# Development and Efficacy of Laser Bird Repeller with PTZ Camera and Caffe Framework

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*Abstract:* - Many researches have been conducted to prevent bird damage not only on farms, orchards, fish farms and airports but also on industrial and urban environments. In this paper, we describe the construction and effectiveness of a laser bird repellent system that scaring it away as soon as the bird settles in a large area. The object classification technique using the Caffe framework detects the bird in real-time captured images of a PTZ camera over a large area, and when the bird sinks into the area, the PTZ camera combining the laser beam generator is steered to the target bird, thereby scaring the bird away by attacking it by the laser beam.

*Key-Words:* - Bird repellent, laser beam, Caffe framework, PTZ camera, Image Classification, Object Detection

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## 1. Introduction

Bird damage not only farms, orchards, fish farms, airports [1], [2], but also industrial and urban environments [3], [4]. Common methods for preventing bird damage include the use of scarecrows [5], [6], the use of chemicals [6], and the use of nets [7]. In recent years, studies that use ultrasound [11], [12], studies that use sound waves [9], [10], and studies that use laser [13] have also been carried out to repel bird.

Most birds are known to have a very sensitive response to light. [14]

Therefore, bird repellent using laser beams has been widely used in both manual and automatic modes as a method of chase bird by influencing the vision of bird in a wide area using the characteristics of lasers. A manual laser bird repeller is a device that chases birds by manually controlling the laser beam collection point of the repeller to the bird position when a person is monitoring a certain area and finding the bird.

An automatic laser bird repeller is a system that allows birds around a track to fly in surprise by repeatedly moving the laser beam spot along a predetermined trajectory in a certain area. [14]

Because the automatic laser bird repeller repeats the operation of illuminating the laser beam along a certain trajectory, with or without the presence of a bird, it is judged difficult to extrude it from the invading area immediately after the bird has invaded.

This may be one factor that prevents the automatic laser repeller from having a high bird repelling effect.

In addition, the long operation time of the laser beam generator and the control device can have a strong effect on the compliance degree of the bird and the lifetime of the devices.

This makes it possible to realize that a bird repelling approach is necessary to minimize the operation time of the laser beam generator and the control device and to scare the bird away that have invaded the area as quickly as possible.

Recently, methods to automatically track and classify birds using deep learning [15],[16],17] together with methods to track birds' movements using cameras[18],[19],[20] have been introduced.

The objective of this study was to construct an intelligent system and measure effect of it to target and expel the invaded bird with a laser beam by running a camera controlling device and a laser beam generator instantly when the bird invaded and landed within an area that requires bird repelling.

First, the target area is monitored in real time by a PTZ camera and the intrusion (sinking) position of the bird object is determined using the object classification technique by the Caffe framework.

The control device of the PTZ camera coupled with the laser beam generator is controlled to the bird position and the bird is expelled from the target area by outputting the laser beam.

Such a system can increase the bird repellent performance and efficiency by minimizing the operation time of the laser beam generator and the control device of camera, thereby increasing the service life of the system and reducing the compliance of the bird, as well as immediately scaring a wide range of birds.

Section 1 summarizes the architecture and structure of the system.

Section 2 presents the devices that make up the system and their combinations, and Section 3 summarizes the bird classification using the Caffe framework.

Section 4 presents the architecture of the software that comprises the system and Section 5 presents the experimental results.

## 2. Formation of system

The system's configuration consists of five components (Fig.1).

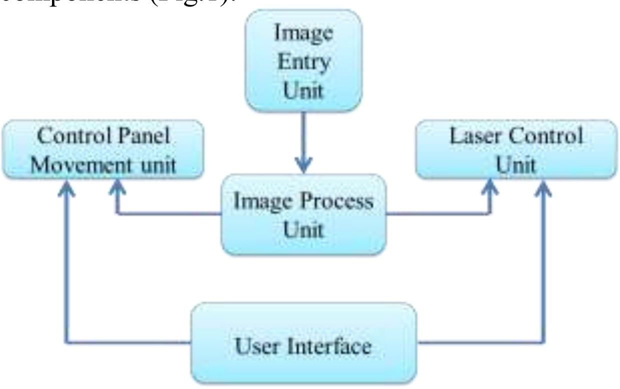


Fig 1: Construction of System

### 2.1 Image entry unit

Capturing and displaying the image in real time on the PTZ camera.

