Measurement 114 (2018) 191–194

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Using dielectric properties and intelligent methods in separating of hatching eggs during incubation

Mahdi Ghaderi[a], Ahmad Banakar[a,*], Ali Akbar Masoudi[b]

[a] Department of Biosystems Engineering, Tarbiat Modares University, Tehran, Iran
[b] Department of Animal Science, Tarbiat Modares University, Tehran, Iran

A R T I C L E I N F O

Keywords:
Incubation
Fertile and unfertilized egg
Died embryo
Dielectric coefficient
Neural network
Support vector machine

A B S T R A C T

Fertility is an important trait in poultry industry so that any reduction in fertility resulted in a huge economic loss by rising incubation costs. In this study, dielectric constant and loss factor of eggs were used as a non-destructive, cheap, and precise method to identify dead embryos and infertile eggs, during incubation. For this purpose, artificial neural network (ANN) and support vector machine (SVM) classifiers were used. The result indicated that SVMs truly identified dead embryos with 100% accuracy at day 18 of incubation before hatching. In addition, SVM could also correctly identify un-hatching eggs, including dead embryos and infertile eggs with 92.31% accuracy at the 5th day. Neural network correctly classified un-hatching eggs with accuracy of 87.5% and 86.7%, respectively. Application of these two different classifiers showed that SVM yield better performance than ANN. The use of these capacitance properties not only present an automatic measurement method in detecting fertilized eggs in chicken, but also can apply in other strains of birds, which might be beneficial in birds' hatchability system.

1. Introduction

One of the challenges in poultry industry is separation of hatching eggs from infertile and dead embryos in incubation period. Detecting of unfertilized eggs at the early days of incubation could improve efficiency of incubation by reducing handling costs, rising incubator space, and energy saving. Eliminating died embryos at the end of incubation period could improve Hatcher efficiency by decreasing costs and preventing Hatcher infection from blasting infertile eggs. Because of the possibility of exploding the eggs in Hatcher and therefore infecting other incubated eggs, separating these eggs before hatching is so important, especially when the number of unfertilized eggs is high as it is reported for US poultry industry which is more than 130 million per year [1]. During candling, the live embryos in eggs are visible like a dark spot with weak visible blood vessels around it while the dead embryos in the early days of incubation period are like string or a dark spot near the egg's shell. In case of unfertile eggs, the egg is fully bright [2].

Das and Evans (1992), by using a combination of image histogram characteristics and neural networks tried to detect fertility and infertility during incubation period [3]. Lawrence et al. (2006) detected growing of the chicks in the incubator by hyper spectral imaging [1]. In a study, Kemps et al. (2010) used visible spectroscopy to assess embryonic development inside the egg between days 5 and 10 of incubation. They found a relationship between spectral data and embryo weight [4]. Smith et al. (2008) applied Hyperspectral Imaging for diagnosing fertile and infertile eggs [5]. Liu and Ngadi (2013) used K-means clustering algorithm and Near-Infrared Hyper spectral imaging to detect fertile, infertile and dead embryo egg. They categorized eggs in two groups of fertile and infertile eggs, which contained infertile and dead embryo eggs. Their method focused on the first three days of incubation period [2].

Electrical conductivity is a nondestructive test, which has been used in many studies. Castro et al. (2003) measured sugar and solid material in strawberry by electrical conductivity [6]. Icier and Ilicali (2004) measured electrical conductivity of apple concentrate and cherry juice during ohmic heating [7]. Sarang et al. (2008), also measured electrical conductivity of fruit and meat during ohmic heating process [8]. Romanoff and Frank (1941) measured dielectric and conductivity properties of the separate components of the fertile and infertile eggs. They indicated that the difference between the fertile and infertile egg in relation to conductivity and dielectric effect occurs principally in the albumen. They found that the greatest difference in relative conductivity occurred at 15 megacycles however, the percentage difference between the readings of the dielectric properties remained approximately constant over the frequency range they employed [9].

* Corresponding author at: P.O. Box: 14115-111, Tehran, Iran.
E-mail address: ah_banakar@modares.ac.ir (A. Banakar).

http://dx.doi.org/10.1016/j.measurement.2017.09.038
Received 24 November 2015; Received in revised form 13 September 2017; Accepted 21 September 2017
Available online 22 September 2017

To carry out this research, two electrical conductivity parameters were used to determine fertile eggs out of unfertilized and dead embryo eggs prior to Hatching. For this purpose, dielectric constants and loss factors of eggs were measured. The data were transferred to WEKA software to analyze by neural network and support vector machine classifiers.

2. Material and methods

In this study, Ross strain eggs and a fully automatic incubator with capability of housing 420 eggs (made by Juybar San'at, Iran) was used. Temperature and humidity of the device were settled on 37.2 C and 70% and the eggs were turn per hour. Data were taken from the numbered eggs on the 5th and 18th day of incubation. Candling showed that 21 eggs were fertile and 6 were infertile. After transferring the eggs to the hatchery, it was known that out of 21 fertile eggs, 13 embryos were died and the rest were born.

