Comparison of Computer-based Methods to Detect Fertilized Eggs

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Abstract: Eggs and their derivatives are important parts of human's modern diet. The accurate detection of eggs' fertility plays a significant role in egg hatching and production efficiency. However, the traditional artificial methods have the drawbacks of being time-consuming, unsanitary, and potentially causing infections such as avian flu in eggs and employees. Furthermore, the growth of an egg embryo is quick and therefore the interior makeup of a developing egg can alter dramatically. Methods with high detection accuracy and low cost at the expense of other flaws such as the long period required for incubation before discovery has become an urgent issue to be settled. With the development of computer science, the computer-based detection methods have attracted more and more academics' and production companies' attention for their precision and efficiency. Considering that computers are versatile in processing data, there are several fields of computer-based methods. In this paper, a comparison of different computer based methods to distinguish fertilized eggs from infertile ones was given. Specifically, the efficiency of different methods was examined and compared, including the accuracy, day of incubation, time spent on incubation as well as economic cost. This paper might provide valuable references to future research and real scenarios.

1. Introduction

Eggs and their derivatives make up a large part of the modern daily diet. Data from the Food and Agriculture Organization of the United Nations [1] showed that per capita consumption of eggs in India is only 66 eggs per year, compared to 300 in neighboring China, and that the rate of egg production is increasing day by day. For egg production facilities, egg survival is very important in terms of egg hatching and production efficiency. However, studies show that current survival rates are only 80% and 70%. Studies [2] have found that fertilized eggs that have been incubated for less than five days are still edible. If sperm-free eggs can be selected early in the incubation process, they can bring considerable economic benefits in the early stages of hatching. Nowadays, most of the eggs are detected with artificial methods by experienced workers because it does not involve the use of any expensive equipment. For example, Danno et al. (1979) distinguishes eggs based on the temperature difference that exists between them at day 4 of incubation. However, the egg shell temperature difference is not significant to recognize after 96 hours of incubation. The artificial method suffers disadvantages of time-consuming, unhygienic and it may cause diseases like bird flu for eggs and workers. If infertile eggs are not taken out of the hatcher, an explosion of eggs in hatchers may occur [3, 14].

Artificial candling and computer-based methods are two major methods people use nowadays. With the development of computer sciences, more and more auto-detection methods based on computer sciences were proposed and applied. Generally speaking, computer-based methods usually involve the acoustic [5], bioelectrical [13], imaging tests [11] and other methods. Empowered by artificial intelligence [2], the computer-based method has already achieved an accuracy higher than ever before.

The development of an egg embryo happens quickly. The longer an infertile egg sits in the incubator, the more likely it is to rupture or rot. However, only a few studies assessed both the accuracy and the incubation date. Because of this knowledge gap, poultry industry decision-makers

may prioritize high accuracy and low cost over other flaws, such as the lengthy incubation period required before discovery.

Considering all the above, a literature review comparing various methods for distinguishing fertilized eggs from infertile eggs was presented in this paper. Method efficiency was investigated, including accuracy, incubation day, incubation time, and economic cost. Computer-based egg identification methods will predominate due to an increase in the quantity and quality of databases. The rest part of this paper was organized as follows: in Section 2, the basis conception and different computer-based methods were analyzed, the advantages and drawbacks of each method were analyzed in Section 3, advises and future consideration were given at last.

2. Computer Based Methods to Detect Egg fertility

Computer based methods have the advantage of being effective as well as accurate. Generally, computers distinguish live and fertile eggs based on the difference in temperature, size and shape, acoustic and electric property, as well as the candling image. Eggs are only distinguishable after a given period of time of incubation. The time required varies from species to species and the time required ranges between 5 days and 6.5 days and 5 days. There are various reasons for it. First, the similarity of morphological development in the chicken, duck, and goose only exists in the early stages of embryogenesis. There's been research on comparison of stages of embryonic development among aquatic bird species and they divided the process into 46 stages [4]. The result showed that major differences only occur after stage 27 when contour of digital plate appears trend in region of first digit. For ducks, gooses and chicks, the time required to reach stage 27 is 6.5 days, 7.5 days and 5 days. Second, research proposed [5] that resonance frequency (RF) value of viable chick eggs decreases after 96-104 hours (4.00-4.33 days) of incubation after stage 24 and before stage 25. At this time, chick wings and leg buds are longer than wide. The W-shaped outline of the maxillary process is clearer than at stage 23. Third, according to [6], eggs are still edible after up to a month of incubation but it tastes fresher only before the fifth day of incubation.

2.1 Bioelectrical Methods

One method of identifying infertile eggs involves the use of bioelectricity. Shen et. al studied the relationship between the bioelectricity of chick egg and its fertilized condition. They introduced a non-destructive test facility to detect the electric signal in chick eggs. In the sample eggs [13], the electrical signal of infertile eggs disappears if the egg dies.

