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An intelligent device for diagnosing avian diseases: Newcastle, infectious bronchitis, avian influenza

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ABSTRACT

In commercial poultry production there are a number of diseases which are of particular importance due to the heavy economic losses that can arise if a flock becomes infected. The development of an automated and rapid disease detection system would therefore be of considerable benefit to both production and animal welfare. This study represents an intelligence device for diagnosing avian diseases by using Data-mining methods and Dempster-Shafer evidence theory (D-S). 14-day-old chickens were divided into four groups. Each group was deliberately infected with a disease: Newcastle Disease (ND), Bronchitis Virus (BV), Avian Influenenza (AI), and the last group was considered as control samples. Fast Fourier Transform (FFT) and Discrete Wavelet Transform (DWT) were used to process the chicken's sound signals in frequency and time-frequency domains, respectively. In order to achieve information, 25 statistical features from frequency domains, and 75 statistical features from time-frequency domains were extracted. During dimensionality reduction stage, the best features of the sound signals were selected, using improved distance evaluation (IDE) method. The chicken's sound signals were analyzed in two consecutive days after virus infection. Support vector machine (SVM) was used as the classifier in this study. The first classification was done with SVM and based on sound features in frequency and time-frequency domains with accuracy of 41.35 and 83.33%, respectively. The accuracy of the method based on D-S infusion of sound data reached 91.15%. The developed model based on achievement result could diagnose Newcastle Disease, Bronchitis Virus and Avian Influenza from sound signals.

1. Introduction

Newcastle Disease (ND) is a contagious bird disease, which is prevalent in both domestic and wild species and was first diagnosed in Newcastle, England, in 1926 (Morgan, 1946). It is characterized by respiratory and nervous signs, bleeding lesions in the digestive system and mild infections in the respiratory system. Newcastle Disease is a single-stranded RNA virus that threatens poultry health and causes great economic losses (Nidzworski et al., 2013). Newcastle Disease causes a very fatal disease in chickens classified under a single avian paramyxo virus serotype 1 (APMV-1). NDV shows a spectrum of virulence, with strains in NDV, causing infection (lentogenic strains). It shows moderate virulence (mesogenic strains), and exhibits very high virulence (velogenic strains), and the velogenic strains cause 100% mortality (Alexander, 2001; Capua and Alexander, 2009).

Bronchitis Virus (BV) is the type of species of the genus *coronavirus* of the family *coronaviridae*. It is an acute and highly contagious viral disease causing severe economic losses for those involved in the chicken industry (Cook and Mockett, 1995; Malik et al., 2004). BV was first reported in the United States as a new respiratory disease for baby chicks in 1931 (Schalk and Hawn, 1931). Confirmation of a diagnosis of infectious bronchitis relies on laboratory findings involving serology (Ganapathy, 2009). BV is a hard to diagnosed and this disease may be mistaken for other diseases such as avian influenza, and avian Newcastle Disease (Ganapathy, 2009).

Avian Influenza (AI) is also one the contagious avian respiratory disease. AI is caused by a type an orthomyxovirus. The influenza virus has two major surface glycoproteins-hemagglutinin (HA) and neuraminidase (NA), and 16 HA and 9 NA subtypes are recognized (Abdoshah et al., 2012). Many species of birds, domesticated or wild, can be infected with the virus (Stallknecht and Shane, 1988). Clinical signs; are swelling of the periorbital tissues and sinuses, nasal and ocular discharge, and respiratory distress (Nili and Asasi, 2002). AI has also caused disease in human (Lin et al.,

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2000; Naeem et al., 1999; Peiris et al., 1999), subtypes such as H5N1, H7N7, and H9N2 have also infected the human life (Guo et al., 1999; Haryanto et al., 2013).

Although the clinical signs such as diarrhea and nasal discharge are variable and influenced by other factors, none can be regarded as pathognomonic. Also, avian Paramyxo virus infections have usually been diagnosed by serology virus isolation (Alexander, 2000). Additionally, diarrhea, nasal discharge and other complications are symptoms not only of Newcastle Disease but may be mistaken for other diseases such as Avian Influenza or fowl cholera. (Hinrichs et al., 2006). ND, BV and AI cannot only be diagnosed by clinical signs with certainty, and their rapid diagnosis is essential for reducing losses and preventing their spread (Rahimian et al., 2011).

There are some certain diagnostic ways available for detecting Newcastle Disease, Bronchitis Virus and Avian Influenza. Several tests are available to detect these diseases, including RT-PCR, real-time RT-PCR, ELISA tests (Corman et al., 2013; Haryanto et al., 2013, 2015; Nidzworski et al., 2013). The viral genome amplification using RT-PCR method for diagnosing poultry diseases is common. RT-PCR can detect only a single virus at a time and the multiplex RT-PCR technique was developed to detect more than one virus.

Although rapid detection of viral diseases is an important aspect of the economics of poultry production, current methods such as ELISA are time consuming (Kataria et al., 1998) and other methods need expert personnel and expensive equipment to confirm the presence of the pathogen (Soltan et al., 2016). As a result, by applying an automatic device with an alarm for key avian diseases, farmers could be given the opportunity to undertake the necessary actions in order to prevent the disease occurring.

