Available online at https://journal.rescollacomm.com/index.php/ijrcs/index

International Journal of Research in Community Service

e-ISSN: 2746-3281
p-ISSN: 2746-3273

Vol. 5, No. 3, pp. 130-137, 2024

Development of Hydroponic Application based on Web and Internet of Things for the Community to Monitor pH and Total Dissolved Solids

Simon Prananta Barus[1*], Yonathan Arya Dhamma[2]

[1,2]*Informatics Engineering Study Program, Faculty of Science, Technology and Mathematics, Matana University, Serpong, Indonesia*

**Corresponding author email: simon.barus@matanauniversity.ac.id*

Abstract

Humans need to consume vegetables for the health of their bodies. To meet the needs of these vegetables, vegetables are not only grown with soil media, but also with soilless media such as hydroponics. Hydroponic cultivation needs to be monitored. Advances in IT, sensor technology and the Internet of Things (IoT) mean that monitoring can be done online. pH levels and Total Dissolved Solids (TDS) levels are important indicators for determining nutritional conditions in hydroponic cultivation. This data is not only to be monitored, but also to be used as a dataset for artificial intelligence needs and a reference for the community to obtain data on the best hydroponic cultivation results. Thus, the aim of this research is to develop a hydroponic application based on web and IoT for the community to monitor pH and TDS. Three phases were carried out, i.e., study of literature, application development with Patas model and report writing. pH and TDS levels are obtained from a pH and TDS sensor connected to an IoT device, NodeMCU ESP8266. The NodeMCU ESP8266 sends the data to the web application (with PHP) on the web server (with Apache) to be stored in the database (with MySql). Three important data are stored in the database, i.e., plants, hydroponic cultivation, and cultivation monitoring. This hydroponic application based on web and IoT were successfully built. Monitoring via this application can be detailed or summary (dashboard). Furthermore, it is necessary to try out hydroponic cultivation and add sensors to complete the dataset.

Keywords: Internet of things (IoT), patas model, pH, total dissolved solids (TDS), web application

1. Introduction

One of the important factors of human health is by consuming vegetables. Currently, there is limited land. However, limited land is not a major obstacle to consuming vegetables independently. These limitations can be overcome by planting vegetables through hydroponic media. Hydroponics is a method of cultivating plants without soil as a growing medium (The Editors of Encyclopaedia Britannica, 2024). With this independence, it can support national food security (Gabrieli, 2022). This food security supports the Sustainable Development Goals (SDGs), which is included in SDGs Goal number 2, i.e. to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture (SDGS Indonesia, 2023). Not only limited land conditions, but also soil conditions that do not support vegetables to grow well, hydroponics can be one solution (Barus, et al., 2023).

Hydroponic plant cultivation allows plants to grow in a controlled environment. Therefore, its success depends heavily on monitoring and managing critical parameters, such as pH, Total Dissolved Solids (TDS), temperature, humidity, light, and others. Monitoring needs data. Data is new oil, but it has only been slightly utilized (Hirsch, 2013). Data is not only important in monitoring, but also for the needs of artificial intelligence, such as machine learning, deep learning, and others.

Conventional monitoring in hydroponic cultivation is usually carried out by recording the output from sensors or other devices into a notebook. There are some limitations to manual monitoring of these critical parameters, such as measurement inaccuracy, delays in problem detection, and the need for human intervention. To address these challenges, information technology (IT), sensor technology and the Internet of Things (IoT) offer solutions that can improve monitoring efficiency and accuracy. There are five core functions in IoT, i.e., demand and supply management, maintenance, information systems, remote access, and services (Adryan, et al., 2017). These advances can realize online monitoring. Online monitoring can be done anytime, from anywhere (connected to the Internet) and in real-time through a web-based application. IoT sensors installed in hydroponic systems can measure these critical parameters continuously and send the data to an integrated management platform.

