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VIRTUAL PROTOTYPING AND IMPLEMENTATION OF A DIGITAL MONITORING SYSTEM FOR FISH DRYING PARAMETERS

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ABSTRACT
Heat and moisture transfer occur simultaneously during the fish drying process. Continuous monitoring is necessary to ensure high quality fish drying. In this study, a digital system was designed to monitor parameters (Temperature (-400C±0.50C to 800C±0.50C), Relative Humidity (0 to 100%RH ±2%RH) and smoke concentration (200ppm to 5000ppm)) in the fish drying process in a dryer. A system engineering design approach with the use of Computer Aided Design (CAD) tools was used to establish the basic layout of the different sections of the system using Arduino UNO (based on ATmega328P), sensors, a Liquid Crystal Display (LCD), a micro SD card module and an alarm system. These components were integrated as an embedded system through the use of a compiler; Arduino integrated development environment (Arduino 1.8.7) and Proteus designer suit (Proteus 8.1 professional). The testing was done on the dryer for about 7Hours and 35minutes by monitoring the drying parameters. The results obtained showed that the virtual system modeler software provided a complete embedded digital laboratory for the simulation and implementation of the fish digital monitoring system. The microcontroller drawn is also able to accept, and execute the code produced with Arduino IDE connected to Proteus designer suit. The developed system works effectively in monitoring the drying parameters inside the drying chamber of a fish dryer with the ability to displayed, stored and retrieved the data for future use.

Keywords: Arduino UNO, Drying Parameters, Digital System Design, Fish Dryer, Fish Drying, Continuous Monitoring

INTRODUCTION

Fish drying is a process that involves the exposure of fish to heat and airflow, resulting in the removal of moisture and the preservation of the fish (Wankhade *et al.,* 2013). In developing countries, the practice of smoking fish is still carried out in a traditional manner using rudimentary equipment (plate 1) that fails to address critical concerns related to health and food safety (Swastawati *et al.,* 2012). In Nigeria, the conventional smoking processes as shown on plate 2 and 3 frequently deviates from established standards. The resulting products as shown on plate 4 are characterized by the presence of carcinogenic compounds, lack of uniformity, and potential air pollution from the smoking process. Also, the quality of the products often falls short of international standards for smoked fish (Anyakora and Coker, 2007). The global food industry's sustainability is influenced by health, nutrition, and convenience, with fish products being a significant source of protein, vitamins, minerals, and fats. However, their perishability necessitates proper processing and packaging techniques (Nagarajarao 2016).


Plate 1: Modified Drum Kiln


Plate 2: Traditional Banda Smoking kiln

Plate 3: Fish Smoking using shaft

Plate 4: Final product from traditional method

On a global scale, there is an increasing reliance on digital and computer technologies for daily activities. Mondejar et al., (2021) Defined digitalization as the process of converting physically collected information (e.g., sensors data) and knowledge into a computer-based language. This process facilitates the development of digital technologies that can be integrated into the Internet of Things (IoT) environment. This IoT framework facilitates the establishment of a robust network of interconnected physical objects across the internet through the integration of embedded sensors, software, and other technologies that enable the exchange and aggregation of data (Mondejar et al., 2021; Rowan et al., 2022). An examination of the diverse applications of digital technologies in fisheries and aquaculture is provided by Neil (2022).

Digital transformation has the potential to support and meet the expansion needs of the fisheries and aquaculture industries. This can be achieved by exploiting and harnessing information and communication technologies (ICT), the Internet of Things (IoT), cloud-edge computing, artificial intelligence (AI), machine learning, immersive technologies, and blockchain. Digital technologies have been shown to yield substantial operational benefits for the global food chain, enhancing efficiencies and productivity while reducing waste, contamination, and food fraud. The paradigm has evolved to Industry 5.0, where artificial intelligence (AI) and robotics are integrated with human capabilities to engineer human-centric solutions (Neil, 2022).