There are several studies in the literature where artificial intelligence has been applied in animals. Acevedo et al. (2009) designed an automated system to detect and classify calls of nine frogs and three bird species (Acevedo et al., 2009). Gutierrez et al. (2010) classified porcine wasting diseases of pigs using sound analysis and labeling method. Pig's cough were recorded by microphone and the sound's feature like intensity, duration and pitch were extracted. They could detect and classify circovirus type 2 (PVC2), porcine reproductive, respiratory syndrome (PRRS) virus, and Mycoplasma hyopneumoniae (MH) diseases using sound's pitch-and-intensity analysis. Furthermore, cough duration was excluded because it couldn't find statistical difference between treatments (Gutierrez et al., 2010). Kasten et al. (2010) classified the bird species based on bird sound. Different feature functions of the signals were extracted to classify the bird sounds. They found that bird gender and species can be identified based on their sounds (Kasten et al., 2010). Lee et al. (2015) detected pig-wasting disease by using support vector machine (SVM) and acoustic features. In their research, 60 statistical parameters were extracted as signal indexes and the best features (RMS, Max Pitch, PSD, Peak frequency) were selected by using acoustic feature subset selection algorithm (AFSSA) method, which were used as inputs of the classifier (Lee et al., 2015). Since it is possible to detect sound signal features, different types of analyses can be performed. Analysis of chicken's vocalization is a powerful tool to study about animal behavior and welfare (Exadaktylos et al., 2014). Numerous factors such as diseases, weakness and species can change bird-generated sound signals. Sadeghi et al. (2015) designed an intelligent procedure for detecting chickens infected by Clostridium perfringens based on their vocalization. Chicken's vocalization was analyzed in time domain, and 25 statistical features were extracted from sound signals and the best features were selected using FDA method to be ANN's input data (Sadeghi et al., 2015).

Although these studies have concentrated on sound analysis of animals, no specific sound processing for different diseases detection were investigated in chickens. Therefore, the main aim of this study was to develop an artificial intelligence methodology based on signal processing to diagnose Newcastle Disease, Bronchitis Virus and Avian Influenza for rapid, efficient and simultaneous amplification. The Dempster-Shafer evidence theory (D-S) was used for decision fusion of sensors and the outputs of the SVM were considered as the inputs of D-S.

2. Materials and methods

The study experiments were carried out in the Agricultural School of Tarbiat Modares University, Tehran, on a brood of chickens. The strain name of NDV was $IR/IRK_1/2013$, and its molecular-and-pathological characterization was carried out in RAZI institute, Karaj, Iran. Virulence type of the NDV in this study was velogenic strains and NDV tropism was viscerotropism, which mainly affects the respiratory system. The Avian Influenza virus in this study was H9N2. Fourteen-day old Ross 308 chickens were divided into four groups of 60 and each group was kept in a separate room. The first group was considered as control samples. The second, third and fourth group were infected by using Newcastle Disease, Bronchitis Virus and Avian Influenza, respectively by eye drops (0.1 cc for each eye). Fig. 1 shows the chickens and virus infection.

ND, BV and AI infection were verified using the RT-PCR test and virus isolation from infected tissues simultaneous with clinical signs. In this paper, RT-PCR was done using protocol 2 which has been described by Capua and Alexander for Avian Influenza and Newcastle Disease (Capua and Alexander, 2009).

The first five minutes of recordings were not taken into account during the sound analysis because the behavior of the chickens might have been effected by the operator during the holding them inside of 50 cm^3 cubes. In order to obtain sound features of chickens and detecting disease without any surrounding noises all samples (chickens) put in the box. (Microphone specifications: 9.7×6.7 mm diameter, less than 2.2 kΩ impedance, 100–16 kHz frequency, and -58 dB ± 3 dB sensitivity). Recordings were saved in the "wav" format and signals in time domain were transformed into the frequency and time-frequency domains and analyzed in Matlab® 2015a (the Mathworks Inc., Natick, MA, USA). A total number of 720 sound signals were collected from 240 samples in two consecutive days after virus infection.

Fig. 2 represents the proposed algorithm for diagnosing the avian Newcastle Disease, Bronchitis Virus and Avian Influenza based on their sound signals. Based on Fig. 2, the chicken's sound signals are firstly transferred to frequency and time-frequency domain using Fast Fourier Transform and Discrete Wavelet Transform. The next stage is Data-Mining part, which is consists of feature extraction and feature selection. After Data-mining stage, the SVM classifier will be trained and evaluated in diagnosing the diseases. The outputs of SVM based on frequency and time-frequency signals were considered as evidences of the Dempster-Shafer evidence theory, and finally the disease will be detected by the model.

2.1. Signal processing

The first advantage of signal processing is to obtain useful and necessary information out of a signal that normally is not available in the unprocessed signal. Other advantages of signal processing are removing and reducing noise effects, accessing the signal's hidden contents, extracting frequency and time-frequency information, and producing a better signal for effective Data-mining (Wang et al., 2010; Zhan and Makis, 2006). There are many techniques for signal processing i.e. Wavelet analysis, Fast Fourier Transform (FFT), Short Time Fourier Transform (STFT).