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Determination of Water Quality in Aquaponics Using IoT

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***Abstract*: Human populations have been able to generate food through traditional farming and fishkeeping, but as societies expand, there is a decreasing amount of land for cultivation. Additionally, it is challenging to produce crops gradually because of climate change. These issues are addressed via aquaponics. Aquaponics is a system that includes both hydroponics and aquaculture. In this system, plants are grown soil-less, the waste water from the fishes grown are fed as food for the plants grown. To increase the productivity and yield of the crops through this system, here we are inducing Internet of Things (IoT) and solar energy. We are developing this system using IoT, to monitor pH, Temperature, Nitrification process, health of the fishes, the quality of the crops and to reduce manual monitoring using the electrical source. This paper aims to develop a minimal cost-effective aquaponics solution by providing an automation for detecting ammonia, nitrite and nitrate gas levels analyze and other parameters sensed in aquaponics through IoT technologies.**

***Keywords*: Traditional farming, fishkeeping, aquaponics, soil-less, productivity, Internet of Things, nitrification, manual monitoring.**

1. Introduction

Food is a basic requirement for everyone where agriculture industry plays a major role in Indian economy. In Traditional farming, on the other hand, plants grow in soil, requires larger area for cultivation has also the disadvantage of being dependent on other factors such as climatic conditions, chemical fertilizers and pesticides, and water. Nowadays, the use of fertilizers and pesticides has been increased, resulting in fast growth of the crops because of which it has caused damage to human health, degradation of soil making the soil unsuitable and unhealthy for the growth of the crops. In order to alleviate the challenges associated with conventional farming, here comes a technology known as Aquaponics.

Also, most of the people prefer fish in their diet so its beneficial for them too as growth of fish also takes place in this system with proper and natural care. Years before everything was natural so to bring up the same natural food, we have introduced this aquaponics system that resolves soil and natural food issues together. Aquaponics system is a combination of aquaculture and hydroponics. Aquaculture is concerned with the growth of fish, whereas hydroponics is concerned with the growth of soilless plants by giving required nutrients. In this technology, the excreta of the fish, is used as the feed for the growth of the plants in a recirculatory method.

Through this technology developed, the country will be provided with natural food without any harmful pesticides and fertilizers applied. It will also provide the mankind, with both fish and vegetables as this approach reuses water, it also occupies less space and provides the consumer with natural nourishment. Manual monitoring of aquaponics cannot be monitored and regulated accurately and efficiently. Therefore, with the application of Internet of Things remarkable changes can be made to maintain and monitor the parameters for effective growth of both the plants and fishes.

Aquaponics may be maintained and regulated automatically using IOT technologies and sensors like as pH, water level sensor, TDS sensor, Ammonia sensor. Sensors are hardware components which are operated on microcontrollers such as Node MCU and Arduino UNO. These are used to acquire information for further analysis. These readings may be retrieved via the Blink program for monitoring purposes. This technology may be used to create both an interior and outdoor system. Sensor readings care used for further study and analysis.

The main objective is to develop a minimal cost-effective remote monitoring and regulating aquaponics system to reduce manual work. This also focuses on making the agriculture soilless as well as making it feasible to use anywhere. For which we will be using all the knowledge of hydroponics and aquaponics. The aim is to make an aquaponics system that will help grow fishes and plants together indoor.

The existing EC aquaponics control system is designed to be able to make the EC water in the reservoir according to the desired target. EC itself is measured in units of Parts Per Million (PPM). To improve performance, automatic control can be well applied to the aquaponics system. The creation of an Aquaponics system with the aid of a local control via several sensors and a GSM (Global System for Mobile Communications) interface capable of sending notifications or alarms by the user's preferences limits that predetermined has been implemented. The undertaking initially distinguishes the parameters of water utilizing different sensors and utilizing PIC 16F877A microcontroller the information will be contrasted and an ideal scope of the particular parameters, at that point if

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the characteristics are beneath or above ideal range the required tasks will be done in like manner. This type of method is difficult to manage over time and with large data sets and requires manual operation to submit data.