Modern fish drying technologies have shown promise in addressing these issues. The drying process involves simultaneous heat and moisture transfer, necessitating continuous oversight for optimal results. Moreover, they lacks real-time monitoring and sometimes experience disruptions due to the introduction of bypass fluids during inspections, which reduces their efficiency, increases energy consumption, and leads to post-harvest losses (Okouzi et al., 2020, Omodara et al., 2016).

The development of a digital system for monitoring fish drying process parameters has the potential to address the health and environmental hazards posed by the traditional method of fish processing. This initiative could also reduce post-harvest losses and high energy consumption in fisheries industries and among consumers. The digital system will also assist in producing a highly hygienic product that is globally acceptable. Digital prototyping will facilitate understanding of the fish drying process and expedite such development. The aim of this study is to design and construct a digital prototype for monitoring drying parameters in the fish-drying process in the aquaculture industry in Nigeria. To this end, the following objectives are to be pursued:

i. To develop a digital system capable of real-time monitoring of drying parameters in a fish dryer.
ii. To implement the digital prototype design physically.

MATERIALS AND METHODS

The study involves the integration of disparate components to function as a device. The present study employs a system engineering design approach, as outlined in the works of Okouzi et al., (2023) and Muller (2013). This approach utilizes Computer Aided Design (CAD) tools to establish the fundamental layout of the system's various sections. Employing sensors to senses parameters that can be processed by the ATmega328P-based Arduino UNO in the form of digital signals, the system stores and displays these parameters on a liquid crystal display (LCD). Arduino 1.8.7 IDE was used for firmware development and to configure the Arduino UNO microcontroller board and Proteus 8.1 professional was used for the circuit design.

System Architecture

The designed digital system comprises the following parts;

i. Power supply unit: The power supply unit provides the required voltage to power the digital system. This unit incorporates the regulators, bulk converter, switch and the 12 volt DC supply.
ii. Sensors Array unit: The core of the monitoring system comprises an array of sensors strategically placed within the fish dryer. These sensors include temperature/humidity sensor and smoke sensors to monitored temperature, relative humidity and any potential emissions during the drying process respectively.
iii. Data Processing Unit: The sensor data is collected by a centralized data unit, which interfaces with the sensors and converts analog signals into digital data. The collected data undergoes comprehensive processing and analysis to extract meaningful insights. This unit incorporate microcontroller (Arduino UNO) for real-time data processing and transmission.
iv. User Interface: A user-friendly interface is essential for operators to operate, visualize and interpret the monitoring data effectively. This interface includes press button, LCD display, micro SD card and alarm systems to alert operators of any deviations from optimal drying conditions.

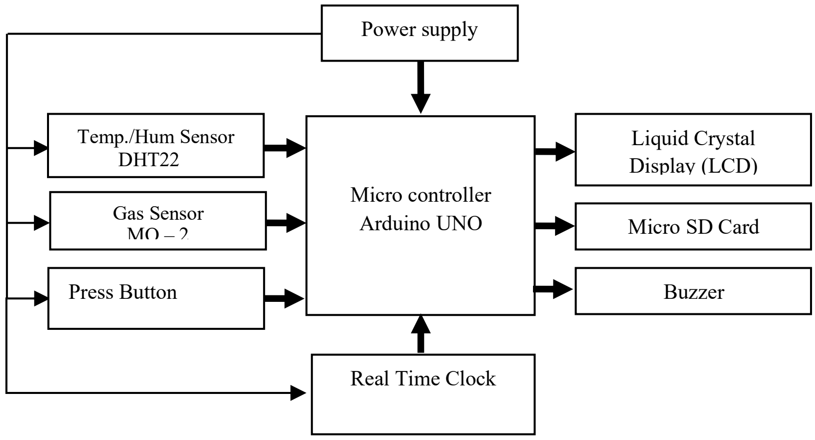

Figure 1: Block diagram of the System

Sensors Calibration

The Temperature/Humidity sensor (DHT22) is a digital sensor with factory calibration, but manual calibration is necessary for higher accuracy. This calibration was done by connecting the VCC, GND and Data pin to the microcontroller (Arduino UNO), and the DHT.h library was use to read the data. A reference thermometer/hygrometer and the DHT22 sensor was placed inside the dryer to read temperature and humidity for about 2 hours, readings was recorded at different time interval for both devices and offsets was calculated.