The Image entry unit consists of a camera, a network hub, a network line, a control computer, and image capture and display software.

Image capture and display use an SDK that is supported by the camera manufacturer.

In addition, due to the different types of cameras, the obtained images are color-transformed in real time into RGB images and sent to the following image processing unit.

### 2.2 Image processing unit

Processing the acquired real-time image to obtain the location of the bird.

The image processing unit consists of a control computer and image processing software.

In the captured real-time image, motion detection is performed to obtain all motion objects and to classify each object into a bird or not.

If the moving object is judged to be a bird, the PTZ position of the bird becomes the input parameter of the following control panel movement unit.

### 2.3 Control panel movement unit

Places the focus center of the camera in the center of the target bird.

The focus of the camera is placed at the center of the bird by controlling the camera by software to the PTZ position of the bird.

And according to the mode of attack, the camera control panel is further controlled.

The camera and the laser beam generator are integrated, and the focus center of the camera and the laser scanning center are aligned.

### 2.4 Laser beam control unit

If a bird is detected in the image processing unit, laser attack according to the mode of attack is performed with the movement of the camera control panel.

The laser beam control unit consists of a laser beam control panel, a laser beam control program, and a laser beam generator.

When the laser attack signal and the attack mode are transmitted to the laser beam controller, the controller initiates the attack by switching on the power of the connected laser beam generator and stops the generation of the laser beam by switching off the power of the laser beam generator when the attack termination signal is transmitted.

Depending on the mode of attack, the attack effect can be enhanced by selectively transmitting or simultaneously transmitting the attack signal to a laser beam generator of blue (420 nm), green (532 nm), or red (650 nm).

### 2.5 User interface

It is an interface program that enables RS-485 communication with the computer and the bird detector and network communication with the camera as user interface of the intelligent laser bird repellent system, and to manually and automatically browse the recording data, view the statistical data, and set various settings together with the control of the laser beam attack and camera control unit.

## 3. Devices

The system includes a PTZ camera, a laser beam controller, a laser beam generator, a coupling sleeve, and a control computer for real-time image acquisition of the bird monitoring area.

### 3.1 PTZ camera

HIKVISION (type number DS-2DC6120IY-A, Firmware V5.3.22 build 181120, resolution 1280 x 720) was used as the main device for the Image entry unit.

The camera is outdoor, capable of PTZ control through a computer network, supports the ONVIF protocol, and has a 3D Position (3D Position) function.

### 3.2 Laser beam controller

It is a device for controlling the start and stop of operation of each laser beam generator.

ARM32-bit CortexTM-M3 CPU Core was used as a central processing chip to ensure good performance.

The circuit of this device consists of the main circuit, the power circuit, the communication circuit, and the gain control circuit (Fig.2).

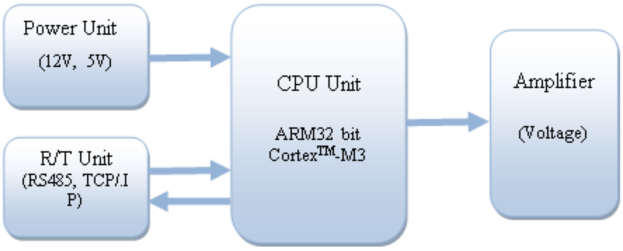


Fig 2: Configuration of laser beam controller

The input power is AC 220 V and is stabilized by DC 12 V and 5 V in the supply circuit to supply the main circuit and the peripheral circuit.

The resulting signal, which consists of an ARM chip and its driving circuits, operates on this chip to control the laser beams through the amplifier circuit. The communication circuit part used RS485 or Ethernet communication mode as a circuit for transmitting and receiving data between the chip and the computer and between the chip and the camera.

### 3.3 Laser beam generators

The laser beam generator (1000 mW Class-III Laser) had 1000 mW power of red, green and blue and was fixed to the coupling sleeve and coupled to the inside of the PTZ camera.

At this time, the overnight lighting LEDs inside the PTZ camera were first separated from the fixture and the coupling sleeve was fixed there.

