Thermoacoustic sensor-based system for detection of respiratory diseases in chicken (*Gallus domesticus* L.)

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Short Report

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Abstract

Objective

Diseases such as avian influenza, infectious laryngotracheitis and Mycoplasma gallisepticum responsible for huge losses in poultry target the respiratory system of birds. The aim of this study was to design and assemble a system which can be used to detect respiratory diseases among chicken basing on the abnormal vocalization and temperature of chicken.

Results

The proposed system was assembled and operated in a way that the acoustic and thermal sensors acquire sound and temperature from the chicken environment, sends them to a microcontroller which then interprets the input and in case of abnormal sounds or temperature due to cough or snore, the system administrator and the farmer are notified. The results illustrated that the system could be used to improve the detection of respiratory disease outbreaks in chicken, which can potentially minimize losses in poultry farming.

Introduction

The global population is increasing steadily, and will necessitate a marked increase in food production so as to support the estimated 9.1 billion people expected to exist on planet earth by 2050 [1]. Poultry farming is an agricultural sector which plays, and will continue to contribute a significant role in realizing the envisaged food security [2, 3]. Chicken (*Gallus domesticus* L.) is the most domesticated poultry bird in the world, with a global number of 33 billion in 2020 [4]. This is because they can efficiently convert feeds into eggs, feathers and meat within a short period of time. Their eggs are ranked second after milk in terms of nutritive value [5].

Despite the nutritional contribution of poultry, pests and diseases tend to cause enormous losses in the sector. Representative examples of respiratory diseases in poultry include Newcastle disease, bronchitis, avian influenza, infectious laryngotracheitis, Mycoplasma gallisepticum and chronic respiratory disease which affects the performance of growing broilers and layers by inducing morbidity, enteritis, diarrhea, reducing egg production, higher mortality due to respiratory infection (plaques in trachea), paralysis, suppression of immune responses and prostration of the head and the neck [6, 7].

Most of the cited diseases are highly contagious, characterized by respiratory signs such as gasping, coughing, snoring, snicking or sneezing, tracheal rales and nasal discharge [8, 9]. In the wake of industry 4.0 technologies [10], signal processing and machine learning algorithms have advanced in several sectors and have led to the release of innovative products [11, 12]. Speech recognition, automatic photo tagging and music recommendation engines are among the most successful [9, 13]. However, there are many other unexplored domains that could potentially be of benefit to the poultry sector [14]. In this study, the design and assembly of a thermoacoustic system for the detection of respiratory diseases in chicken is reported for the first time.

Materials And System Design

The disease-detection system consisted of an acoustic sensor and a temperature sensor 7101 (in a molded housing, allowing operations in damp environments and is detected automatically once connected to RJ45 port of the device) for collecting sounds and temperature of chicken in the poultry house. The sensors were connected to an Arduino microcontroller (based on ATmega 328P, for its multiple analog input pins [11, 15]), which is the development board for programming the microcontroller and processes the data before relaying it to a cloud platform through an ESP8266 Wi-Fi module (**Figure 1**). The program was coded in embedded C language in Arduino (**Additional File 1: Code S1**) and taken through various levels of simulations to ensure that it attained the required standard. The program was then uploaded onto the microcontroller. The Wi-Fi module (via an internet connection) then sends the data to a web application. The temperature and sound graphs are monitored over the web application on a liquid crystal display monitor by the system administrator who notifies the farmer in case of abnormal conditions through a Short Message Service. The logical design of the system and its schematic diagram are presented in **Additional File 2: Figure S2** and **Figure 2**, respectively.

System implementation

Implementation of the system's physical design commenced with laying the components on a copper board and soldering to create connections among them. After all the modules were integrated into a complete system, testing was done to evaluate its compliance with the specific requirements and the project objective. The sounds/vocalizations and temperatures from healthy chicken and those sick of respiratory diseases were recorded and stored. Tests were performed with both normal, sick and mixture of sick and healthy chicken for the different scenarios when the system was switched ON and OFF. Chicken with body temperature less than 37 and frequency less than 500 Hz were considered to be sick (**Additional File 2: Figure S2**); otherwise they were considered to be healthy (not sick).

Results And Discussion

The use of artificial intelligence in the detection and diagnosis of diseases in agriculture has been practiced since the start of the century [16, 17]. For chicken, the clinical signs of diseases in infected fowls may either be digestive or respiratory; the former influences the color of the droppings while the latter influences the sounds produced [14]. This study designed a system that automatically detect chicken with symptoms of respiratory diseases and relays real-time information to the farmer before the disease spreads throughout the whole poultry house. The farmer's action may involve isolating the sick chicken from the rest, treating or vaccinating the remaining healthy chicken.

