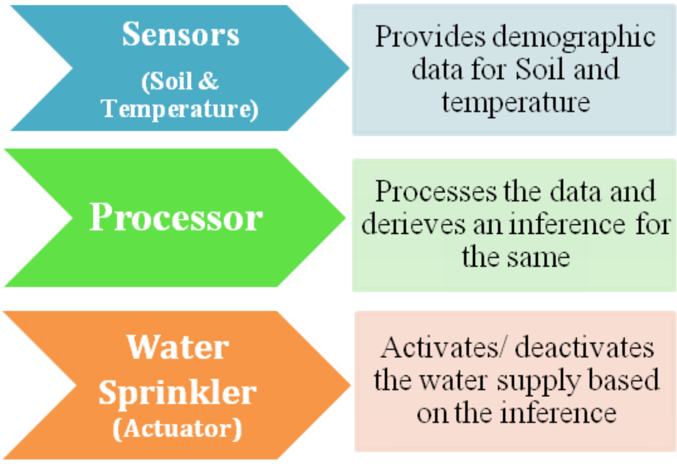

Figure 1: Working of sensor and actuators: An example of an automatic water sprinkler system

2.2 Audio/Video interfaces

Audio/Video interfaces primarily used to transfer audio and video signals. In the aspect of speech recognition new development led to the machine learning and artificial intelligence incorporated into IOT. The examples of AI into IOT are Siri, Alexa, and google assistance [10].

2.3 Storage interfaces

In IOT systems data is required to be stored for future use. The storage devices include technology such as volatile and non-volatile technology. The IOT interface uses Flash memory, Hard disk drive (HDD), Magnetic tape, etc. Depending upon the usage, cost, response time, size the storage interface is selected. [8]

2.4 Connectivity

In IOT the data sharing is a crucial part and it is important to use reliable communication to transfer data. This technology is divided into two classes 1) LOWPAN (Low Power Wide Area Network) and 2) mobile based. LOWPAN is better suited for low data transfer speed and is less expensive. Other methods are Wi-Fi, NFC, and Bluetooth [8, 9].

2.5 Processor

There are two types of processors low-end and high-end. If the system requires data such as moisture, humidity then a low-end processor is used and if the data collection is big for example audio and video then high-end processors may be used. Speed requirement and how many data buses IOT needs to handle determines the microprocessor. The microprocessor could either be very simple or large and fast depending on the need [8, 10].

2.6 Memory

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Memory is either volatile or non-volatile memory. Volatile memory has relatively faster speed than non-volatile memory. On the one hand volatile memory does not retain its data during loss of power supply but on the other hand nonvolatile memory retains the data. If the cost factor is considered then the less expensive non-volatile memory is used [10].

3. Application of IoT on Biotechnology

3.1 IoT in Agriculture

The approximate world population is estimated to reach 10 million by 2050 and challenges like extreme weather and climate situation, groundwater depletion and related environmental impacts include demand for more food which are managed by the agriculture sector [11]. As a result, agricultural biotechnology involving IoT provides an appropriate choice for the change agricultural practices. Today's world, the idea of smart and precision farming opens the way for technological development to increase the productivity of crops in a controlled and precise way [12, 13]. The expansion in smart transducers, automatic vehicles, and advanced control systems has created new and advanced techniques for food production with better hygiene and feasible ways [14]. Latest technology in different IOT systems has allowed the farmers to do farming in an efficient manner and on top of that these systems are also easy to implement. For instance, soil moisture probes, variable rate irrigation optimizer (VRI), and virtual optimizer PRO and other IoT dependent methods. The mentioned machines enable farmers to be conscious of fertility of soil, composition, and employment of water in an effective way [15].New advancement in green houses that incorporate IoT systems making them smart greenhouses can calculate and manage humidity, pressure, temperature and light levels can save cost, energy consumption, and manual work of farmers without human effort to improve productivity [16]. Use of drones in the agriculture field may help in observation and real time tracking of soil, variability, field analysis, irrigation, planting, disease assessment and crop health [17]. Utilizing the cloud based computing may enable the farmers to use real time data for forecasting the crop yield, plant health and height, canopy area mapping and nutritional composition. Hence, from the above mentioned points it can be said that IoT may lead to advancement in the agriculture biotechnology sector. Even with all the advantages of IoT based systems the implementation of IoT systems must be done at a larger scale to be effective [18].

3.2 IoT in pharmaceutical

Discovery of novel drugs and biologics are the encouraging approach to commercialize pharmaceutical products. Although it's always been challenge for pharmaceutical industry with subsequent recalls, maintain stability of product, stringent regulatory compliance for the maintenance of GMPs and GDPs practices, supply chain adoption and operational abilities [19]. Hence, it's been compulsory to adopt IoT in modern world of digitalization along with pharma which tend to contribute excessive opportunities for innovation, compatible quality, celerity, branding and value at all around the world.Quality of drug and preciseness along with nominal errors is became possible due to execution of smart and computerized instruments [20]. "Organ in a Chip" concept provides high-throughput examination for the development of essential diagnostics with on-line surveillance. IoT based sensors has helped in reducing the price of enormous clinical trials [21].

The cost of biopharma has been reduced heavily by 65% due to channeling of real time information for the location of products, preservation of temperature for thermo-sensitive biological samples and catalog details. Lately, online tracing of products from manufacturing to distribution is been progressed because of smart covering labels for instance RFID tags, 2D bar-coding [22].Transportation of temperature sensitive drugs in cold chains has been accurately controlled by enactment of smart serialization via Auto-ID with Automatic Information Data Collection (AIDC) in packaging materials.