### 3.4 Connecting bush

The laser beam generator is fixed to the camera and is a device for matching the focus of the camera with the laser scanning center.

A laser beam generator of three colors, red, blue and green, was installed in two each.

The laser beam generator and the connecting bush for mounting on the camera are shown in Fig. 3.

After all mounting, the bolts of the connecting bush were adjusted so that the focus of the laser beams was matched to the viewing image focus of the camera.

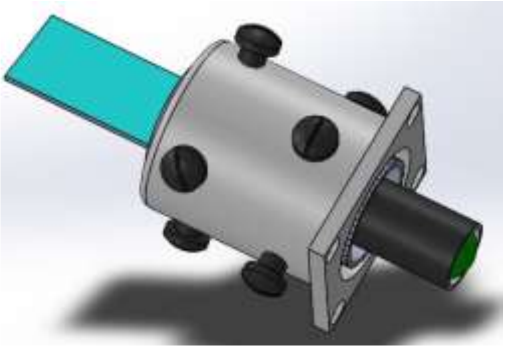

Fig 3: Laser beam generator and connecting bush

### 3.5 A computer for control

In the computer for control, a bird repellent program is executed, such as processing images captured in real time through a local area network (Ethernet) from an IP camera, classifying birds using the Caffe model, and transmitting attack start and attack finish signals to the laser beam controller using RS-485.

The operating system is Windows 7-x64, the computer processor is Intel Core (TM) i5-3340 M CPU @ 2.70 GHz, and RAM 4.00 GB.

## 4. Moving Object Detection and Bird Classification

### 4.1 Moving Object Detection

First, we detected moving objects in the surveillance area image captured in real time from the camera.

Motion detection was used with the Background Modeling Detector (Aforge.Net Framework 2.2.5 version).

The difference threshold (DifferenceThreshold) of the detector was set to standard value 10 and the background update frame value (FramesPerBackgroundUpdate) was set to standard value 5.

### 4.2 Train data gathering

First, training data were collected for bird classification using Caffe.

The training data were constructed by storing the bird candidates obtained by motion detection described above as files in real time and classifying them as bird and no-bird.

When selecting bird images, flying birds were not selected as bird candidates, and only sedentary birds were selected as learning objects.

The bird images collected for training were 31,000 (23,000 magpies, 8,000 crows), and the no-bird images were 30,500 color BMP files, which were stored in different folders (bird images in birds folder and other images in others folder).

After deep learning, the data to be used for testing are stored in the Test folder (3,000 bird images, 3,000 no-bird images).

### 4.3 Bird Training

For deep learning, preprocessing of the training data was performed first.

For preprocessing, gray-scale and image size conversion are used, and image size conversion is set to 50*41. After pre-processing, deep learning is performed, when the Mobile Network 2.0 version (mobilenet_v2) is used.

The mobile network version 2.0 is composed of four overlay layers (Convolution Layer), four selection layers (Pooling Layer), and two fully connected layers (Fully Connected Layer) with a gray-tone image of size 198 x 161 as input to the neural network and the position of five reference points as output.

In Solver.prototxt, change only the maximum number of iterations (max_iter) to 500,000 times, and in Train.prototxt, change the input layer to ImageData.

```
layer {
 name: "data"
 type: "ImageData"
 top: "data"
 top: "label"
 include {
  phase: TRAIN
 }
 transform_param{
  scale: 0.0078125 # 128
  mirror: true
 }
 image_data_param{
  source: "./prototxt/trainval2.txt"
  #batch_size: 32
  batch_size: 16
  shuffle: 1
  is_color: false
  new_height: 41
  new_width: 50
 }
}
```

Since our system is a Binary Classification (Binary Classification) problem that perform laser attack if it is a bird and does not perform laser attack if it is not a bird, the number of the last output network (num_output) is set to 2.

Deep learning is done by re-learning (finetuning) the default model of Mobile Network version 2.0.

After the training was completed, the test data were tested to obtain a classification accuracy of 95.2%.

### 4.4 Bird Classification

We used the newly constructed network model to perform bird classification in real time.