The system was validated and proven to be safe and secure because it implements a complete login and registration system where all the passwords are encrypted using hash encryption algorithm (**Additional File 3**: **Figure S3**). The system uses Wi-Fi and can therefore be accessed remotely provided there is a computer or a smart phone with a web browser and internet access. The communication time between the middle hardware (circuit) and the web application (remote administrator) is in seconds. Based on the tests performed, the system was able to distinguish between sick birds (with body temperatures and frequencies less than 37 °C and 500 Hz, respectively (**Figure 3**) and healthy birds.

Previous studies have designed systems for detection of avian diseases. For example, Banakar et al. [9] utilized an intelligent device for diagnosing Newcastle disease, bronchitis virus and avian influenza using datamining methods and Dempster-Shafer evidence theory, harnessing fast Fourier Transform and Discrete Wavelet Transform for processing the chicken's sound signals in frequency and time-frequency domains with about 41.4% and 83.3% accuracy. Another study by the same team successfully implemented an intelligent procedure for the detection and classification of chickens as healthy or infected (by *Clostridium perfringens*) based on their vocalization [18]. The latest report by Mbelwa et al. [14] harnessed tools of artificial intelligence and machine learning based on computer vision and image analysis of chicken droppings for diagnosis of flocks infected by *Salmonella* and coccidiosis. Deep learning solution based on Convolution Neural Networks was used to predict where the feces belonged.

In comparison to previously designed systems for detection of poultry diseases, the current system is more user friendly, requires little technical know-how and can be used on either a mobile phone or a computer. Thus, it could be used to improve the detection of respiratory disease outbreaks in chicken which can potentially minimize losses in poultry farming. Future research should introduce or incorporate more sensors for detection of feeds and water consumption rates, humidity, ammonia and carbon dioxide levels and digestive signs of diseases based on chicken droppings.

Limitation

Whereas the assembled thermoacoustic system is real-time, its operation relies on the availability of a smart phone or a computer with an installed supported web browser, electricity and internet connection to be able to collect and relay data to the cloud and consequently the web application.

Abbreviations

LCD
Liquid Crystal Display
Wi-Fi
Wireless Fidelity

Declarations

Ethics approval and consent to participate

Not applicable

Consent to publish

Not applicable

Availability of data and materials

The datasets supporting the conclusions of this study are available from the corresponding author upon request.

Supplementary materials

Additional File 1: Code S1. Arduino code for hardware of the thermoacoustic sensor-based system for detection of respiratory diseases in chicken

Additional File 2: Figure S2. Logical flow of the thermoacoustic system for monitoring respiratory diseases in chicken.

Additional File 3: Figure S3. Log in and registration system for the designed system for detection of respiratory diseases in chicken

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Authors’ contributions

CM and GGO designed the study, CM undertook the designing, assembling and testing of the system under the guidance of GGO, TS and AEA. CM and GGO analyzed the collected data. CM, GGO & TO wrote the first draft of the manuscript. All authors revised and approved the final manuscript.