There are many online monitoring of hydroponic cultivation that have been built-in, such as monitoring irrigation (Nandika and Amrina, 2021), plant health conditions from leaf images (Himawan, 2024), daily recording (temperature, humidity, pH, TDS, and water) (Suroso, 2020; Bogdan, 2023), automation of pH, temperature, turbidity, and maintenance of electrical conductivity in a greenhouse environment (Anjini, et al., 2021), monitoring nanobubble-based hydroponics (Safira, et al., 2023d), and some more complete monitoring and data utilization (Nguyen, et al., 2022; Tatas, et al., 2022; Lembaga Penelitian dan Pengabdian kepada Masyarakat, n.d). However, only a few integrated applications have been built and datasets that are not open or shared with the public. This is a challenge in this research to try to build its own application which will later be developed to become a large system and dataset owned for the development of smart systems and future research.

The two main indicators to determine the quality and availability of nutrients in hydroponic cultivation are pH and TDS. An inappropriate pH level can interfere with nutrient absorption by plants, and TDS levels provide an indication of the concentration of nutrients available in the solution. As a first step, these two indicators were chosen to be monitored. Thus, this study aims to develop hydroponic applications to monitor pH and TDS in hydroponic cultivation. This application will not only monitor pH and TDS conditions in real-time but also collect and analyze the data to support artificial intelligence, such as expert systems, fuzzy logic, machine learning or deep learning.

2. Materials and Methods

2.1. Materials

The IoT device used is NodeMCU version 1 with an ESP8266 WiFi microcontroller chip, Figure 1. In the documentation it says that, "NodeMCU is an open source Lua based firmware for the ESP32 and ESP8266 WiFi SOCs from Espressif" (NodeMCU documentation, n.d).

Figure 1: NodeMCU version 1 ESP8266

pH data is obtained through a pH sensor, Figure 2. The pH sensor is used to measure the acidity or alkalinity of the hydroponic cultivation solution. The specifications of the pH sensor used can be seen in Table 1.

Figure 2: pH Sensor

Table 1: pH Sensor Spesifications

No.	pH Sensor Specifications
1	Working voltage: 5V
2	Working current: 5-10mA
3	pH detection range: 0-14
4	Temperature detection range: 0-80 deg celcius
5	Response time: <5s
6	Settling time: <60s
7	Module size: 42mm x 32mm x 20mm
8	Equipped with 4 M3 bolts

TDS data is obtained through TDS sensors, Figure 3. TDS sensors are used to measure the concentration of dissolved solids in hydroponic cultivation solutions. The specifications of the TDS sensor used can be seen in Table 2.

Figure 3: TDS Sensor

Table 2: TDS Sensor Specifications

No.	TDS Sensor Specifications
1	Adapter board dimensions: 42x32 mm
2	TDS probe length: 83cm
3	Input voltage: 3.3 - 5.5v
4	Output signal: 0 - 2.3V
5	Working current: 3 - 6 A
6	TDS measurement range: 0 - 1000 ppm
7	Interface module: XH2.54-3P
8	Electrode interface: XH2.54-2P

The software used is MySql (database management system (DBMS)), Apache (web server), C++ (programming language for IoT), JavaScript and PHP (programming language for the web). The C++ program is embedded in the ESP8266. Apache and MySql are installed on the server computer. JavaScript program for the front end and PHP program for the back end.

2.2. Methods

The research method in this research consists of three phases, as shown in Figure 4, i.e., study of literature, application development with PATAS model and report writing.

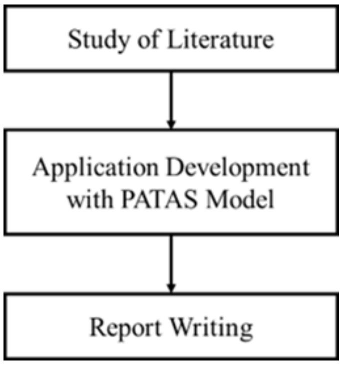


Figure 4: Research flow

2.2.1. Study of Literature

Study of literature aim to understand existing knowledge, identify research gaps, and identify appropriate research methods. A lot of previous research has discussed the Internet of Things (IoT) as applied to hydroponic systems. There are those who just monitor the condition of the plants, but there are also those who record the condition of the plants but the numbers are small. However, a dataset of hydroponic cultivation results is not yet available.

2.2.2. Application Development

Application development in this research uses the Patas model. The Patas model has seven phases, i.e. user requirements, selection of devices, modification, evaluation, implementation, and maintenance, see Figure 5. In this research, all phases of the Patas model were not carried out, from the user requirements phase to the evaluation phase only.

