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AN OVERVIEW OF ANIMAL BEHAVIORAL ADAPTIVE FRIGHTENING SYSTEM

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Abstract: **Animal for a long time has been categorized either as wild or domestic. The wild animals are confined to zoo most of the time in civilized countries when captured while some uncivilized countries substitute the captured wild animals for meat. To some extent the wild animals do not intrude the restricted areas. By instinct, they maintain their territories. But the domesticated animals play the reverse as they are let loose under the free-range system where they are allowed to go from one place to another without control, and these animals, sooner or later become habituated to most of the frightening devices, techniques, and methods put in place to scare them because of inadaptability of the frightening devices to the behavioral changes exhibited by the animals. This has been a great challenge to animal detection and recognition system developmental efforts. Having studied previous works on animal behavior and frightening system, it is the objective of this paper to present an overview of adaptive frightening system as reliable frightening method to the behavioral changes exhibited by animal, having motivated by the limitations of the past efforts and opportunity to improve on the existing frightening methods. It was discovered that most works are left as future work due to the fact that adaptive frightening device is species specific making it difficult for the adaptive frightening device to adapt to the behavioral changes exhibited by the unspecified species as it is not easy to design one-fit-all animal behavioral adaptive frightening system.**

Keywords: **Animal; Frightening device; Detection; Recognition; System; Adaptive; Species; Behavioral.**

I. INTRODUCTION

A very few investigation has been done till date on animal sounds which is a part of environmental sounds [1]. These environmental sounds are varieties of creature's sounds including human sound. Many animals produce sounds either for communication or as a by-product of their living activities such as eating, moving, or flying, etc [2]. Researchers for a long time have been facing difficulty of acquiring high quality acoustic data such as alarms and distress calls in adverse environments, and inadequate knowledge about how animals produce and perceive sound. This is also a challenge to behavioral recognition and frightening devices. By having the recognition system, the security of some areas can be improved [3], [4]. But to get the security of these areas improved, the behavioral changes of the target species should be adapted to by the detection and recognition systems. In a frightening scenario, the intended result is flight, based on fear. Therefore, an adaptive system needs to be able to monitor change in behavior, based on the ability to recognize behavior, and react accordingly. Methods used within animal behavior research include attached tracking devices like GPS [5] or other wireless transmitters in a wireless sensor network [6], or accelerometers, measuring the movement of specific parts of the animal body [7]. Acoustic information has also been used in chewing behavior recognition of cows [8]; however, these methods also rely on attaching a device on the animals. These methods are not suitable when the purpose of the animal behavior recognition, is to utilize the results in a free-range system as it is not possible to attach these devices on the animals. Therefore, non-invasive sensors, like cameras, are a necessity in this context. In [9], acoustic measurements, within an array, are utilized to recognize vocalizations for source identification and localization, and thereby recognize bird behavior. However, their study is focused on individuals. Having studied previous works on animal behavior and frightening system, it is the objective of this paper to present an overview of adaptive frightening device as reliable frightening method to the behavioral changes exhibited by animal, having motivated by the limitations of the past efforts and opportunity to improve on the existing frightening methods. It was discovered that most works are left as future work due to the fact that adaptive frightening device is species specific making it difficult for the adaptive frightening device to adapt to the behavioral changes exhibited by the unspecified species as it is not easy to design one-fit-all animal behavioral adaptive frightening system.