The resulting images of motion detection from the real-time input image from the camera were fed into the input of the bird classification library using the newly constructed network model, and the outputted classification accuracy was judged to be bird if it was more than 0.5, laser attack was performed, or not.

## 5. Software

The software was written for the 64-bit operating system using the C-Sharp development language of Microsoft Visual Studio 2015.

**Interface for camera SDK**. HCNetSdkCom, SDK of HIKVISION camera, is used. In the CHCNetSDK.cs file, the CHCNetSDK class that maps all internal functions and structures of the SDK library in C-Sharp language is defined and used. The use of all functions of the camera, such as camera connection, setting, real-time image collection and display, and camera control, is conducted through this face-to-face.

**Interface for image process library**. A library including image processing modules necessary for the system was prepared and used. The function to convert the YUV12 image acquired by the camera to RGB image (GIP_CovertToRGB function), initialization of Caffe library (GIP_CaffeInit) and bird classification (GIP_CaffeClassify) functions have been implemented, and real-time image processing is performed through this interface.

**Function of capturing and display from camera**. The image of the PTZ camera is captured in real time and displayed by dividing the screen according to the number of cameras.

**Function of control panel manual control and camera setting**. The camera SDK is used to manually control the PTZ movement of the camera and includes the camera setting function, such as the movement speed and the basic positioning.

**Function of auto and manual attack**. In the manual attack, if any position in the real-time captured display image is selected as a rectangle, the camera moves the PTZ to that position, allowing the laser beam generation to start operation as well.

At the end of the attack, the laser beam is returned to the default position, and the laser beam generation is also stopped.

In an automatic attack, if a bird classification is performed in real time and judged to be a bird, i.e., the bird classification result has a similarity value of 0.5 or more, then PTZ moves the camera to the scene position, initiates the generation of the laser beam, returns to the default position after the attack according to the attack mode, and stops the generation of the laser beam.

**Function of attack history view**. The ability to browse video data recorded on a hard disk during an attack on a bird by recording time.

**Function of statistics view**. It is a function of browsing the statistics of attack on birds on a bar chart.

The start and end dates were selected so that the number of bird invasions and the number of attack successes during the period were displayed as statistics.

**Function of system configuration**. The system setup consists of the network control functions such as IP address and user and password setting of the cameras and COM communication setup functions such as COM port and communication band, video storage location setting, and laser attack mode setting functions.

# 6. Results

## 6.1 Test condition

For the experiment, a square airspace area of 200m x 200m in Moran Hill, Pyongyang, where magpies and crows flew a lot, was selected, and the area was divided in half and a total of two our bird repellers were installed at 20m height of pine trees in a position to monitor each area.

There are 28 pine trees and 520 $m^2$ of pond in the area of the open area, while the rest are lawn areas.

Depending on the distance from the camera (50 m, 100 m, and 200 m), a red flag was placed at both ends of the zone to make the distance visible on the screen.

The experiment was conducted from October 2019 to August 2023 throughout the spring to winter, during which 31,308 birds (21,142 magpies, 8046 crows, and 120 others) were observed to invade the area.

In addition, bird infestation was observed from 5 to 19 a.m. and almost no other time.

And the experiment was carried out by changing the laser color from blue, red and green every day.

## 6.2 Classification result

For the results of deep learning, an evaluation of the bird classification performance was performed.

. For 10308 magpies and crows, positive (False Positive Rate) and negative (False Negative Rate) sampling rates were calculated.

Here, the positive sample rate is the rate estimated by fitting a moving object with no magpies or crows, and the negative sample rate is the rate estimated by not being magpies or crows for a moving object.

In our study, FPR = 3.8% and FNR = 1.2% were calculated.

## 6.3 Effective rate by Laser color and attack distance

Experiments were carried out to evaluate the response of laser color and distance from 5 a.m. to 19 p.m. when the attack mode was changed to red, green and blue in the laser control unit according to the laser color and distance, with bird infestations such as magpies and crows being the most frequent.

If a bird subjected to laser attack evades the invasive area within 3 s, it is considered to have an attack effect, or it is considered to have no attack effect if not.

For the total number of birds measured, the percentage of the number of birds that had an attack effect was evaluated as responsive.