2.1. Capacitance measuring instrument

For measuring capacitance, an electrical board was developed consisted of a power supply, an AVR microcontroller, a sine-function generator (MAX038), a dielectric measurement component (AD8302), a PC interfac7e (Port COM) and a capacitive sensor. Fig. 1 shows the capacitance measurement setup. The capacitor plates were made from aluminum (50 × 60 × 1 mm). The gap between plates was selected to be 30 mm for housing an egg. The sine function generator was capable of generating 192 waves per second with frequency range of 40 kHz to 20 MHz. Waves were transmitted to the capacitive sensor and the output voltage of the sensor was sent to the AD8302 IC for determining phase difference and attenuation. The developed system was capable of measuring phase differences from 0° to 180° and attenuation levels from −30 dB to +30 dB with 10° and $30\frac{mV}{dB}$, respectively. Finally, dielectric (ε') and loss factors (ε“) were determined using Eqs. (1) and (2) [10]. These factors were transferred to PC via a serial port and were stored in an Excel spreadsheet for analysis in WEKA.

$$\varepsilon' = \left[1 + \frac{\Delta\varphi}{360d}\frac{c}{f}\right]^2 \quad (1)$$

$$\varepsilon'' = \frac{\Delta A}{8.68\pi d}\frac{c}{f}\sqrt{\varepsilon'}, \quad (2)$$

where C is the speed of light (m/s), f is the signal frequency (Hz), d indicates the thickness of material layer (m), ΔA shows attenuation (dB), and Δφ is the phase difference (degree).

2.2. Feature selection

A total number of 384 data were generated by the experimental setup including dielectric and loss factors within 40 kHz to 20 MHz of the frequency ranges. To select the best data, the Correlation-based Feature Selection (CFS) algorithm of WEKA was used [11,12]. The CFS method is based on fitting a hyper-plane or curve to learning data or enclosing them into a hyper-surface [13]. Using a heuristic search strategy, the searched algorithm for a proper correlation between 384 output voltages (192 for dielectric factors and 192 for loss factors). Therefore, 384 voltages were tagged as f1, f2, f3, …, f384 to find the best voltages as the classifier's inputs.

2.3. Intelligent classifiers

To find the features with the highest correlation with outputs, a classifier was used. The main idea of a classifier is selecting features with high correlated in their classes and poor correlation with other classes. The characteristics of a good classifier are shorter classification time, elimination of noisy data and selection of the best features [14].

2.4. Artificial neural network

ANNs are a branch of artificial intelligence with capability of machine learning technique. One of the most applied ANNs used in classification and approximation is Multilayer Perceptron (MLP). It is a

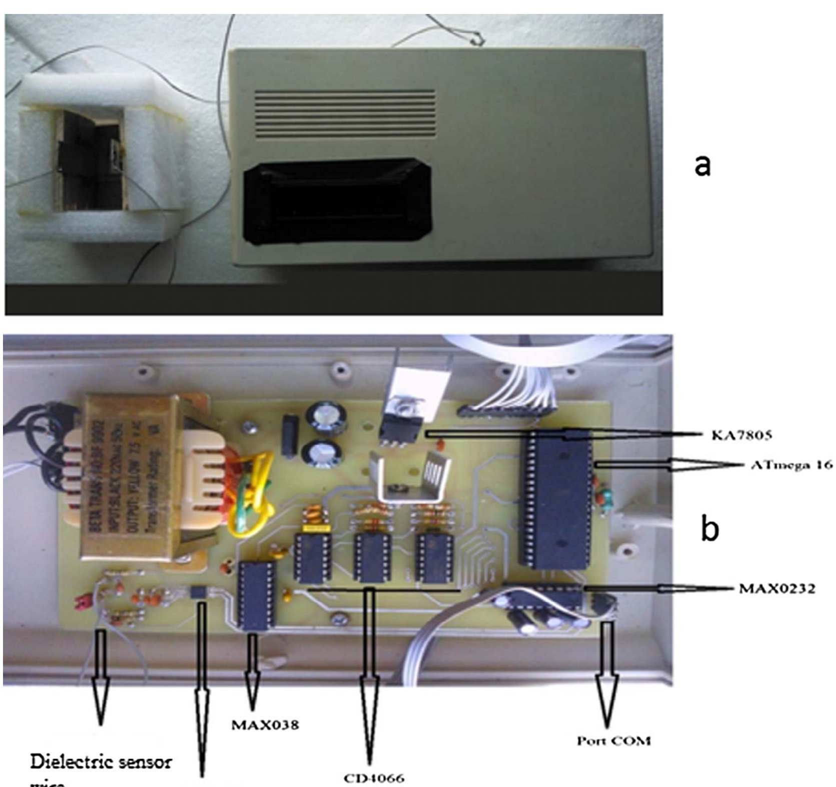

Fig. 1. Electronic system (a) and board (b) for measuring dielectric factor.