II. LITERATURE REVIEW

In [10], wildlife damage management involves the timely use of a variety of cost efficient control methods to reduce wildlife damages to tolerable levels. Frightening devices are an important tool used in wildlife damage management to reduce the impacts of animals [11], and the goal of using frightening devices is to prevent or reduce the damage of animals and damage caused by animals by reducing their desire to enter or stay in an area [12, 13]. Visual and acoustic stimuli are among the frequently used methods in the effort to reduce wildlife damage caused by birds such as geese, rooks, gulls, blackbird and starlings [11]. Systems include gas exploders, mylar ribbon, moving and reflective objects, firecrackers, models of predators, ultrasonic devices and distress/alarm calls [12]. The effectiveness of these devices ranges from a few days to a few weeks, at best. In [11], a combination of stimuli is recommended to increase the effectiveness. Also, the timing of activation of frightening devices is often a critical factor, and random or animal-activated devices may reduce habituation [12, 13]. Here radar, or motion sensors can be utilized [14], however, these methods are not very cost-efficient and non-specific. A type of acoustic stimuli that are promising for future frightening devices is bioacoustics [11]. Bioacoustics is animal communication signal, and this communication includes alarm or distress calls. Alarm calls are vocalizations used to warn other animals of danger. An example is the loud calling of a disturbed Canada goose [15]. The communication signals are usually species specific [16]. Frightening devices using bioacoustics-based stimuli have been used in various research applications. In [15], the authors used bioacoustics for management of Canada geese, and found that the geese moved up to a 100 meters away from the device but never left the area. In [17] they reported a reduction of 71% in goose numbers when using bioacoustics. In [18], the author compared the use of species-specific distress calls to using suspended crow carcasses for wildlife damage management. It is concluded that the use of distress calls proved to be very effective, whereas the carcasses had no effect. In [19], the authors also concluded that treatment with tape-recorded distress calls were able to scare crows away from their roosts. There exist a few commercial systems, which utilize bioacoustics. The Goose-Buster is specifically designed for Canada geese. The system is based on alarm, alert and distress calls which are played back from multiple speakers. The calls are altered in sequence of play, frequency, duration and interval, thus providing variability in the frightening stimuli. In [20], the effect of the system is studied in three controlled experiments. The author concludes that the use of timed alarm and distress calls alone experience habituation, however, ”on-demand” playback and reinforcement (using screamers and bangers) proved to be efficient to avoid habituation. Another, more diverse system is the Scarecrow Premier 1500, together with the Ultima. This system is based on manual operations and is specifically designed for airports. The system uses a roof mounted loud speaker system, together with an arsenal of alarm and distress calls, which can be played back if the operator sees the birds. The Ultima includes a visual description of the birds of interest, which makes it easy for an operator to recognize the birds. This system is not suitable for agricultural production; however, it has proven efficient in airports, where cost-efficiency is surpassed by flight security. The LRAD system also utilize bioacoustics to protect airports/runways, wind turbines and agricultural activities. The system is based on a directional system, which can playback predator sounds at great distance. The activation of the system is either based on manual operation or radar technology. This makes the system too expensive in most cases of agricultural production. Habituation to bioacoustics has been reported in [15, 11, 21]. In [21], the authors argue that this may be a result of the fact that the geese, used in the experiment, were not able to escape the enclosed study site. In [16], the authors conclude that alarm and distress calls are more resistant to habituation than other sounds, but a pest controller needs to be able to identify species, as most calls are species-specific. Vocalization of farm animals as a measure of welfare, and Measuring pig welfare by automatic monitoring of stress calls, was presented in [22] and [23]. These papers were motivated by the need to measure the welfare of animals, and they based their objectives on the need to automate how stress calls could be monitored and how farm animals could be vocalized as a measure of welfare. This was achieved by (1) the expert knowledge of the relationship between a specific vocalization and the emotional or health state of an animal. (2) the descriptive features of the vocalizations, and (3) the statistical methods to compare these features. Although in most cases, the processing steps according to the authors, involved some degree of pattern recognition, and human speech recognition methods and have incorporated both feature extraction and pattern recognition methods from this [24, 25]. A wide variety of acoustic features were used to describe the vocalizations of animals; this included time domain features, such as energy and duration, frequency domain features, such as fundamental frequency, harmonics and bandwidth, cepstral features, known from human speech recognition and coding models, such as linear predictive coding. The results showed that visual measurements like acoustic measurements, offered a non-invasive method to monitor livestock; or crops. Given the appropriate camera technology it is possible to record and recognize the behavior and health status of livestock or even distinguish between plant and weed during weed control.