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Figures

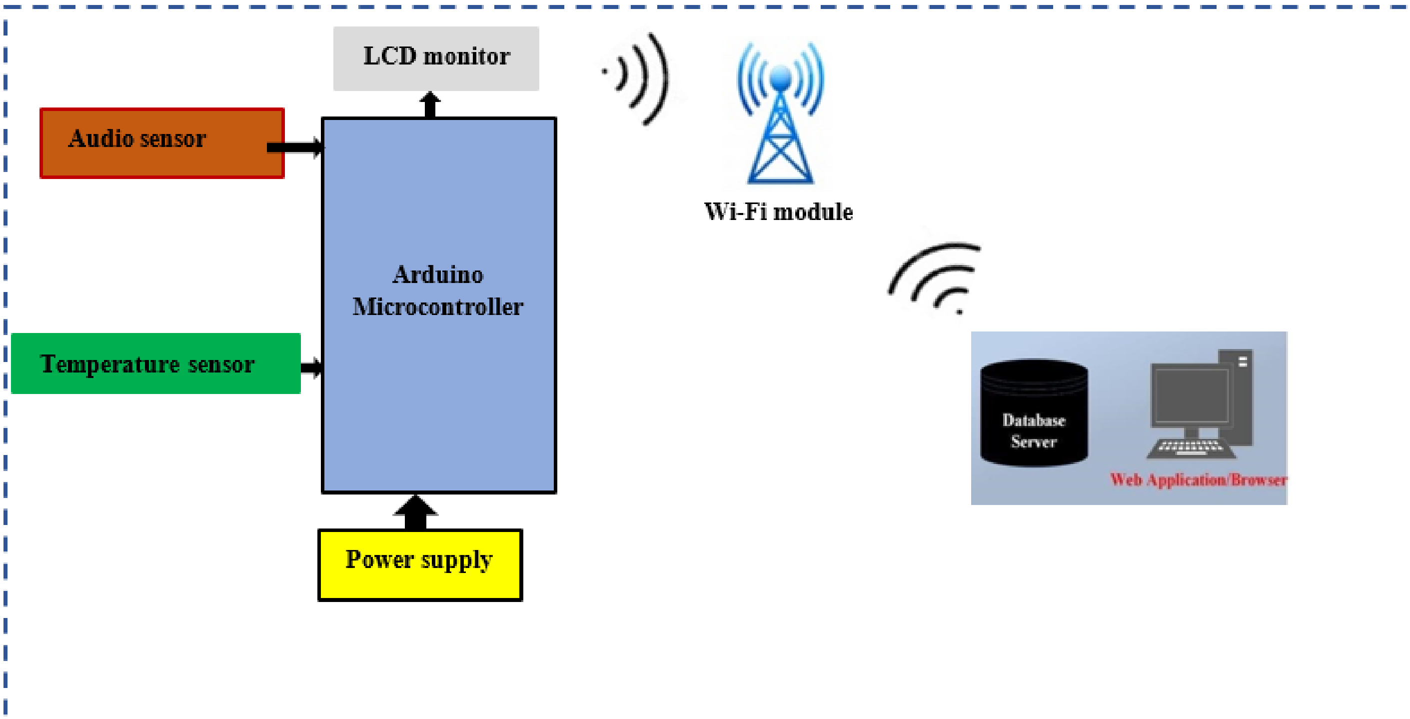
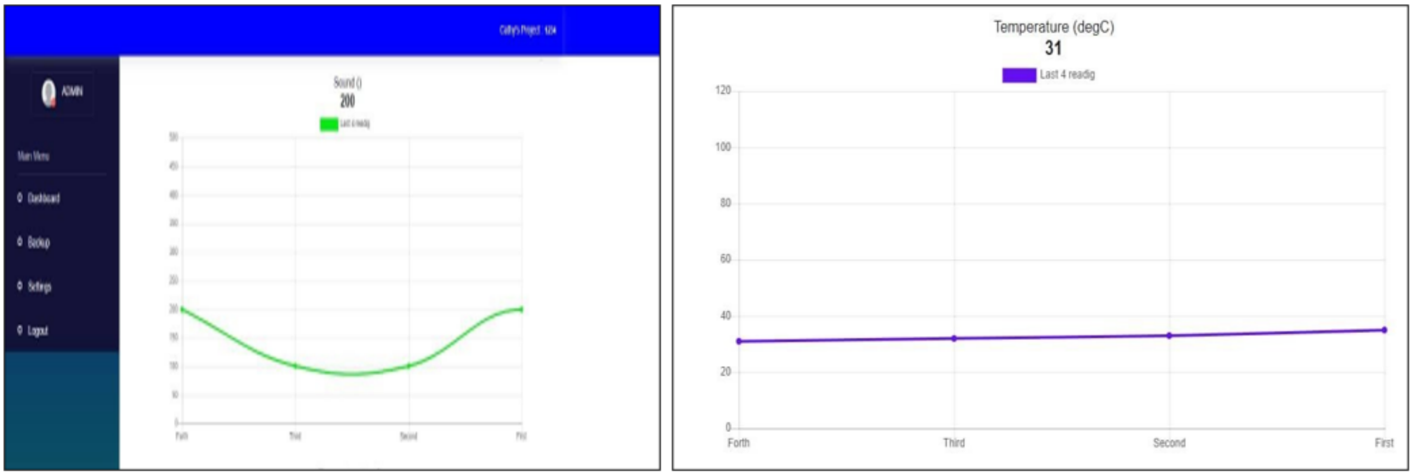


Figure 1

Block diagram of the thermoacoustic system for the detection of respiratory diseases in chicken. LCD = Liquid Crystal Display.

Figure 2

Thermoacoustic system for detection of respiratory diseases in chicken (a) schematic diagram, and (b) interior design.



(a) (b)

Figure 3

Web application showing (a) sound graph, and (b) temperature reading in four tests.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AdditionalFile1.CodeS1.Arduinocodeforhardware.docx
- AdditionalFile2.FigureS2.Logicalflow.docx
- AdditionalFile3.FigureS3.Loginand.docx