2.2 Spectral Methods

Robert M. A. N. [14] et. al designed an electrooptical measuring device to detect blood spots in intact eggs based on the difference in spectral transmittance. Since eggs with blood vessels show strong characteristic hemoglobin absorption for λ=539 and λ=577nm. An experiment conducted by Bart J. Kemps [15] proved that a very accurate prediction of embryotic development is possible based on VIS/NIE transmission measurements. The detection focuses on the displacement of carotenoids from the yolk into the blood circulation. Eva Verhoelst et. al developed a method measuring the angiogenesis in the chorioallantois membrane. In the experiment, a spatially resolved spectroscopy set-up was elaborated. The result shows that the blood values calculated from the signal of the fiber closest to the source and the power of a simple exponential model is significantly correlated with the incubation age of the eggs. Md. Hamidul [18] Islam et.al uses the visible transmission spectroscopy for the prediction of chick hatching time. They measured the transmission spectra and recorded the following incubation time. A PLS regression system shows the results for the prediction of chick hatching time for different pre-processing techniques on the fourth day of incubation. An experimental setup was also used for the measurement of transmission spectra. The experimental result indicates that visible transmission spectra and multi variable is effective for predicting the birds' eggs incubation. Furthermore, the prediction of individual egg incubation time allows the manager to control the hatch window and make the industry more profitable.

2.3 Acoustic Methods

Another method of measuring egg embryo development involves acoustic resonance frequency (RF) analysis. After 96-104 hours of incubation, the RF of viable eggs decreases dramatically. By contrast, infertile eggs and dead eggs have a relative constant value of RF. This method only works on eggs after 5 days of incubation. Moreover, if eggs are stored in a cold environment, the incubation will delay after 24h or 84h. It is easy to reach a conclusion that the decrease of RF is a strong indicator of development. In human history, Coucke [5] was the first scientist that developed RF. In the following years, some studies [16] have succeeded in monitoring the course of vibration parameters and finding the relationship between these changes and embryotic characteristics.

2.4 Artificial Intelligence based Methods

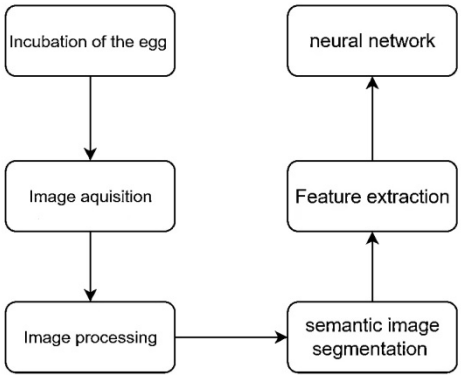

Figure 1. Neural network structure

Differentiating viable eggs relies on the differences between fertilized eggs and non-fertilized ones. A live embryo appears as a black spot on the larger end of the egg surrounded by faint blood vessels, while a dead embryo sometimes appears as a ring or blood stain on the egg, or a black spot dried to the inside of the cell [7]. Moreover, the size of the blastodisc seen during visual candling and the rate of development at some early stage of incubation are also used as parameters for predicting the viability of the embryo. [8]

There are various attempts to sort eggs with computer vision. Das and Evans [8] developed a machine vision system to detect fertile eggs based on histogram shape differences. According to their observation, fertile eggs with developing embryos have a much larger pixel number at the lower gray levels while the infertile egg histograms had a more uniform frequency distribution because light passed more uniformly through an infertile egg. The program was run on a SunSPARCstation. However, the result of this experiment is poorer than some of the preliminary testing due to the intentionally introduced variability in the testing set by using eggs from different flocks of different ages. Zhang et.al designed a computer vision system [2]. In this system, four major features include the area features of egg yolk and egg white, the brightness of yolk and egg white. In order to eliminate the difference in fundamental unit of measurement of area and brightness, data is de-unitized and normalized with an output of two characteristic values. The normalized grey-scale feature vectors are then used as inputs to the BP neural network. The designed neural network consists of an input layer, an implicit layer and an output layer. Sigmoid-type function was used for the implied layer neuron transfer function. Xu et.al [11] identified the dead or low activity egg for vaccine production by using a novel method based on the smallest univalve segment assimilating nucleus. In order to acquire the binary image including major blood vessels, a multi-layer feature extraction method was then used to acquire the binary image including main blood vessels. Finally, the percentage of blood vessel area occupied in ROI image is evaluated. In another experiment [12], Geng et.al proposed a method combining transfer learning strategy with convolutional neural network (CNN). The dataset is first trained with a model which is based on AlexNet network. After that, the dataset is directly trained on a multi-layer network which contains six convolutional layers and four pooling layers. The final accuracy approached 99.5%. Two years later, Geng et.al designed

[9] a novel method combining a convolution neural network (CNN) and a heartbeat signals of hatching eggs after 9 days of hatching by the method of Photo Plethysmo Graphy (PPG). In this experiment, heartbeat sequence is analyzed by E-CNN while SR-CNN is used to process heartbeat waveform images of hatching eggs.