The gas sensor (MQ-2) is an analog sensor requiring calibration for specific gases. It needs a warm up time and baseline adjustment. Pre-heating was carried out on the MQ-2 by powering it for about 20minute for stable reading and was then exposed to fresh air environment to establish a baseline. The sensor was then place inside the dryer during drying process to check response and exposure to similar emission during drying, readings were recorded and a threshold was set and stored on the microcontroller.

Flow chart diagram of the fish digital Monitoring System

Figure 2 presents a process flow chart and the working principle of the developed system.

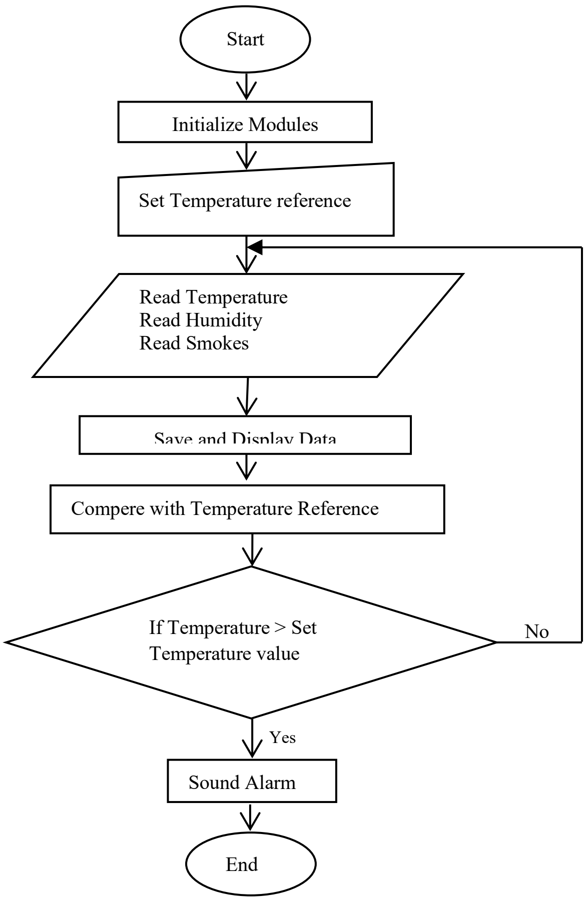

Figure 2: Flow diagram of how the system works

The complete sketch model in Arduino 1.8.7 IDE for ATmega328P MCU based Arduino UNO consist of four sections. The first section declares the library of the different drives by including the library code. These include the drive for the liquid crystal display, DHT22 sensor, MQ – 2 sensors, clock and the SD card modules. Thereafter, the LCD library is initialized with the numbers of the interface pins and then objects are created to control the sensors and the modules. The second section declares the integer and constant variables. The third section is the void setup ( ){ } which is a declaration for a function called "setup". This exact line is required in every Arduino sketch ever. The void setup routing is technically a function that is created at the top of each program. Inside the curly brackets is the code that is expected to run one time as soon as the program starts running, after each power-up or reset of the MCU. It is used to initialize variables. The last section of the model is the void loop ( ){ }. Void loop is yet another Arduino-sketch function that Arduino uses as a part of its structure. The code inside the loop function runs repeatedly as long as the MCU is turned on. This is where the bulk of the Arduino sketch is executed. The program starts directly after the opening curly bracket ({), runs until it sees the closing curly bracket (}), and jumps back up to the first line in loop() and starts all over.

The 16×2 LCD is used to display the data of the drying parameters including time. Hence, the Liquid Crystal library enabled the use of the LCD.