The distance-dependent flags were estimated to be 50 m distance when the invading bird were near 40-75 m, 100 m distance when near 75 m to 150 m, and 200 m distance from 150 m to 200 m.

The total measured data were calculated by arithmetic averaging because the magpies and crows were similar in responsiveness and the illuminance varied with time over the seasons.

The figures below show the reactivity of the algae at distances of 50 m, 100 m and 200 m, respectively (Fig. 4, Fig. 5, Fig. 6).

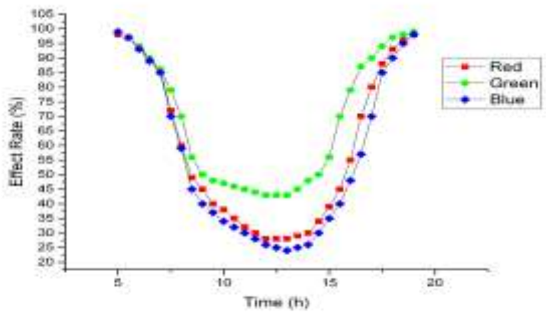


Fig 4: Response effect rate according to the laser color (50m)

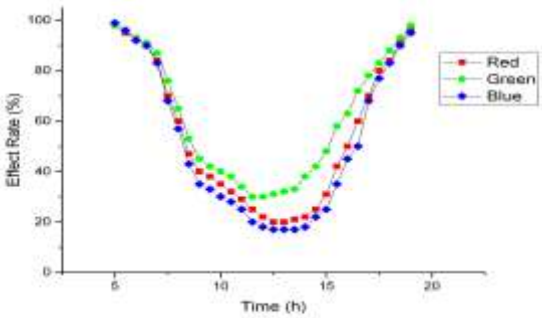


Fig 5: Response effect rate according to the laser color (100m)

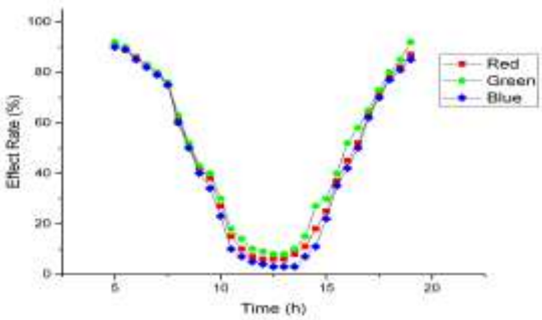


Fig 6: Response effect rate according to the laser color (200m)

Graph shows that the reactivity with Laser Color depends on the illuminance.

It can be seen that the response of the bird is the lowest, especially at noon, when the illuminance is greatest, and the response is large in the morning and evening when the illuminance is relatively small.

It can also be seen that the green laser has a relatively large bird repelling effect and a low reactivity with distance.

### 6.4 Shirking Time of bird

We measured the time it took for a bird to start to run out of surprise from the time it was perceived by the camera to enter the survey area.

The magpies or crows flew in astonishment as soon as a circular beam of light appeared, as the laser beam descended into the field of the intrusion area.

With the ranging accuracy of the laser beam generator and the slight movement of the bird, the effect is different, but the evacuation time is estimated to be about 0.5 s to 3 s.

This was attributed to the inability of the bird to perform its desired behavior in the descending position.

## 7. Conclusion

Considering the bird classification performance and reactivity, the bird repelling rate of the system is estimated to be 93% in the morning and evening and 7% in the day time within the distance 200 m region when using a 1000 mW green laser.

And the prevention area of one bird repeller is estimated at about 2000 $m^2$ in daylight and 25 000 $m^2$ in morning and evening.

The operating time of the laser beam generator and the camera control panel is about 5 to 7 seconds per cycle starting the attack and returning to its position, and the operating time of the day is equal to the operating time per cycle multiplied by the number of birds detected.

It can be seen that the service life is much longer and the compliance of the algae is as small as that of the scanning laser algae detector.

Intelligent laser bird repeller using PTZ cameras and Caffe frameworks have high bird repellent effect due to their long service life, large area of protection, and prompt repelling of bird infestations, and can be widely used in farms, aquaculture farms, orchards, airports, etc.

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**Conflict of Interest**

The authors have no conflict of interest to declare.