3.3 IoT in Research and Development

The world has made its path into the new era of "omics" due to which we are gathering and employing the knowledge at molecular level. Biotechnological research has become more precise and lively by evolutionary finding of novel phages, microbial strains and other biological discoveries. Biotechnological research is facing problems of reproducibility and constancy since ages [23]. In 2011, Distressful case has been highlighted about reproducibility of drug, healthcare leader Bayer has carried out experiment of drug development which has already been published in a reputed journal shown only 25% of results reproduced. Same as Bayer, Amgen has also carried out experiments and found that 11% of results could be reproduced [24]. The reproducibility of results can be obtaining under similar experimental conditions and structural equipment [19]. Due to this problem many companies have been led to early destruction such as Amyris, who tried to scale up the chemicals to 200,000-L bioreactors from 2L.

3.4 IoT in Food

Food quality could be defined as a physical property, which includes the texture, appearance, flavor and other similar characteristics [25]. There are many different food and safety regulations designed around the word to keep a check on the available food quality and food safety. These regulations are much needed to maintain the necessary standards and avoid adulterations. Food processing is a huge industry around the world where there have been many reports mentioning a compromise on the food safety standards. Traceability and digital food chain are major application of food. IoT is useful in FSC as it can manage agriculture precision, food production, processing, storage, distribution, and consumption (farm-to-plate). IoT applications help with the traceability, visibility, and controllability challenges. FSC is lengthy, with a difficult process flow and it is hard to automatically collect quality and safety information [26]. Intelligent equipment such as seamless automatic acquisition with sensing terminals, bus structure, and host computer management system, convergence of industrial information and reliable transmission of product quality information using upper computer management system through the bus can improve the product quality and safety supervision capabilities [27].

For a duck product company using a semi-automated technology throughout their supply chain composed a stable and reliable automatic collection system for efficient, complete, and accurate data collection with high degree of automation that improved

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the product quality and safety supervision capabilities. Their intelligent industrial information collection equipment removed the need for manual data entry and improved acquisition and convergence of industrial information from more than 10 processes, such as poultry farmers' information, employee information, weight information, initial processing information, deep processing links, refrigeration information, and packaging information [28].

Traceability is the ability to retrieve any amount of information relating to the product, which is under consideration, through the course of its entire life cycle, by means of recorded identifications. Additionally, traceability encompasses the principles, practices, and norms needed to achieve traceability of food products, regardless of how they are implemented [29]. Most traceability systems are computerized and implemented using information and communications technology (ICT). In the past, traceability systems were manual and labor-intensive encompassing documentation, liable to manual errors affecting the performance and efficiency of the system [30]. Food traceability has received much traction lately and has become the Centre of legislation globally.

Many researches, technical development initiatives and projects across the food chain too has received attention. It has also become an important aspect for food quality. It allows the producer to relocate and possibly recall the product that is already circulating in the market supply chain. It is the only way to ensure quality in addressing various market complaints. Traceability range is tested for the last 6 months' production in the food industry. The primary purpose of the food regulating agencies and public healthcare agencies is ensuring the prevention of the spread of food borne threats to public health [31]. To outline some of the previous incidents where traceability has played an important part in recalling products from the market, in 2017, about 2,485,374 pounds of ready-to-eat (RTE) breaded chicken products were recalled on account of undeclared allergens like milk and misbranding. In another instance, salmonella contamination caused 36 million pounds of ground turkey to be recalled, which was responsible for the death of one and sickening of over 75 people. Documentation plays an important part in making the recalls efficient. Advances like RFID are used these days to overcome the shortcomings of unwanted error in the documentation done manually. Above this, traceability links between software artefacts provide crucial support in comprehension, efficient development, and effective management of a software system [32].

3.5 IoT in Healthcare

Diagnostic, sensor and imaging systems use intelligent smart devices to interlink IoT network for sensing, testing, diagnosis, and monitoring and analysis purpose. This helps in the prediction of diseases and its complexities, subsequently managing and caring the patients [33]. The upsides of IoT are its low cost, lesser visits to hospital, remote monitoring, and better outcome of treatment, reliable and accurate diagnostic data, automation and overall better disease management. IoT is used to monitor pain remotely through a system built by utilizing facial surface Electro-Myo-Gram (sEMG), cloud platform and a wearable solution which has potential scope of being an automatic pain assessment via facial expressions [34]. This system is also used for

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the automatic detection of cardiac variability [35]. It holds significance in the management of Parkinson's disease (PD) using smart wearable technologies [36]. It has role in the assessment, diagnostics and treatment of PD. Their findings suggest that IoT has scope in healthcare domain by providing an efficient and affordable approach in PD management and other chronic neurological disorders [37].

4. Conclusion

IoT provides a window for the efficient, reproducible, fast and precise research into the biotechnology world. The IoT leads to paradigmatic developments in performing tasks for efficient outcomes. The papers reviewed showed that IoT can be utilized in tasks like keeping soil in check for better production, in pharmaceutical industry to do quality assessment of medicines, to check for traceability in food to remote monitoring in health sector. Though the technology is embraced with certain interoperability and technical challenges but the biotechnological research is certainly on horizon by inculcation of IoT in near future.

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