RESULTS AND DISCUSSION

This section presents the results of the firmware development as well as the interactive physical construction. The interactive physical construction was used to see if the design works effectively.

VSM Simulation of the Digital Monitoring System

Plate 5 present the Arduino 1.8.7 IDE (integrated development environment) user-friendly and intuitive environment for the development of the digital monitoring system computer software (firmware)

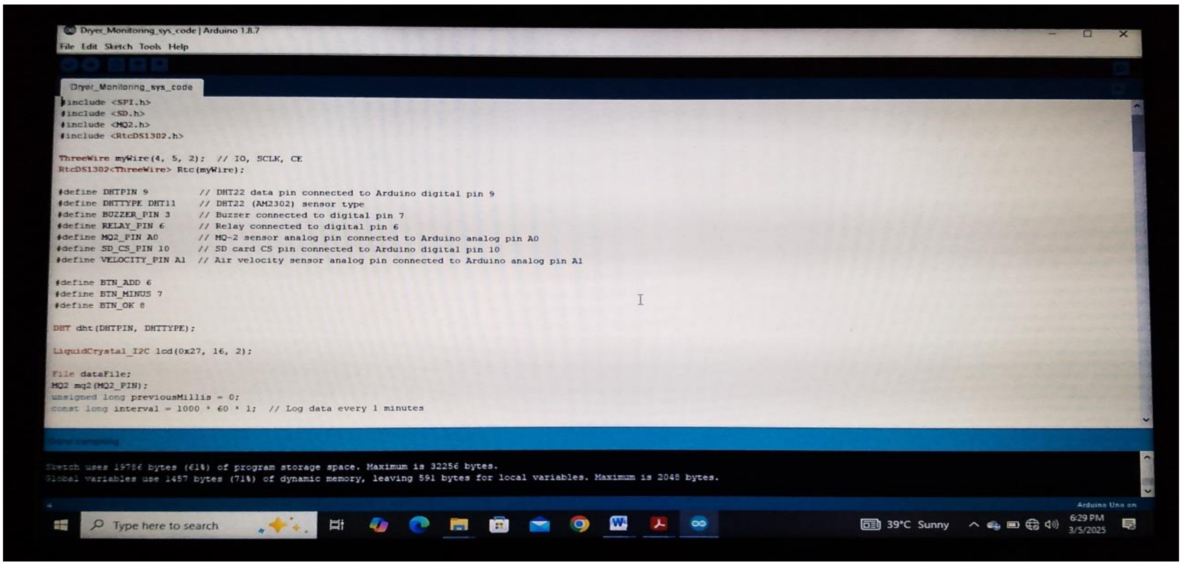

Plate 5: Arduino IDE Sketch Model of the digital system

The sketch model showed in the progress bar that the compilation which follows the creation of the project and writing of the source code was successful.