In order to overcome these problems, we have proposed undertaking initially distinguishes the parameters of water utilizing different sensors and utilizing ATMEGA328P microcontroller the information will be contrasted and an ideal scope of the particular parameters, at that point if the characteristics are beneath or above ideal range the required tasks will be done in like manner. Another innovation called the Internet of Things (IoT) crosses over any barrier between the physical world and the computerized world. In this aquaponics observing framework, with the utilization of IoT the webserver persistently shows the estimations of the parameters and data. The proposed solution monitors real time data along with the parameters like pH, water level, TDS, Ammonia. This whole system can be remotely controlled from anywhere by using a IOT application. The whole system is self-monitored as well as semi-autonomous. The collected data is then stored and can be further analyzed to give an insight on the parameters important for the efficient growth and maintenance of such a system.

2. Literature Review

Rachida Ait Abdelouahid, et.al (2021) created an Internet of Things (IoT) platform to facilitate their interaction, control them intelligently using a web interface or a voice assistant. This platform was implemented by a Web application and virtual assistance that ensures interoperability regardless of form factor, operating system, service provider or transport technology, creating a" network of everything" in the "Journal of Procedia Computer Science".

Ibtissame Ezzahoui, et al. (2021) proposes a comparative study between hydroponic and aquaponic farming. This study tells us how both the methods are cultivated and are beneficial from the "Journal of Procedia Computer Science".

Taji Khaoula, et al. (2021), provides an innovative solution based on an interoperable, secure, scalable, low-cost, fully self-powered, flexible, reliable and generic IoT architecture that meets the requirements of hydroponics from the "Journal of Procedia Computer Science".

A. ReyesYanes, et al. (2020) reviewed the automation of aquaponics by monitoring, IoT Technology and Smart Systems. Further, the proposed review highlights potential gaps in the research literature and future contributions to be made in regards of automated aquaponics solutions from the "Journal of Cleaner Production".

Kamal Gosh, et al. (2019) researched for a technically Feasible and economically profitable Aquaponics System from the "Journal of Agricultural, Environmental and consumer Sciences".

Shiny Abraham, et al. (2017) focuses on using Internet of Things (IoT) technology to configure and deploy smart water-quality sensors that provide remote, continuous, and real-time information of indicators related to water quality, on a graphical user interface (GUI) from the "IEEE Global Humanitarian Technology Conference".

K. S. Aishwarya, et al. (2018) develops an automated System with the help of sensors interfaced with the Arduino board, it possible to automate fish feeding and water supply to the plants at the regular interval of time from the "2018 Second International Conference on Inventive Communication and Computational Technologies".

Rolf A. Kjellby, et al. (2019) presents the prototype design and testing of a long-range, self-powered IoT devices for use in precision agriculture and aquaponics. The devices are designed using the ultra-low power nRF52840 microcontroller with Bluetooth 5 support and ambient energy harvesting. A power of 942μW is harvested in an indoor environment from "IEEE 5th World Forum on Internet of Things (WF-IoT)".

Lean Karlo S. Tolentino, et al. (2019) developed an automation where The Internet remote access includes the effective wireless transmission and reception of data report between the system and an Android unit with the Android application in real-time from the "International SoC Design Conference".

MF Taha, et al. (2022) comprehensively highlights research regarding the utilization of fully automated and operated aquaponics system, by discussing all the parameters aligned with smart automation and IoT supported scenarios and results. Furthermore, this article is an attempt to determine potential gaps in the present and future contributions related to aquaponics. It is also reviewed that the future expected system supported with smart control units will be more accurate, profitable and effective.

Flordeliza L. Valiente, et al. (2018) studied to create an aquaponics system using Nile Tilapia and Romaine Lettuce with the control of pH level, temperature and access through Internet of Things (IoT). Intel Edison is used to continuously send data about the status and adjusts them according to the optimum parameter level. The system is monitored with the use of an Internet Protocol camera and growth of the plant and fishes are monitored and compared weekly that has resulted significantly greater than its traditional counterpart.

Wanda Vernandhes, et al. (2018) designs the latest aquaponics technology using the concept of Internet of Things (IoT) making the process easier, by conveying information from the sensor and can be accessed through control actuator values and the applications installed on the smartphone from anywhere with the Internet connection.

Abhay Dutta, et al. (2018) introduced Internet of Things technology that bridges the gap between the physical world and the digital world that is the sensors, database server and application server which can be managed to display the sensor readings. They have also used Raspberry Pi microcomputer in order to enhance the productivity of the traditional aquaponics system.