Evaluation of a deer-activated bio-acoustics frightening device for reducing deer damage in cornfields was presented in [26]. This paper was motivated by the need to reduce the damage caused by deer in cornfields. This was aimed at evaluating ungulate-activated bio-acoustics frightening device using frightening devices. The system was based on alarm, alert and distress calls which were played back from multiple speakers. The calls were altered in sequence of play, frequency, duration and interval, thus providing variability in the frightening stimuli. The device was not effective in reducing damage: track-count indices (F1, 4=0.02, P=0.892), corn yield (F1, 9=1.27, P=0.289), and estimated damage levels (F1, 10=0.87, P=0.374) did not differ between experimental and control fields. The size (F2, 26=1.00, P=0.380), location (F2, 25=0.39, P=0.684), and percent overlap (F2, 25=0.20, P=0.818) of use-areas of radio-marked female deer did not differ between during-and after-treatment periods. In [11], the use of frightening devices in wildlife damage management was also presented. This paper was motivated by the need to device a type of stimuli that can serve as a frightening device in wildlife management. The objective was to develop bioacoustics device that can handle habituation. To carry out the objective in this paper, animal activated methods were used, and the methods used to delay habituation included changing the location devices and altering the periodicity of stimuli or the use of a combination of devices. Notable limitations with these methods were the time consumption, which was undesirable in an efficient agricultural production, and gas exploders, which also disturbed nearby residents due to high noise levels. In most cases, these frightening devices are non-specific, making it possible for any animal to activate them, and not only by the target species. This increases the risk of habituation. However, a type of stimuli that are promising for future frightening devices is bioacoustics [11]. Bioacoustics refers to animal communication signals, which includes calls like alarm and distress calls. Other studies utilizing acoustics measurements include recognition of dolphin behavior [27], measuring pig and chicken welfare [28, 22], and real-time stress monitoring of piglets [29]. This research showed that it is possible to recognize behavior based on acoustics measurements, whether it being recognition of adaptive frightening device specific calls or the soundscape of multiple animals. A more frequently used non-invasive technique for behavior recognition is video recordings. In video recordings, digital image processing techniques and tracking algorithms can be utilized to detect and recognize specific movements, which are linked to certain behaviors. Compared to acoustics measurements, the range of visual information may be lower. However, the link between visual information, like movement or posture, and behavior is more straightforward. A popular application in automated video based behavior recognition is laboratory experiments, where changes in mouse or fish behavior are important for medical research or behavioral research [30, 31]. More domain related applications include monitoring of livestock behavior, including pigs [32, 33], chickens [28] and cows [34]. These applications are either focused on controlled experiments or indoor applications, which is not the case with wildlife in an agricultural setting.

III. ADAPTIVE, DETECTION AND RECOGNITION SYSTEMS

For any device put in place to detect and recognize the target species, such device must be able to adapt to the behavioral changes displayed by the species as device designed for unspecified species can be easily manipulated by any animal. An adaptive system is a set of interacting or interdependent entities, real or abstract, forming an integrated whole that together are able to respond to environmental changes or changes in the interacting parts, in a way analogous to either continuous physiological homeostasis or evolutionary adaptation in biology. Feedback loops represent a key feature of adaptive systems, such as ecosystems and individual organisms. Every adaptive system converges to a state in which all kind of stimulation ceases [35].