Table.1. Comparison of Different Computer-based Fertilized Eggs

Method	**Advantage**	**Disadvantage**	**Age of eggs (days)**	**Accuracy**
BP Automatic identification [2]	1) suits embryo development 2) elimination of the interference of individual differences and environment	1) low accuracy for the first two days of incubation	1-5	85.57% 97.14% 98.57% 98.57%
Thermal imaging system [3]	High accuracy	Too complex	Mixed	96%
Acoustic resonance analysis [5]	First prove a possibility for automation of the measuring technique	Accuracy is still unknown	5	/
Near-Infrared hyperspectral imaging [7, 13]	Best unsupervised classification result after day 0	Relatively low accuracy after day 0	1-5	100% 78.8% 74.1% 81.8% 84.1%
Machine Vision [7]	A trend towards consistently lower misclassification of fertilized eggs	Low accuracy on the first two days of incubation	2-4	93.9% 93.5% 67.6%
Combined method [9, 10]	High accuracy	1) Expensive and hard to use 2) Too long time after incubation	4-9	99.50% (E-CNN) 99.62% (SR-CNN)
Machine vision system based on the smallest univalve segment assimilation nucleus [11]	High classification accuracy	Ineffective when the area of speckle is greater than the mask	9-11	97.78%
Deep learning based on TB-CNN [12]	1) High accuracy 2) Multi-classification (the ability of detecting dead eggs)	Dependence on large-scale data	5	99.5%
Bioelectricity methods [13]	1) Cheaper and less technology-demanded 2) High accuracy at early stages of incubation	Objective	2	91.7%
Electrooptical blood-spot detection [14]	Less dependent on a stable light source	1) Reduction of signal output 2) expensive	/	/
Visible transmission spectroscopy [18, 22]	1) fast 2) nondestructive and noncontact 3) reasonable price		0-8	r=0.873

2.5 Thermal Imaging Method

Work done by Danno et. al (1979) [10] represents early attempts on using thermal imaging methods to differentiate fertilized eggs from non-fertilized ones. Two of the separated experiments estimated the possibility of detecting embryonic development in eggs using the same spectrophotometric method which is a combination of two wavelength (577 and 610 nm) spectra. However, this methodology is not effective because the difference in temperature is not detectable at that time. Research conducted by L. Liu & M. O. Ngadi [7] proposed a near-infrared hyperspectral imaging system in order to detect fertility and early embryo development. Eggs are observed in a dark room with candling. The region of interest (ROI) of each image was segmented and image texture information was processed using Gabor filters. This approach has a 100% classification rate on the first day of its identification. Chern-Sheng Lin [3] proposed a thermal imaging system filtering and identifying the fertilized eggs by checking the temperature of the target from the infrared image. With the help of a sober operator, the outline of eggs is found out. The accuracy of the system approaches 96%.

3. Discussion

The detection of embryo maturity is of great importance for industrial production. The speed of earlier embryological development is correlated to the growth of poultry embryo and time of incubation [17]. The evaluation of early embryo development according to the chemical or structural traits of the eggs including the thickness of egg shells, the color of yolk and the variation of eggs traits is necessary for economic growth. Among the current methods of embryo maturity testing, the traditional methods are based on experienced workers, and this method has a lot of shortcomings. The computer-based methods have the advantages of high efficiency, speed and accuracy. As a result, computer-based methods have become more and more popular. Due to its significance and importance, this paper provided a summary analysis based on this way of computer. This review hopes to provide a reference for a more accurate and faster detection method in the future. This part includes a discussion of the work done by previous researchers.

From the analysis, it can be seen that: 1) the research of computer-based methods used in fertilized eggs detection still remains limited, more robust methods with high accuracy and low cost should be developed 2) considering the real application scenarios, the combination of these detection methods should be combined with precision instruments and be put into the actual production line.

4. Conclusion

This paper provides a summary and review of the modern techniques used for fertilized egg detection. Based on the context above, it is obvious that egg identification techniques have evolved from primitive to sophisticated. Many hybrid methods have been introduced in the last 3 years, and these hybrid methods have achieved the highest accuracy rates. Among the early egg identification methods, there were not many experiments related to acoustic sound methods. However, with the development of artificial intelligence, especially the introduction of deep learning and neural networks, the combination of acoustics and artificial intelligence may be a future development direction.

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