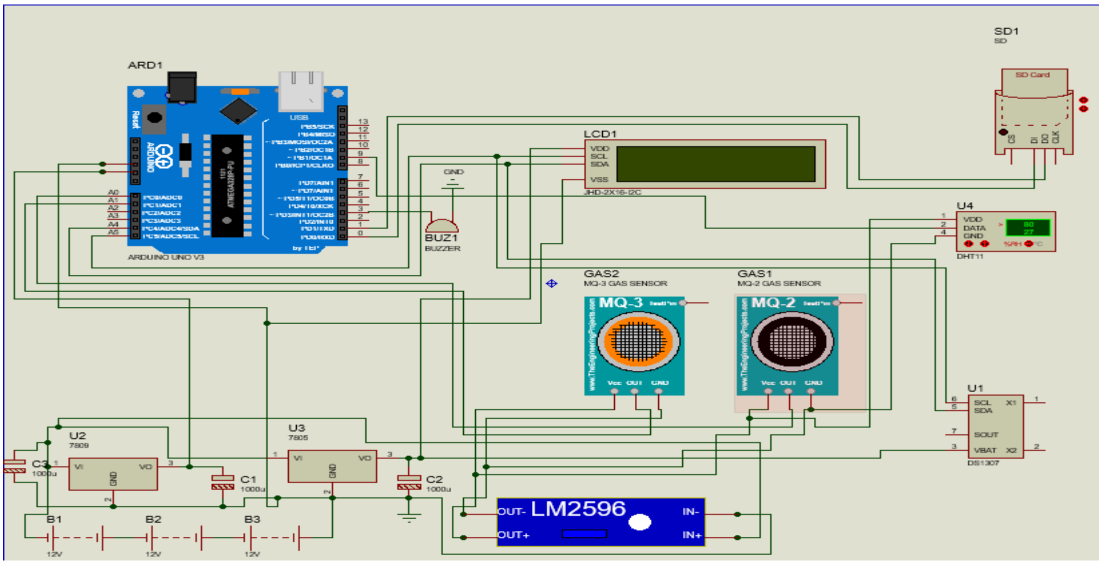

Figure 3: Schematics circuit design of the digital system

Testing of the digital system

Plates 6 to 11 below presents the pictorial test evidence and a step by step process of operation of the functional digital system, displaying temperature and humidity with reference to time on the LCD and a lead light displaying on the sensors signify the functionality of the sensors.