Chien Lee, et al. (2020) has proposed a cloud-based Internet of things monitoring system in aquaponics. It is designed in such a way that it measures parameters like water temperature, water depth, dissolved oxygen, and pH value. Furthermore, aquarium glass has been attached with three infrared distance sensors and water depth is sensed continuously in the rearing tank that can be used to monitor the ebb and flow irrigation and calculates the flow rate of water circulation.

Divas Karimanzira, et al. (2019) has enhanced aquaponics IoT-based Predictive Analytics for efficient information utilization. In this paper, they have discussed the enhancement of SCADA, ERP and MES with IoT in aquaponics and how Predictive Analytics can improve the idea. They have used five demonstration sites in different geographical locations to show the benefits of IoT along with the Predictive Analytics Services. Moreover, it is concluded that MES has several capabilities that cannot be replaced by Internet of things. It acts as proxy if sensors are absent and ensures correct execution. These systems can produce improvements but need MES to bring out their true potential and benefits.

Shu-Ching Wang, et al (2020) studied the feasibility, advantages and disadvantages of precision technology and greenhouse planting system. In addition to this, the Intelligent Voice Control System (IVCS) of IoT was proposed to solve the lacking ability to use information interfaces. This method lowers the barrier for small scale farmers to enter agriculture science and technology and inspire more diverse applications to improve the production of agriculture, fishery and planting effectively and efficiently.

Nikhil Kurian Jacob, et al. (2017) designed and developed a smart and portable indoor aquaponics system with the required electronic components and sensors, combining with IoT technology. Remote controlling of the watering and lightning cycle, live visual updates of the system using a camera, and detection of water overflow and temperature monitoring. Such a system has to be developed in the market for the people in urban areas who have neither time and the required physical space to grow their food.

From various literature survey it is evident that there are very few research has been carried out to detect the levels of Ammonia, Nitrite an d Nitrate gas in the aquarium. This study focuses to develop to minimal cost-effective aquaponics solution by providing an automation for detecting ammonia, nitrite and nitrate gas levels analyse and other parameters sensed in aquaponics through IoT technologies.

3. Objectives and Methodology

A. Objectives

- To develop remote monitoring and regulating aquaponics system to reduce manual work.
- To set up an aquaponics system consisting of fish tank and grow bed for plants.
- To develop an Internet of Things based aquaponics system to display parameters continuously to the user.
- To monitor water level through ultrasonic sensor, PH value through PH sensor, nitrate levels through MQ-137 Ammonia sensor of aquaponics system using IoT.

B. Methodology

Below chart (Figure. 1 Methodology chart) gives a glimpse on the end-to-end process carried out during the entire research work.