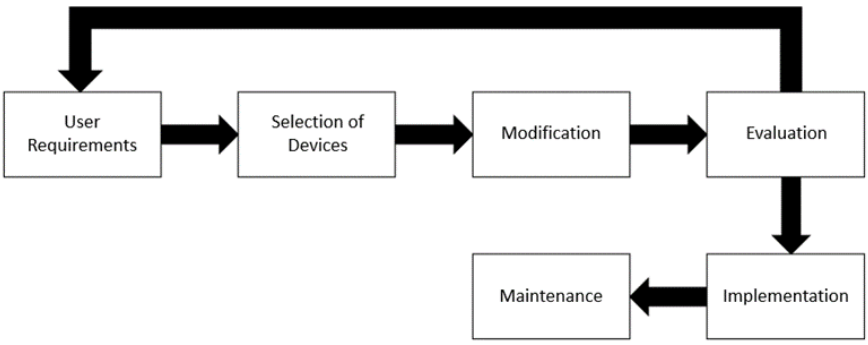


Figure 5: Patas model (Barus, 2022)

From the analysis results, three entities were obtained, i.e., Plant, Hydroponic Cultivation, and Cultivation Monitoring. The relationship between these entities can be seen in Figure 6. Each entity has its own attributes. These three entities are implemented in the MySql database management system (DBMS).

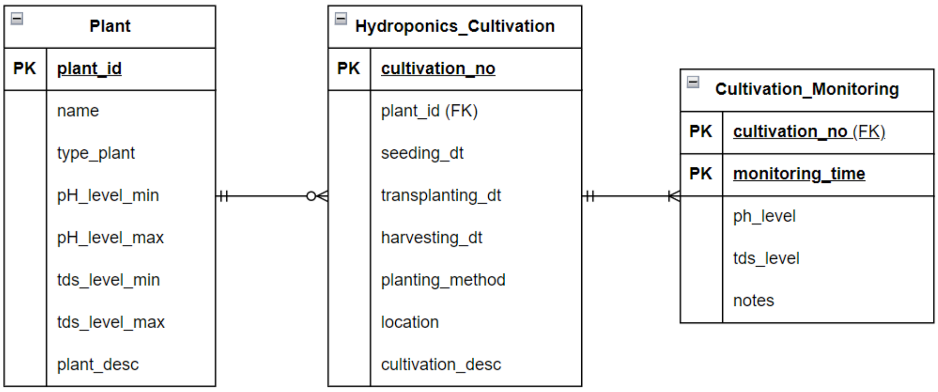


Figure 6: Entity Relationship Diagram

2.2.3. Report Writing

Report writing plays an important role in the process of scientific communication and knowledge dissemination. Report writing is a tool for disseminating knowledge, building strong scientific arguments, and advancing the fields of science and technology. Some of the activities in writing reports are the preparation of report structure, preliminary preparation, literature review, description of research methods, presentation of results, analysis and interpretation, discussion, conclusion, and preparation of bibliography.

3. Results and Discussion

The monitoring architecture, Figure 6, illustrates the work of a monitoring application. The monitoring application works as follows, IoT devices (NodeMCU ESP8266) are connected to a pH sensor (figure 3) and a TDS sensor (figure 4). NodeMCUs ESP8266 read data from pH and TDS sensors through analog pins. After being processed by NodeMCU ESP8266, the data is sent to a web application located on a web server via WiFi with the Hypertext Transfer Protocol (HTTP) protocol to be stored in a database (MySql DBMS). Furthermore, online monitoring is carried out through a web application that can be accessed from a PC (personal computer), notebook, smartphone, or tablet.