Plate 6: Initialization and product brand name displayed

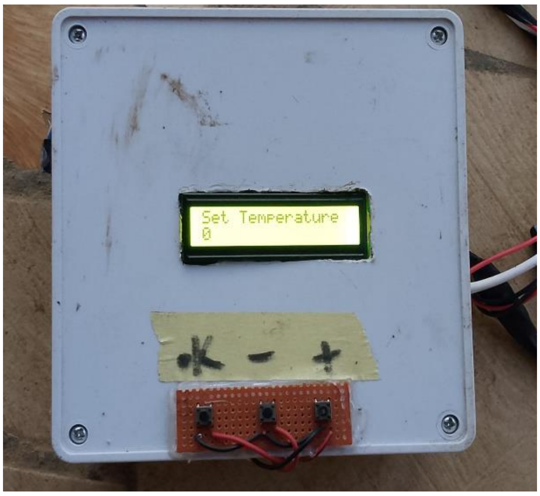

Plate 7: System preset temperature mode

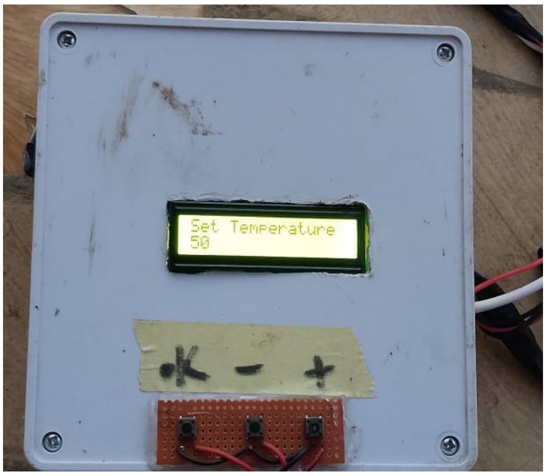

Plate 8: Temperature value set

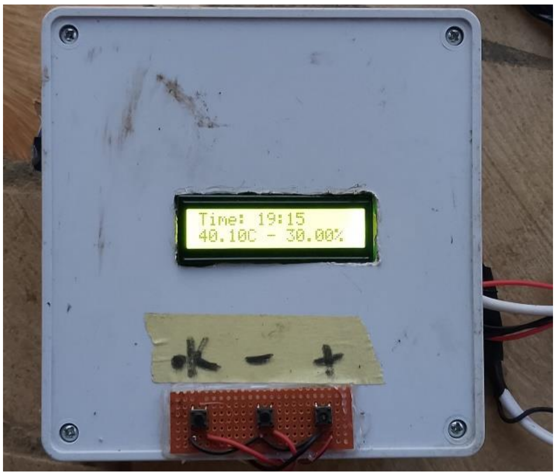

Plate 9: Displayed temperature and humidity value with time

Plate 10: Automatic Data saving mode displayed

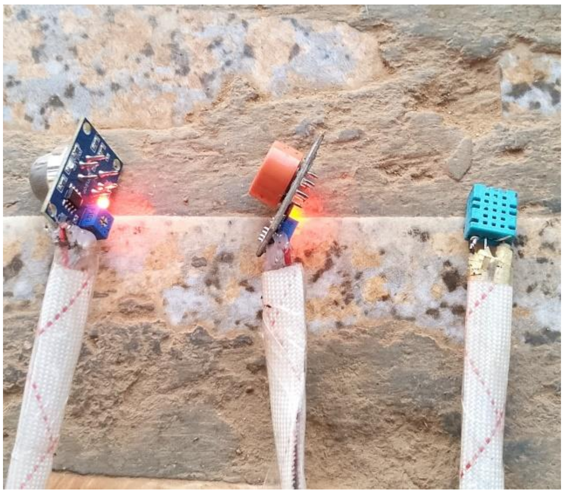

Plate 11: Temperature/Humidity and Smoke sensors

As illustrated on plates 6, upon activating the system, all modules are initialized, and a dialog box prompts to the user to specify a temperature limit for the system to operate on as shown on plate 7. Following the input of the temperature value (plate 8), the system automatically stores and displayed the value as seen on (plate 9) and operates within the established temperature limit. In the event of a deviation from the preset temperature value, the system emits an alarm, indicating that the preset temperature value has been attained within the drying chamber. This sequence of events persists while the system automatically stores drying parameters data with reference to date and time as shown on plate10. The temperature sensor (DHT22) has operating and accuracy range of (-40^{0}C±0.5^{0}C to 80^{0}C±0.5^{0}C and 0 to 100%RH ±2%RH) and smoke sensor (MQ-2) with standard detecting condition of 20^{0}C ±2^{0}C and 65%±5%RH, and a sensitivity resistance of 3KΩ to 30KΩ (200ppm to 5000ppm). Plate 11 shows the temperature/humidity and smoke sensors with a led display signifying their functionality. This conforms to the works of Mishra *et al.* (2023) and Mabrouki *et al.* (2021). Temperature and smoke concentrations may deviate from optimal values, this is due to the combustion of melted fat from the fish, which, may be attributed to the high temperature within the drying chamber, contributing to rapid drops of melted fats onto the hot damper plate of the dryer thereby producing more heat and smoke. This smoke is also carcinogenic and exerts an effect on the end products, as reported in the work of Ramatou *et al.* (2023). Excessive heat denatured the protein value of a fish, thus integrating a digital device with modern dryers to monitor drying parameters is therefore necessary to enhanced seafood quality and security. A distinctive feature of the digital system is its rechargeable nature, enabling it to operate continuously for up to 24 hours upon full charge. This attribute is particularly salient in rural communities where electricity is not readily available. The digital system offers several advantages, including portability, ease of operation, rechargeability, and the capacity to store and retrieve data for future use.

CONCLUSION

In this study, the virtual system modeler software, known as Proteus, was utilized to provide a comprehensive embedded digital laboratory for the prototyping, simulation, and implementation of a fish digital monitoring system. The system was developed for the purpose of monitoring the drying parameters in the fish-drying process. The schematics of the digital system for monitoring the fish drying process were developed and implemented. The microcontroller unit demonstrated the capacity to both receive and execute the firmware developed for the monitoring of drying parameters in the fish drying process. Lack of control over excessive heat and smoke denatured the protein content of a fish, This system's capacity to ensure the safety and quality of seafood products during the smoking process is noteworthy thereby contributing to food security. The system's portability and durability are noteworthy, as they enable its functionality in rural areas where electricity supply is a prevalent factor. However, future research may upgrade the system to in cooperate internet of things (IoT) for remote monitoring.

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