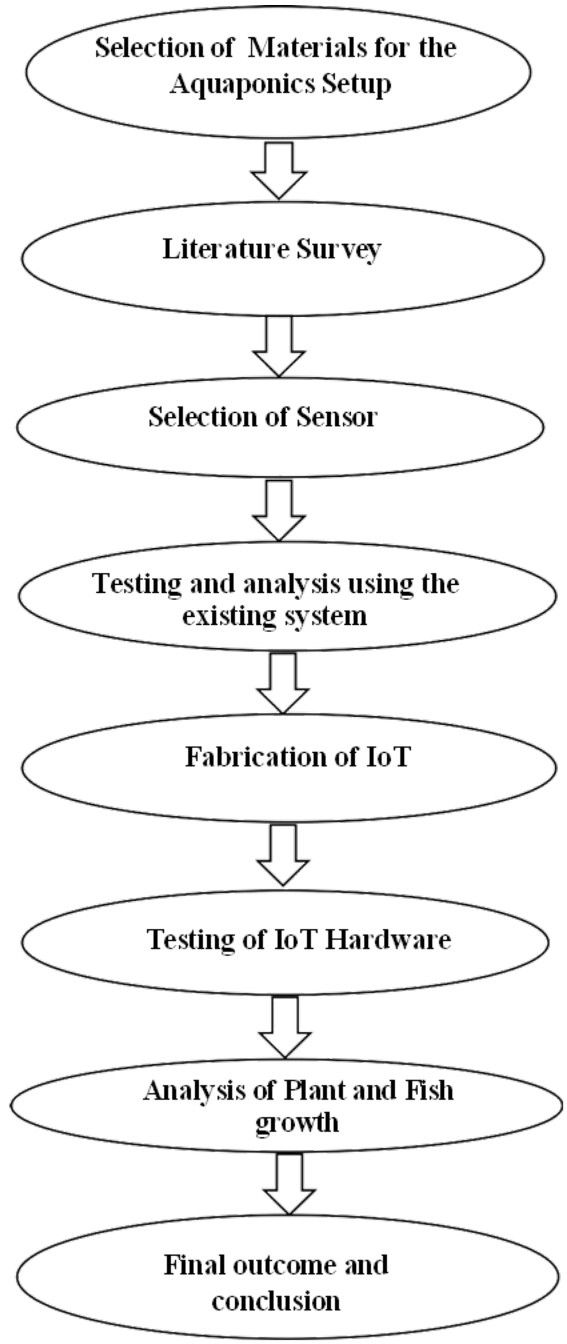

Fig. 1. Methodology chart

4. Experimental Procedure

This section would give an overview of the experimental procedures followed throughout the entire process. Each and every procedure tells us exactly how the process was exhibited, giving clear-cut ideas and detailing every aspect of the procedure carried out. As this is a step-by-step procedure, nothing can't be skipped in between and even the flow can't be altered. Each procedure requires a certain amount of time and all should in accordance with the flow of happening. This will give a glimpse of how the process flow happens in an overall experimental procedure. The main objective of this system is to develop an IoT-based aquaponics system that monitors and displays parameters such as pH level, water level, TDS and ammonia level, etc. continuously to the user. Real-time observations of the parameters inside the aquarium tank can be done for the favorable growth and survival of the fish.

A. *Installation of Aquaponics Setup*

For the installation of the Aquaponics Setup, the things required are an aquarium tank, a prepared PVC pipe frame, grow bed. Then, the aquarium tank was built with minimal cost of dimension. After that, in order to build a space for the plants to grow in the system we have prepared frames out of PVC pipes. Then, for the proper setup of the tank combining frame was done by fixing upon a table.

Fig. 2. Installation of setup

B. *Fabrication of Hardware*

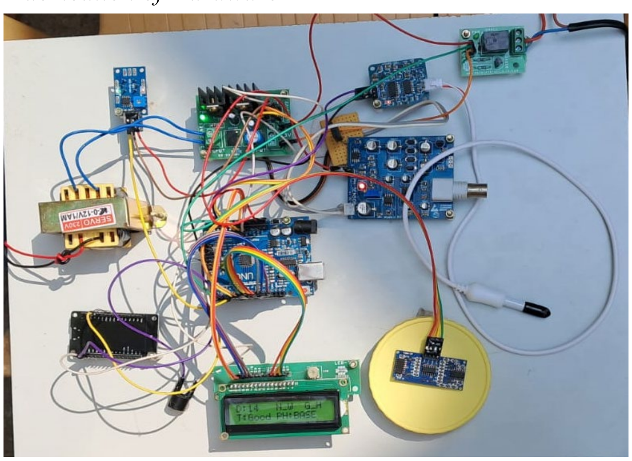

Fig. 3. Fabrication of hardware

Hardware has been designed and developed in order to determine, measure and display the parameters observed in the aquaponics system. This section is the monitoring section, which is developed using the technologies that have made things easier to percept about the favorable conditions required for the fish and plants to grow within the same combined system. Here we have used four types of sensors to detect the levels of the required parameters, connected to the Arduino Uno microcontroller used to collect data and deliver them to a web server. The sensors used in this architecture are pH, TDS, Ultrasonic, and Ammonia sensors. The other hardware components used are Arduino UNO, the microcontroller, and Proteus software to display the observed values through portable applications.

Block Diagram of the System:

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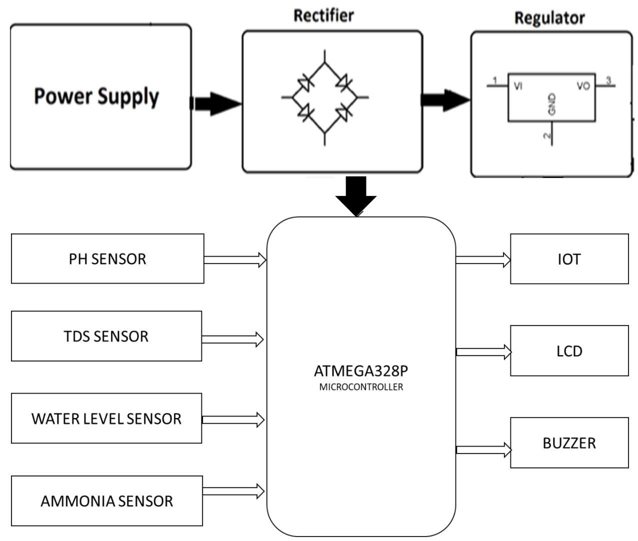