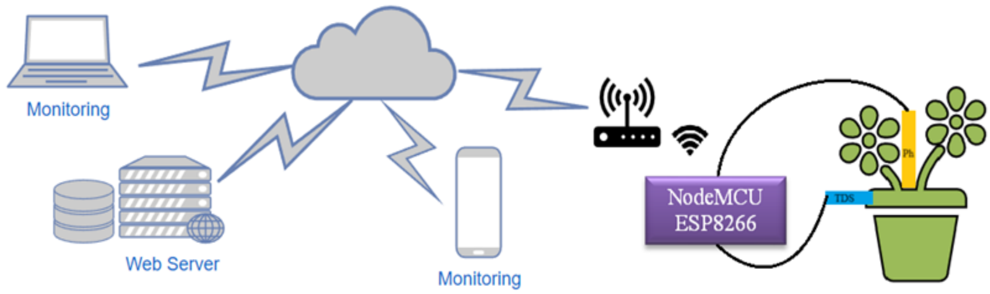
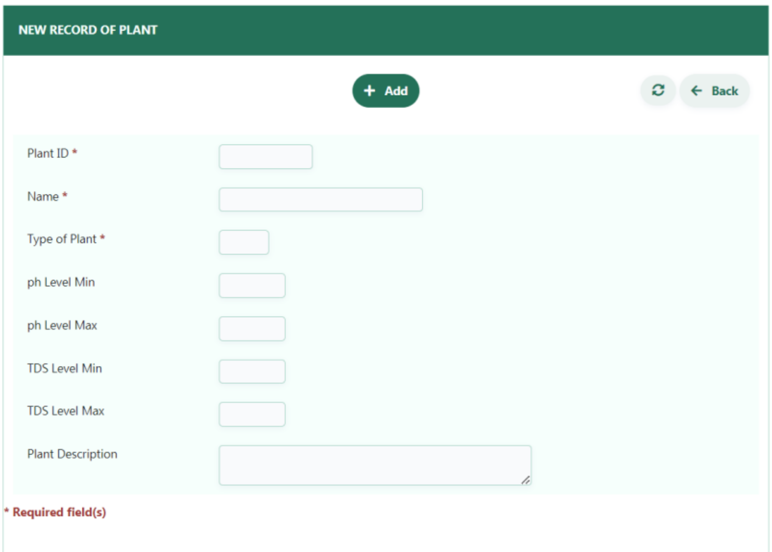


Figure 6: Monitoring architecture

This hydroponic application has two forms, namely a form to enter plant data and a hydroponic cultivation form. Not only forms, but also monitoring tables and dashboards are available. Therefore, before monitoring is carried out, plant data and hydroponic cultivation must first be entered, then readings from pH sensors and TDS sensors are carried out until harvest. The data reading by the sensor is based on a predetermined timer.

Plant data can be entered through the plant form, Figure 7. The plant data includes plant id, name, type of plant, pH level min, pH level max, TDS level min, TDS level max, and plant description. Next, the data is used for hydroponic cultivation.


NEW RECORD OF PLANT

+ Add

Back

Plant ID *

Name *

Type of Plant *

ph Level Min

ph Level Max

TDS Level Min

TDS Level Max

Plant Description

* Required field(s)

Figure 7: Plant form

Hydroponic plant cultivation data can be entered through the plant cultivation form, Figure 8. The plant cultivation data includes cultivation no, plant id, seeding date, transplanting date, harvesting date, planting method, location, and cultivation description.

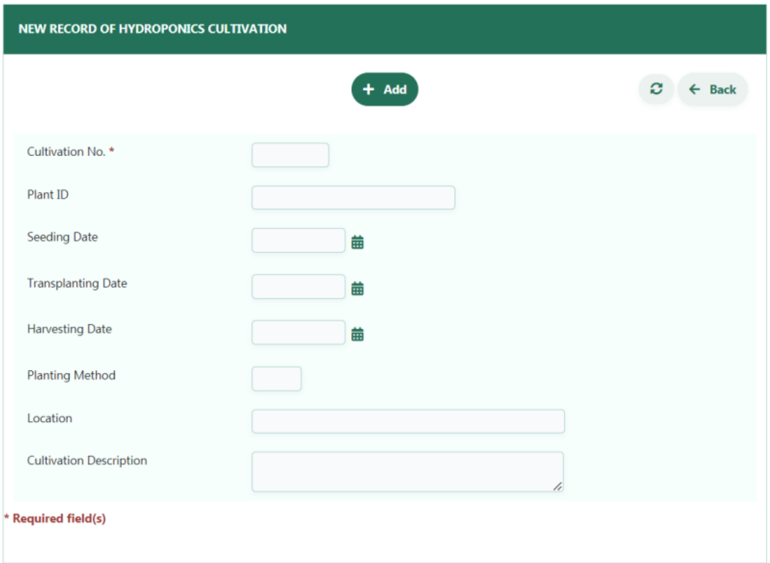


Figure 8: Hydroponics cultivation form

The pH and TDS data recorded through the sensor and stored in the database can be seen in the report of hydroponics plant cultivation monitoring, Figure 9. If there is no data saved, a "No Records Found" notification will appear. However, if available, a monitoring report with data will be displayed, i.e., the date and time of data collection, pH level, TDS level, and notes. If the pH or TDS level is lower or higher than the reference recorded in the plant data, then the pH or TDS level is red. Hydroponic cultivation data and subsequent monitoring data can be used as a dataset of hydroponic plant cultivation results.