Given a system S, we say that a physical event E is a stimulus for the system S if and only if the probability

$P(S \rightarrow S'|E)$ that the system suffers a change or be perturbed (in its elements or in its processes) when the event E occurs is strictly greater than the prior probability that S suffers a change independently of E:

$$P(S \rightarrow S'|E) > P(S \rightarrow S') \quad (3.1)$$

Let S be an arbitrary system subject to changes in time t and let E be an arbitrary event that is a stimulus for the system E: we say that S is an adaptive system if and only if when t tends to infinity $t \rightarrow \infty$ the probability that the system

S change its behavior ($S \rightarrow S'$) in a time step t_0 given the event *E* is equal to the probability that the system change its behavior independently of the occurrence of the event *E* In mathematical terms:

$$-P_{t0}(S \rightarrow S'|E) > P_{t0}(S \rightarrow S') > 0 \qquad (3.2)$$

$$-\lim_{t\rightarrow\infty} P_t\,(S \rightarrow S'|E) = P_t(S \rightarrow S') \qquad (3.3)$$

Thus, for each instant *t* will exist a temporal interval *h* such that:

$$P_{t+h}(S \rightarrow S'|E) - P_{t+h}(S \rightarrow S') < P_t(S \rightarrow S'|E) - P_t(S \rightarrow S') \qquad (3.4)$$

From the above equations, it is seen that an adaptive system must be able to alter the periodicity of stimuli and make it possible to utilize a combination of stimuli. When frightening stimuli is based on bioacoustics for example, the system should be able to detect and recognize specific species. Thereby, the stimuli can be targeted towards these species most effectively. Furthermore, the device should enable reinforcement, if needed. A framework for these characteristics is shown in Fig. 3.1. The framework is based on perception and action, which is the fundamental design of an intelligent agent [36]. In this design, a model is used to interpret incoming signals, and act accordingly. The model can be a simple or a more sophisticated model, which perceives the world in a statistical manner, and base decisions on learning algorithms, such as pattern recognition algorithms. The framework enables detection and recognition of species, which promotes timely use of bioacoustics, or other, stimuli. Furthermore, behavior recognition could monitor subsequent changes in behavior when frightening stimuli has been applied. This will make it possible to act accordingly, if reinforcement is needed. This framework, based on the design of an intelligent agent [36], features the components of an adaptive frightening device. The identified components of the framework are: detection based on 1st classifier, region of interest/preprocessing, recognition based on 2nd classifier and action. This framework takes two stages: detection accuracy and recognition speed. This is to enable the detection accuracy rate set as a critical goal in order to decrease the false positive rate (false alarm); the reliability of the system will be enhanced as well. To achieve the aforementioned criteria, a double-stage system is suggested. As shown in Fig. 3.1, in the first stage, a fast detection algorithm was applied which supplies the second stage with a set of regions of interest (ROIs) containing real animals and probably other similar objects (false positive targets). To fulfill the system requirements, the detection step of the first stage should be simple and fast because it is applied to the entire input frame.

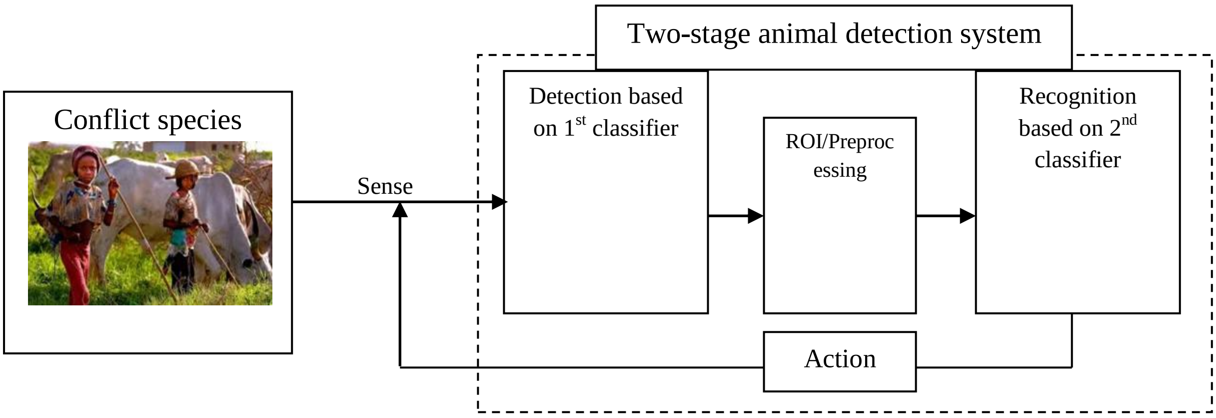

Fig. 3.1. Theoretical framework of animal detection and recognition system

Table1. The overview of active animal detection based on image processing. (Adapted from Depu Zhou, 2014)