Fig. 4. Block diagram of the system

C. *Selection and Cultivation of Fishes*

We have selected Tilapia fishes as it is one of the best suitable for aquaponics, because it is hard that makes them impossible to kill. They are cultivated at a temperature range between 82° – 86°F but can survive outside the range. They cannot survive when the water temperature goes lower than 50°F (10°C). They prefer a pH range of 6.5 to 9. They are also easily available in most parts of the world.

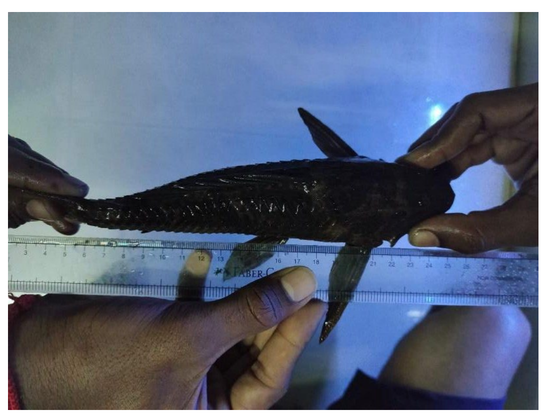

Fig. 5. Growth of Tilapia Fish

D. *Selection and Cultivation of Crops*

We have cultivated Spinach as our crop as it is a classic superfood and is one of the best leafy green that can be grown in our aquaponics garden. They don't contain long roots, so they are ideal for the NFT or Raft system as they don't require a deep growing bed to grow. They grow at a temperature of about 45-60f. They prefer a pH range for the growth of the crop is 6-7.

Fig. 6. Growth of Spinach Crop

E. Nitrogen Cycle

The nitrogen cycle comprises three steps. They are Ammonification, Nitrification, and Assimilation.

Ammonification is the process of releasing ammonia from the excreta of the fish. Nitrification is the conversion process of ammonia to nitrite with the help of Nitrosomonas bacteria in the inert medium of the system. And with the help of Nitrobacter nitrite is then converted into the final form, Nitrate which is the feed for the growth of the plants. Assimilation is the process of absorbing nitrate into the plants.

Waste of the fishes contain high levels of ammonia that is toxic for the growth of the plants, so the system should be properly monitored and maintained regularly. In order to overcome this problem easily, we have developed this system containing an Ammonia sensor that detects the amount of ammonia, nitrite, and nitrate and sends the observed data to the microcontroller. If this data is not at the optimum level, the buzzer connected will alert us through mobile notifications and an alarm.

5. Results and Discussion

This section deals with the outcome of the research from the installation of the Aquaponics System to the analysis of plant and fish growth.

A. Testing of Water Level

Using an Ultrasonic sensor, we have tested and compared the measurement results with the results of manual process using a ruler. This test also aims to determine the error value generated by the ultrasonic sensors readings that had changes of water levels in the aquarium tank.

From Table 1, we can see, results shown is the success rate of measurement for the ultrasonic sensor was 99.94%.

B. Testing of pH and TDS

Using pH sensor, we test, measure and adjust the results obtained by inserting a probe into the water with different acidity degrees(pH). This test is done to calibrate the pH meter and find the values of the acidity of water in the aquarium. Then the final results are compared to the digital meter. Using the TDS sensor, the total solid dissolved in the water is measured and the value is noted.

Table 1
Readings of water level

S. No.	Measurement(M)	Water Level(cm)		Success (%)	Error (%)
		Ultrasonic Sensor	Manual		
1	M1	39	39.5	99.57	0.43
2	M2	40	40	100	0
3	M3	38	38	100	0
4	M4	39	39	100	0
5	M5	40	40	100	0
6	M6	38	38.7	99.86	0.14

Table 2
Comparison between the pH sensor and the digital pH meter

S. No.	Reading (R)	Acidity Level		TDS (ppm)
		pH sensor	Digital pH meter	
1	R1	6.60	6.6	947
2	R2	6.63	6.6	1163
3	R3	6.61	6.6	1436
4	R4	6.64	6.7	1228
5	R5	6.69	7.0	769
6	R6	7.01	7.4	1133

Table 2 shows us the comparison between the pH sensor and the digital pH meter and its accuracy.