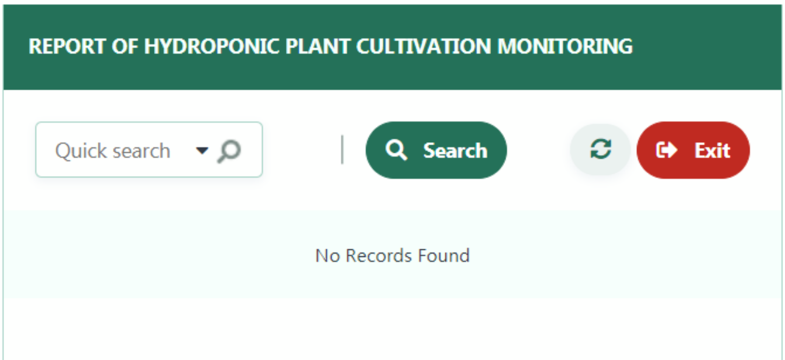


Figure 9. Hydroponic plant cultivation monitoring

A summary of the monitoring of pH and TDS levels is made in the form of a dashboard, Figure 10. Not only a summary of the ph level and TDS level, but also a comparison with the previous ph level and TDS level. It is red when the condition is down and green when it is up. However, for more detailed data needs, it can be seen in the report of hydroponic plant cultivation monitoring.

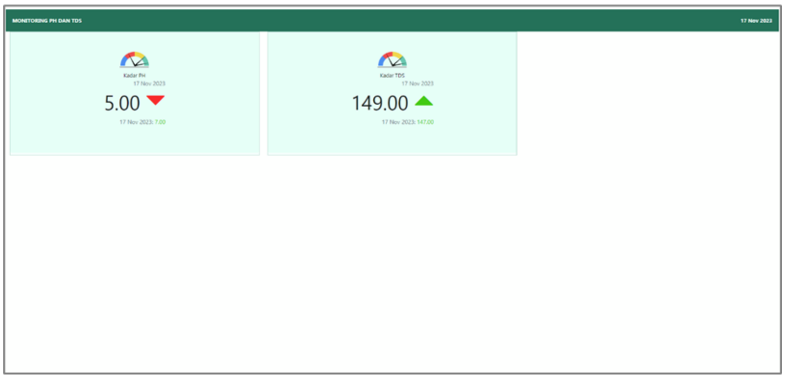


Figure 10. Monitoring dashboard

Hydroponic application based on web and IoT to monitor pH and TDS have been successfully developed. With this application, the hydroponic cultivation carried out can be recorded (stored) and monitored, especially pH levels and TDS levels. Thus, hydroponic cultivation datasets, plant data from seedling to harvest will be obtained. This has not been seen in previous studies. The application of this application can be started with the hydroponic cultivation of the wick method. Some of the things that need to be considered in the application are, sensor condition, sensor calibration, electricity availability, signal to connect to the Internet, stable web server. This can be an obstacle in recording and monitoring.

4. Conclussion

The application of web-based water pH and TDS monitoring and Internet of Things (IoT) for plants with hydroponic media has been successfully carried out. The pH and TDS data is obtained through pH and TDS sensors which are then sent by the WiFi microcontroller ESP8266 sent to a web application on the Apache web server where the data is then stored in the MySql DBMS. Through the web application, hydroponic cultivation can be monitored for its nutrient levels, especially pH levels and TDS levels, in detail or a summary (dashboard). Thus, hydroponic cultivation can be monitored from anywhere and anytime if it is connected to the Internet. In addition, the monitoring data becomes a dataset that can be used for many things in the future, such as predictions or classifications based on artificial intelligence, imitating the success of a good harvest for the community. For the application to run well and smoothly, it is necessary to pay attention to the energy source for the microcontroller and the server and Internet connection, as well as the calibration of the sensors. Further development needs to add features so that the application is more reliable, such as recording temperature, humidity, light, and growth images. This application should also be applied to various types of hydroponic plant cultivation so that it can have various plant datasets that can be a reference.