Year	Reference	Techniques	Advantages	Disadvantages
2006	37	Haar-like features based on AdaBoost and image feature based tracking	-Real-time -Smooth and accurate -tracking included	-Some false positive -Only focus on face detection
2009	38	Background subtraction method after getting the background image	-Very fast -Can detect any kind of animals	-The background must be stable -Cannot work as on-vehicle system
2011	39	Haar of oriented gradient	-Various animal head	-Slow

			(cat, fox, panda, wolf, etc.)	-Only front face
2012	40	Thermal camera and GNT+HOG	-Fast to get ROIs -High detection rate -Plenty of deer postures included	-Only deer detection -Cannot work in strong light intensity environment -Misidentification (car, human)
2013	41	2-Stage: LBP+AdaBoost and HOG+SVM trained by separate databases	-Real-time -Variety of animals -Low false positive rate -Different weather Conditions	-Only consider two types animal postures
2017	42	Convolutional Neural Network	- The best experimental results of animal recognition were obtained using the proposed CNN - The experimental result shows that the LBPH algorithm provides better results than PCA, LDA and SVM for large training set - On the other hand, SVM is better than PCA and LDA for small training data set	-Reliability of the methods on larger databases of animal images were not carried out -Experiments with the methods on other animal databases were left as future work

Table2. Feature extraction algorithms [43]

Methods	Notes
Principal Component Analysis (PCA)	Eigenvector-based, linear map
Kernel PCA	Eigenvector-based, non-linear map, uses kernel methods
Weighted PCA	PCA using weighted coefficients
Linear Discriminant Analysis (LDA)	Eigenvector-based, supervised linear map
Semi-Supervised Discriminant (SDA)	Analysis semi-supervised adaptation of LDA
Independent Component Analysis (ICA)	Linear map, separates non-Gaussian distributed features
Neural Network based methods	Diverse neural networks using PCA, etc.
Multi-Dimensional Scaling (MDS)	Nonlinear map, sample size limited, noise sensitive
Self-Organizing Map (SOM)	Nonlinear, based on a grid of neurons in the feature space
Active Shape Models (ASM)	Statistical method, searches boundaries
Active Appearance Models (AAM)	Evolution of ASM, uses shape and texture
Gavor wavelet transforms	Biologically motivated, linear filter
Discrete Cosine Transform (DCT)	Linear function, Fourier-related transform, usually used 2D-DCT
MMSD, SMSD	Methods using maximum scatter difference criterion.

Table 1 is the overview of active animal detection based on image processing and Table 2 is the feature extraction algorithms. Presented in Table 1 were some of the various techniques used by different authors in carrying out their works on animal detection and recognition system with individual's advantages and disadvantages. Presented in Table 2 were some of the features extraction methods that could be used on images with individual's attributes.

IV. CONCLUSION

This paper presented overview of animal behavioral adaptive frightening system. As there are different species of animal, so also there are, different behaviors exhibited by these animals. The behavior of livestock, wild animals, and domestics animals are not the same. And the taxonomy of animal does not guarantee the same behavior from these groups. This is a challenge for adaptive frightening device to adapt to the behavioral changes exhibited by these animals. Both acoustics and bioacoustics methods of frightening animals were seen as weak methods due to the habituation of animals to them after some time. But, if combined, these methods are seen as breakthrough in overcoming the habituation exhibited by animals. It was discovered during the course of this paper that most related works are left as future work due to the fact that adaptive frightening device is species specific making it difficult for the adaptive frightening device to adapt to the behavioral changes exhibited by the unspecified species as it is not easy to design one-fit-all animal behavioral adaptive frightening system.

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