C. Testing of Ammonia, Nitrite, and Nitrate levels

Using an Ion sensor, we measure the levels of ammonia, nitrite, and nitrate, that gives nutrition for the growth of the plants.

When the ammonia level is between:

- 0-0.25 ppm - Safe, no action required, should be monitored regularly.
- 0.25-0.5 ppm - Caution, check water quality and feeding rate, monitor more frequently
- 0.5-1.0 ppm - Warning, increase aeration and water flow, reduce feeding rate, add bacteria to the system.
- Above 1.0 ppm – Danger, immediately perform a partial water change, check water quality, reduce feeding rate, add bacteria to the system.

Table 3
Readings of Ammonia Levels

S. No.	Reading (R)	Ammonia Level (ppm)	Observation
1	R1	0.25 - 0.50	Caution
2	R2	<0.25	Safe
3	R3	0.25 - 0.50	Caution
4	R4	0.50 - 1.0	Warning
5	R5	<0.25	Safe
6	R6	<0.25	Safe

Table 3 shows us the readings of levels of Ammonia and its forms in the proposed system.

D. Server Testing

This experiment uses one of IoT platform servers namely Blynk. This application helps in the process of sending data to the application by the account created via a WiFi network. In this study only one device was used to send data to the ATMEGA328P microcontroller with 4 variables. Then the final data was sent and stored in one variable.

6. Conclusion

The application of IoT to aquaponics has the potential to completely transform how we grow food by making it more profitable, efficient, and sustainable. Aquaponic systems can monitor and manage vital environmental factors such as water pH, and nutrient levels in real-time by integrating sensors, actuators, and other smart devices. This can lead to higher crop yields and better fish health. The adoption of IoT can also save labour costs, lessen the possibility of crop failure, and enable remote system monitoring and administration.

In general, aquaponics utilising IoT can be a successful response to the rising need for locally farmed and sustainable food. The implementation of such systems, it should be noted, may necessitate large expenditures on infrastructure, technology, and knowledge. The long-term success of aquaponic systems utilising IoT requires careful planning, monitoring, and management.

Acknowledgment

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References

[1] Wei, Y.; Li, W.; An, D.; Li, D.; Jiao, Y.; Wei, Q. Equipment and intelligent control system in aquaponics: A review. *IEEE Access* 2019, *7*, 169306–169326.

[2] Blidariu, F.; Grozea, A. Increasing the economic efficiency and sustainability of indoor fish farming by means of aquaponics-review. *Anim. Sci. Biotechnol.* 2011, *44*, 1–8.

[3] Love, D.C.; Fry, J.P.; Genello, L.; Hill, E.S.; Frederick, J.A.; Li, X.; Semmens, K. An international survey of aquaponics practitioners. *PLoS ONE* 2014, *9*, 102662.

[4] Yep, B.; Zheng, Y. Aquaponic trends and challenges—A review. *J. Clean. Prod.* 2019, *228*, 1586–1599.

[5] Tyson, R.V.; Treadwell, D.D.; Simonne, E. Opportunities and challenges to sustainability in aquaponic systems. *HortTechnology* 2011, *21*, 6–13

[6] Martinez, P.; Ahmad, R.; Al-Hussein, M. A vision-based system for pre-inspection of steel frame manufacturing. *Autom. Constr.* 2019, *97*, 151–163.

[7] Blau, B.; Kramer, J.; Conte, T. Service value networks. In Proceedings of the 2009 IEEE Conference on Commerce and Enterprise Computing, Vienna, Austria, 20–23 July 2009.

[8] Li, Q.; Tang, Q.; Chan, I.; Wei, H.; Pu, Y.; Jiang, H.; Li, J.; Zhou, J. Smart manufacturing standardization: Architectures, reference models and standards framework. *Comput. Ind.* 2018, *101*, 91–106.

[9] El Hendy, M.; Miniaoui, S.; Fakhry, H. Towards strategic information & communication technology (ICT) framework for smart cities decision-makers. In Proceedings of the 2nd Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE), Nadi, Fiji, 2–4 December 2015.

[10] Wolter, D.; Kirsch, A. Smart environments: What is it and why should we care? *KI-Künstliche Intell.* 2017, *31*, 231–237.