Acknowledgments

We gratefully acknowledge the support and research funding provided by Matana University.

References

Adryan, B., Obermaier, D., & Fremantle, P. (2017). *The Technical Foundations of IoT*. Norwood: Artech House.

Anjini, R., Jenifer, J. J., & Blessy, A. M. C. (2021). IoT Based Automated Hydroponics Greenhouse Monitoring. *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), 4*(2), 671-681. https://doi.org/10.48175/IJARSCT-960.

Barus, S. P. (2022). Implementation of the PATAS model in the development of the Matana University Graduation Information System. *Jurnal Informatika Dan Sains/JISA (Jurnal Informatika Dan Sains), 5*(2), 116–119. https://doi.org/10.31326/jisa.v5i2.1327.

Barus, S. P., Tangdililing, M. M. L., Widjaya, P. a. A., Sujanto, S., & Jong, N. E. (2023). PENERAPAN METODE HIDROPONIK PADA DESA BENTENG MAMULLU TANAH TORAJA UNTUK MENGATASI KEBUTUHAN SAYUR MAYUR. *Universal Raharja Community (URNITY Journal), 3*(1), 31-36. https://doi.org/10.33050/urnity.v3i1.2435.

Bogdan, R., Paliuc, C., Crisan-Vida, M., Nimara, S., & Barmayoun, D. (2023). Low-cost internet-of-things water-quality monitoring system for rural areas. *Sensors, 23*(8), 3919.

Gabrieli, F., & Almubaroq, H. Z. (2022). The Potential of The Hydroponic Vegetables to Support Food Security in Defense Management Perspective. *JESS (Journal of Education on Social Science)*, *5*(2), 194-206.

GOAL 2 - SDGS Indonesia. (2023b, December 3). Tanpa Kelaparan: Menghilangkan Kelaparan, Mencapai Ketahanan Pangan dan Gizi yang Baik, serta Meningkatkan Pertanian Berkelanjutan. Retrieved from https://sdgs.bappenas.go.id/17-goals/goal-2/.

Himawan, A., Putra, W. H. N., & Setiawan, E. (2024). RAFT: An IoT-Based Nutrition Monitoring System for Bok Choy Hydroponics Plants. *Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi)*, *8*(2), 258-264.

Hirsch, D. D. (2013). The glass house effect: Big Data, the new oil, and the power of analogy. *Me. L. Rev*., 66, 373.

Info Terbaru - Lembaga Penelitian dan Pengabdian kepada Masyarakat. (n.d.-d). Retrieved from https://research.lppm.itb.ac.id/information/hidroponik_komersial_berbasis_internet_of_things.

Nguyen, H. C., Thi, B. T. V., & Ngo, Q. H. (2022). Automatic Monitoring System for Hydroponic Farming: IoT-Based design and development. *Asian Journal of Agriculture and Rural Development*, *12*(3), 210–219. https://doi.org/10.55493/5005.v12i3.4630.

NodeMCU documentation. (n.d.). Retrieved from https://nodemcu.readthedocs.io/en/latest/.

Safira, M., Yusuf, A., Salim, T. I., & Alam, H. S. (2023d). Design and implementation of IOT-Based Monitoring System on Nanobubble-Based Hydroponics Farming. *Jurnal Teknik Pertanian/Jurnal Teknik Pertanian Lampung*, *12*(2), 470-483. https://doi.org/10.23960/jtep-l.v12i2.470-483.

Suroso, J. S., Kaburuan, E. R., Angelica, N., Tanujaya, W., & Munandar, F. (2020, December). Entrepreneur of Internet of Things (IoT) in Portable Hydroponic. *In 2020 8th International Conference on Orange Technology (ICOT) (pp. 1-4). IEEE.*

Tatas, K., Al-Zoubi, A., Christofides, N., Zannettis, C., Chrysostomou, M., Panteli, S., & Antoniou, A. (2022c). Reliable IoT-Based monitoring and control of hydroponic systems. *Technologies*, *10*(1), 26. https://doi.org/10.3390/technologies10010026.